

Theory of Computer Games

- Schedule: 6:30pm~9:30pm (Tue),
 - Location: EC114 (實體),
<https://meet.google.com/kdx-rdub-dpr> (virtual)
- Instructors:
 - I-Chen Wu (吳毅成), TEL: x31855
 - Email: icwu@cs.nycu.edu.tw
 - WWW: <http://cgilab.nctu.edu.tw/~icwu/>
- TAs: tcg@cgilab.nctu.edu.tw
 - Hung Guei (桂泓) + Tai-Lin Wu (吳岱霖). TEL: x31603
 - Maybe, some more.
- Course web site: <http://e3.nycu.edu.tw>
 - TA: Listed in this web site.
 - Slides: Given in this web site.



Goal

- Learn all kinds of algorithms and techniques to let programs **play**, **design** and **solve** various games, such as
 - 15-puzzle, 2048, Sudoku, ...
 - Gomoku, Connect6, Chess, Chinese Chess, Go, ...
 - Bridges, Mahjong, Big2, ...
- Learn how to deal with problems with exponential time.
 - Many games require the time complexity in exponential times.
 - Other exp-time applications: mathematical optimization problems.
- Learn how to solve similar issues in AI.
- Disclaimers:
 - NOT a course on arcade games or MMOG.

Prerequisite

- Algorithm
- Maybe, artificial intelligence/machine learning.
 - Good to take in advance, but not required.

Evaluation

- Homework (~20%): several take-homes and pop quizzes.
- Final Exam (24%)
- Presentation (~20%) About 3-5 weeks near the end.
 - Discussion before presentation.
 - 10-minute talk with ≤ 30 slides in PDF or PPT.
 - 15-minute Q & A
 - ▶ 6 min from 2 teams and 9 min from lecturers/TAs.
 - Submit your revised set of slides one week later.
- Program projects (~36%)
 - Design AI programs for designated games.
(Described in the next slides.)
- Note: The above percentages are used in the past, and are for references only, not fixed.

Game Program Project – A Good Tradition

- Change games each year, while learning and winning some prizes
 - 2008: the program project is for **Othello**
 - 2009: the program project is for **Connect6**
 - 2010: the program project is for **Puzzles**
 - ▶ Nonograms: Silver, Bronze (Gold went to our TA) in TAAI 2010
 - ▶ Light up: Gold, Silver, Bronze in TAAI 2010
 - 2011: the program project is for **NoGo**
 - ▶ NoGo: Silver, Bronze (One PhD student), the fourth in TAAI 2011
 - ▶ NoGo: Gold & Silver in Computer Olympiad 2013.
 - 2012: the program project is for **Dark Chinese Chess (DCC)**
 - ▶ DCC: Gold in Computer Olympiad 2013.
 - 2013: the program project is for **NoGo**.
 - ▶ NoGo: Gold & Silver in TAAI 2013.
- After 2014, break the rule. All are **2048-like games and Hollow-NoGo**, due to the era of machine learning.
 - Won the gold and silver for Threes! Game in 2048-bot tournament in 2014.
 - Won the silver for 2048 game in 2014, gold in Computer Olympiad 2015.

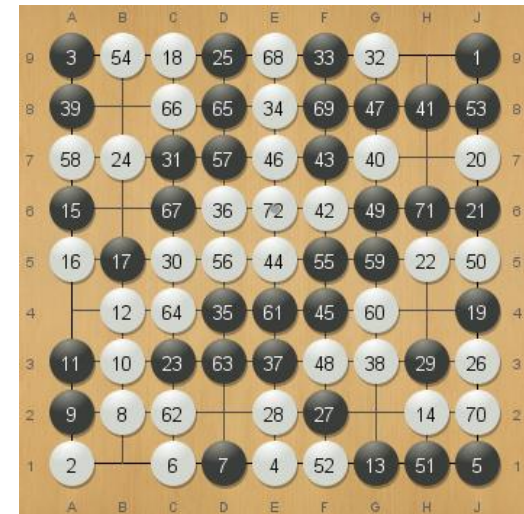
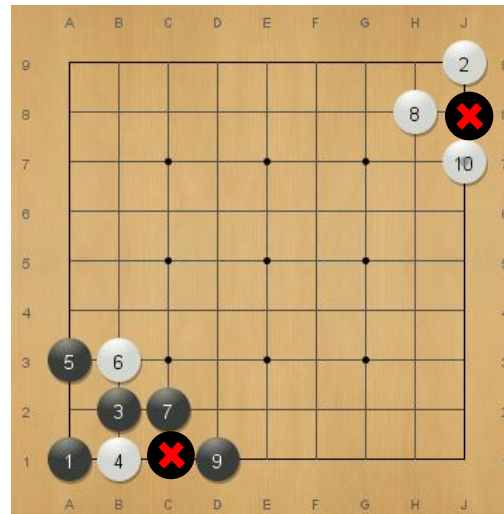


The Games for the Program Projects

- All program projects are related to a 2048-like game called **Threes!**. (Fib-2584 Last time)
 - See <http://threesjs.com/> with the following changes:
 - ▶ TBA
 - Player (also called solver)
- A game for MCTS
 - Hollow-NoGo
 - ▶ a variant of NoGo

NoGo (禁圍棋)

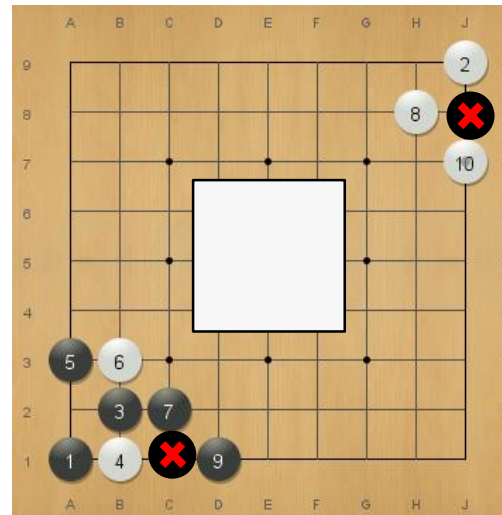
- Rule: The same as Go (圍棋) except
 - Cannot capture
 - Cannot suicide
 - The player who cannot move loses.



Black Loss

Hollow-NoGo (中空-禁圍棋)

- Rule: The same as Go (圍棋) except
 - Cannot capture
 - Cannot suicide
 - The player who cannot move loses.
 - Play on board with a hole
 - ▶ The hole last year.
 - ▶ Different hole this year!!



Program Projects

● Projects:

1. Write a simple player to play Threes!. (week 2)
 - ▶ Time limit: 0.001 seconds/move
 - ▶ Hint: use some simple heuristics to play; no search is required.
2. Write a player to play Threes! with high winrates. (week 3)
 - ▶ Time limit: 0.01 second/move
 - ▶ Hint: use TD learning only. No search is required.
3. Increase the winrate of the player. (week 6)
 - ▶ Time limit: 5 seconds/move (to be modified)
 - ▶ Hint: incorporate expectimax search into the player.
4. Write a MCTS program for the game of Hollow-NoGo. (Week 8)
 - ▶ Beat a weak program given by TA.
5. Improve the above MCTS program to attend the final tournament. . (one week after final)
 - ▶ Hint: no limitation about the method you use. E.g., you may use AlphaZero to do it.



Course Outlines (I)

- Introduction (1.5hr) ([games-computers-ai.pdf](#)) (week 1)
 - Survey – Game solved. (3hr) ([game-solved.pdf](#),) (week 2)
 - Playing games and evaluation function ([evaluation-features.pdf](#)) (week 3)
- Single-player games
 - DFS, BFS, DFID, A*, IDA*, ... (2hr) ([DFID.pdf](#)) (week 5 or not)
 - Pattern databases. (2.5hr) ([pattern-database.pdf](#), [dual.pdf](#)) (week 5 or PR)
 - Other puzzle games including 2048/Sudoku/Nonogram (PR: for presentations)
- Two-player perfect information games
 - Alpha-beta pruning and its analysis (4hr) ([alpha-beta.pdf](#)) (week 6)
 - More about alpha-beta search (2hr)
 - ▶ Scout search ([scout.pdf](#)) (week 6)
 - ▶ SSS* search ([sss.pdf](#)) (week 7)



Course Outlines (II)

- Practical considerations for alpha-beta
 - History Heuristics, Z-hashing (1hr) ([history-heuristic.pdf](#)) (week 7)
 - Null move (1hr) ([null-move.pdf](#)) (week 7)
- Practical considerations for general games
 - Endgame databases and retrograde (2hr) ([retrograde.ppt](#)) (week 7 or PR)
 - Bit board ([bitboard.pptx](#)) (week 9 or PR)
 - Timing and resource usage control, Opponent model, etc. (PR: for presentations)

Course Outlines (III)

- Advanced search techniques
 - Expectiminimax and expectimax search (week 8)
 - Monte-Carlo tree search (2hr) ([monte-carlo.pdf](#)) (week 8)
 - ▶ RAVE ([rave.pdf](#)) (week 8)
 - ▶ A case study: NoGo or Dark chess ([more-on-mcts.pdf](#)) (week 8)
 - Give a project for MCTS simulation and UCT.
 - Include a little bit bitboard. ([bitboard.pptx](#)) (week 9)
 - Threat-space search (3hr) ([threat-space-search.pdf](#) and [lambda-search.pdf](#)) (week 9)
 - ▶ Dependency-based search
 - ▶ Lambda search
 - Proof number search (2hr) ([proof-number-search.pdf](#)) (week 10 or PR)
 - ▶ PN2, PN*, etc.
 - AlphaZero: (week 10)
 - ▶ muZero (PR): stochastic (PR), Gumbel (PR)
 - Brute-force search for solving puzzles,
 - ▶ Sudoku or Nonogram (1hr) (N.A.)



Course Outlines (IV)

- Advanced research topics: (may be presented by students)
 - Combinatorial game theory (3hr) ([numbers-games.pdf](#)) (week 11)
 - Parallelization (3hr, PR: student presentation)
 - ▶ Parallelism MCTS ([parallel-mcts.pdf](#)) (student presentation)
 - ▶ Lockless ([lockless.pdf](#)), (student presentation)
 - ▶ Parallel alpha-beta ([parallel-ab.pdf](#)) (student presentation)
 - ▶ Job-Level Search based on volunteer computing. (optional)
 - The graph-history interaction (GHI) problem (1hr) ([GHI.pdf](#)) (PR)
 - Solving Connect games (2hr, PR) ([drawn-connect-k.ppt](#)) (optional)

Course Outlines (V)

- Machine learning and computer games (most for presentation)
 - Reinforcement learning (week 3)
 - ▶ TD learning and 2048 ([td-learning.pdf](#))
 - Deep reinforcement learning (week 4)
 - ▶ Convolutional Neural Network for Go
 - ▶ Atari games
 - Simulation Balancing (PR: student presentation)
 - Minorize-Maximization (PR: student presentation)
- Student Presentation: (week 11-15).

References

- Slides: <http://e3.nctu.edu.tw>
 - Not all released at the very beginning.
- References:
 - Papers.
 - Book: 電腦對局導論 (徐讚昇等著)
- Acknowledgements:
 - Many slides of this course are directly from or are modified from Prof. Hsu's teaching material, under the courtesy of Hsu.
<http://www.iis.sinica.edu.tw/~tshsu/tcg2007/index.html>
 - Some are from Prof. R.J. Chen's slides.
 - Some are from Students' slides in the past.
 - ...



Resources (I)

- ICGA web site, <http://www.icga.org/>
 - Formally as ICCA (International Computer Chess Association)
 - Rename International Computer Games Association (ICGA), since 2000.
- Proceedings of the CG conference
 - Computers and Games Conference
 - Since 1998, every even numbered of year
- Proceedings of the ACG conferences
 - Advances in Computer Games Conference
 - Every odd numbered of year
- IEEE Computational Intelligence and Games
 - 2015 in Tainan
- Proceedings of AAAI
 - Since 1980
- Proceedings of IJCAI
 - International Joint Conference on Artificial Intelligence
 - Since 1969, every odd numbered of year



Resources (II)

- ICGA journal
 - Quarterly publication since 1977.
 - Called ICCA Journal before 2000 (exclusive).
- IEEE Transactions on Computational Intelligence and AI Games
 - A new journal since 2009.
- Theoretical Computer Science
 - More about theory.
- Artificial Intelligence
 - Flagship journal
 - Since 1970

Claim

- THE SLIDES ARE USED FOR THIS COURSE ONLY, NOT IN PUBLIC. LINKS TO THESE SLIDES ARE ONLY POSTED IN THE DESIGNATED BOARD, <http://java.csie.nctu.edu.tw/course/> STUDENTS IN THIS COURSE OR SEARCH ENGINES ARE FORBIDDEN TO PUBLICIZE THESE SLIDES OR LINKS OVER THE INTERNET.