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# games, puzzles, algorithms

# CMP355 lecture notes

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# 1

# intro

On March 16 2016, in a luxury hotel in Seoul Korea, the legendary 9-dan professional Lee Sedol sat down to start an unusual go match. Aja Huang, who faced him across the board, was there only to place stones: Lee's opponent was the computer program AlphaGo.

Millions of people watched this game live, including 60 people who met late at night to watch on a big screen in the Computing Science Center at UAlberta.

The opening moves were typical of a professional match, until move 7, when Lee played a strange move perhaps intended to confuse AlphaGo. But AlphaGo, apparently not confused, soon established a strong position which continually improved as the game progressed. More than three hours after it had begun, the game ended when Lee Sedol resigned.

For the first time ever, a computer program – with no handicap advantage – had defeated a top go professional in a game.

How did this happen?

In this course, we address the above question by taking a brief look at the history of algorithms used to play or solve *puzzles* or *games*, especially two-player board games such as chess or go or hex. In the world of artificial intelligence (AI), a *player* of a puzzle or game is called an *agent*, so these are *single-agent* or two-agent games.

Here is some discussion to get us started.

## AlphaGo.

- AlphaGo movie https://www.youtube.com/watch?v=WXuK6gekU1Y
- do you know the UAlberta connection?

  David Silver (Phd with Rich Sutton and Martin Müller), Aja Huang (post-doc with Müller and Ryan Hayward).
- other UAlberta games connections?

  checkers (Jonathan Schaeffer et al. including Paul Lu), chinese checkers (Sturtevant), go (Müller), hearts (Sturtevant), hex (Hayward), lines of action (Yngvi Björnsson), multi-arm bandits (Csaba Szepesvari), poker (Michael Bowling), reversi (Michael Büro), video games (Vadim Bulitko)

## games/puzzles/algorithms.

- puzzles: mazes, peg solitaire, sliding tile
- games: tic-tac-toe, chess, checkers, hex, go, connect-4, reversi, nim, rock-paper-scissors, poker, dark hex
- math: discrete/recreational, combinatorial game theory, Nash equilibria
- algorithms: breadth-first search, depth-first search, dynamic programming, minimax search (negamax, alpha-beta), monte carlo tree search, proof number search, convolutional neural networks

## go.

- weiqi (China), baduk (Korea), go (Japan)
- weiqi played from around 1000 BCE
- around 2000 professional players
- originated in China, played by upper-class (xianqi – chinese chess – played by masses)
- building superhuman go-bot longstanding AI challenge
- 2016 AlphaGo
- can you write a program to play perfectly? what about small boards?

### tic-tac-toe.

- played from around 100 BCE in Rome terni lapilli (3 pebbles at a time)
- who wins? can you write a program to play perfectly?

### peg solitaire.

- played by 1687 wiki
- can you write a program to play perfectly?

### go questions.

- does AlphaGo play perfectly?
- can you write a program to play perfectly on small boards?

# 2

# intro to go

### go.

- links
  wiki https://en.wikipedia.org/wiki/Go_(game)
  sensei https://senseis.xmp.net/?About
  famous game: master of go https://en.wikipedia.org/wiki/The_Master_of_Go

### rules.

- Tromp-Taylor http://tromp.github.io/go.html
  T-T at Sensei https://senseis.xmp.net/?TrompTaylorRules
  T-T explained
  https://webdocs.cs.ualberta.ca///~hayward/355//gorules.pdf

### how these rules are used.

- Tromp-Taylor rules allow suicide
- no-suicide TT is close to Chinese rules
- many computer programs use no-suicide TT
- some programs use situational superko: a move cannot recreate a position that that player created earlier

### how humans play.

- they stop moving once they agree 1) that neither player can increase their score by continuing to play and 2) on which groups can be captured by the opponent (this saves them from having to make those moves)
- they remove agreement-captured groups and apply TT scoring formula
- weaker player has a komi (handicap adjustment score) added to her score
- between players of equal rank, White often gives komi 6.5

### learn.

- online-go.com https://online-go.com/learn-to-play-go
- point, stone, liberty, group (or string or chain), atari, ko, komi, byoyomi (AlphaGo-Lee Sedol match, for each match, each player had 2 hr + 3x 60s byoyomi), positional superko, situational superko, live group, dead group, eye, life and death problem, semiai, seki
- browser opponent https://www.cosumi.net/en/ on 5x5 you can win by 24 points (site uses Japanese scoring, TT score would be +25)
- 5x5 perfect play
  http://erikvanderwerf.tengen.nl/5x5/5x5solved.html

**gobots.**

- go programs https://senseis.xmp.net/?GoPrograms
- go clients https://senseis.xmp.net/?GoClient
- gobots (go-playing programs) https://senseis.xmp.net/?GoPlayingPrograms
- current fuego code https://sourceforge.net/p/fuego/code/HEAD/tree/
- sabaki go client https://sabaki.yichuanshen.de/

# 3

# prologue: AlphaGo

- end of era: human go supremacy
- watch alphgo movie https://www.alphagomovie.com/
- 2006 start of computer go revolution
  - MCTS, Crazystone Coulom
  - UCB, UCT Kocsis+Szepesvari
  - UCT, patterns, MoGo Gelly+Wang+Munos+Teytaud
- go ranking system https://en.wikipedia.org/wiki/Go_ranks_and_ratings#Kyu_and_dan_ranks
- 2015, top Go programs Zen, Crazystone, about 8dan
  - 2014 Crazystone + 4 stones defeats Norimota Yoda by 2.5 points
  - weaker than top amateur
  - weaker than any pro (around 1200 go pros)
- boom
  - 2016 Jan 28 AlphaGo Nature paper https://storage.googleapis.com/deepmind-media/alphago/AlphaGoNaturePaper.pdf
  - 2015 Oct AlphaGo v Fan Hui 5-0
  - AG to play Lee Sedol March 2016 Seoul

- AG-LS pre-game predictions
  - AG-FH match: many AG moves sub-optimal, throwing away points
  - top pro should easily beat this version of AG
  - so LS will win ?
- but some sub-optimal moves were not errors: AG picks move that maximizes est. win-prob, not est. win-score,
- and between matches AG algorithm changed, AG NNs trained non-stop (and improved)
- 2016 Mar AG v Sedol 4-1
  - game 1, LS tries unususal early moves to throw AG off its game, fails
  - 10 Mar game 2 move 37 to me, era ends here (commentary Michael Redmond)
  - more on AG-Sedol and computer go http://webdocs.cs.ualberta.ca/~hayward/670gga/jem/go.html
- how does AlphaGo work ?
- in this course, we explore basic algorithms for solving puzzles and games
- general algorithmic principles: search, knowledge, simulations
- by the end of the course you will learn most of the ideas behind AlphaGo
- missing pieces (image recognition via deep convolution neural nets) in CMPUT 455
- DCNN (not covered in this course)
  - wiki CNN
  - wiki deep learning
  - Goodfellow+Bengio+Courvill DL
  - Chris Olah's blog http://colah.github.io/

# 4

# life

**Conway's game of life.**

- brief JHC bio https://www.theguardian.com/science/2015/jul/23/john-horton-conway-the-most-charismatic-mathematician-in-the-world
- Edwin Martin's gameoflife.com https://playgameoflife.com/
- Martin's github https://github.com/edwinm/game-of-life
- Martin Gardner's columns (via MAA) https://www.maa.org/sites/default/files/pdf/pubs/focus/Gardner_GameofLife10-1970.pdf