Theory of Computer Games (電腦對局理論)

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Goal

- Prerequisite: computer programming, data structure, algorithm
- This course introduces techniques for computers to play various classical board games.
  - Include Chinese chess and Go
  - Not a course on game theory, video games, or war game simulations

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Class Materials

- **電腦對局導論**
  Computers and Classical Board Games: An Introduction
  - Author: 徐讚昇 等
  - Publisher: 國立臺灣大學出版中心, June 2017
  - ISBN: 978-986-350-237-1
  - 勘誤表
- Class notes
- Collection of papers

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Grading (1/2)

- 30% for attendance, assignments and class performance
- Midterm (30%)
- Final project (40%)
  - An alpha-beta based computer game program for Chinese dark chess
    - A simple code with GUI will be provided.
    - The usage of this sample code is restricted for anything related to this course only.
  - Submitted package: code + documents
- The final score of 0 in case of cheat or plagiarism in any exam, homework or projects

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Grading (2/2)

- Presentation/report of a research paper on game tree search
  - Required for each students
  - If time allows, give an in-class presentation.
    - Discussion before presentation
    - 30-minute talk
    - ≤ 30 slides in PDF format
    - 10–15 minutes of Q&A
    - Each student asks ≥ 1 non-trivial question
    - Submit your revised set of slides one week later
  - If time does not allow, submit a written report.
    - Pick a paper related to the course
    - Write a report with at least 100 words in PDF format
    - Summary of results in the paper
    - Comments about this paper, its strength, weakness and potential improvements

Course at a Glance (1/2)

- Introduction: an AI oriented overview
- Single-player games
  - Basic techniques
  - Advanced techniques
- Homework 1
- Two-player perfect information games
  - Survey
  - Introduction from chess's point of view
  - Alpha-beta and its extensions
- Midterm

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Course at a Glance (2/2)

- Two-player perfect information games
  - Monte-Carlo based method
- Homework 2
- Practical considerations
  - Memorizing knowledge
    - Transposition tables
    - Endgame databases
  - Advanced pruning techniques
  - Parallelization (?)
  - The graph-history interaction (GHI) problem
  - Opponent model (?)
  - Timing control
  - Hardware enhancements (?)
- Conclusion
- Final project

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Introduction and an AI Oriented Overview

- Relations between computer games and Artificial Intelligence
  - Why we study computer games?
  - Why we play or study games?
- History [SvdH02] [Sha50a]
  - The Turk, a chess playing "machine" at 1780's [LN82]
  - The endgame playing machine at 1910's [McC04]
  - C.E. Shannon (1950) [Sha50b] and A. Samuel (1960) [Sam60]
- Games that machines have beaten human champions [SvdH02] [Sch00]
  - Chess [CHH02]
  - Othello [Bur97]
  - Checker [SLLB96]
  - Go [SHM+16]
  - ...

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Single-player Games

- Games that can be played by one person [DH09]
  - combinatorial games such as 15-puzzle or Sukodu
  - other solitaire
- Classical approaches [Kor85] [KF02] [CS98]
  - Brute-force, BFS, DFS and its variations including DFID
  - Bi-directional search
  - A*
  - IDA*
  - IDA* with databases
- Disk-based approach [KS05]

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Two-player Perfect Information Games (1/2)

- A survey of current status [vdHUvR02]
- The original Computer Chess paper by C.E. Shannon [Sha50a] in 1950.
- Classical approaches
  - Alpha-beta search and its analysis [KM75]
  - Scout and Negascout [Pea80] [Rei83] [Fis83]
  - MTD(f): Best-first fixed-depth search [PSPdB96] [Pea80] if time allowed
- Enhancements to the classical approaches
  - Aspiration search
  - Quiescence search [Bea90]
  - Move ordering and other techniques [Sch89] [AN77] [Hsu91]
  - Further pruning techniques [SP96] including null move pruning and late move reduction
  - Proof-number search [AvdMvdH94] if time allowed

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Two-player Perfect Information Games (2/2)

- Monte-Carlo game tree search [BPW+12]
  - Original ideas [Bru93]
  - Best first game tree growing
  - UCT
  - Pruning techniques
    - Online knowledge [BH04] [YYK+06]
    - Offline knowledge [ST09] [HCL10a]
    - Deep learning [SHM+16]
- Case study
  - Computer Chinese chess [YCYH04]
  - Computer Chinese dark chess [CSH10] if time allowed

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Practical considerations (1/2)

- Transposition tables
  - Recording prior-search results to avoid researching
  - Design of a good hash function
    - Zobrist's hash function [Zob70]
- Open-game [Hya99] [Bur99] and endgame databases [Tho86] [Tho96] [WLH06]
  - Off-line collecting of knowledge
  - Computation done in advance
- Parallelization
  - Parallel alpha-beta based game tree search [Bro96] [FMM94] [HM02] [HSN89] [Hya97] [Man01]
  - Parallel Monte-Carlo game tree search [CJ08] [CWvdH08]

Practical considerations (2/2)

- The graph-history interaction (GHI) problem [Cam85] [BvdHU98] [WHH05]
  - The value of a position depends on the path leading to it.
    - Position value is dynamic and static.
- Opponent model [CM96]
  - How to take advantage of knowing the playing style of your opponent.
- Timing and resource usage control [Hya84] [HGN85] [MS93]
  - Using time wisely
    - Use too little time in opening may be fatal.
    - Use too much time in opening may be fatal, too.
    - Knowledge from real tournament environments [vV09].
    - For Monte-Carlo type of search [HCL10b].
- Hardware enhancements [DL04]

Other games – if time allowed

- Games with imperfect information and stochastic behaviors [FBM98]
  - Backgammon
  - Bridge
- Multi-player games [Stu06]
  - Poker
  - Mahjong

Concluding remarks

- Search chance nodes
- How to put everything together?
- How to test your implementation?
- How to measure the strength?

Resources (1/5)

- International Computer Games Association (ICGA) (1/2)
  - Formerly as International Computer Chess Association (ICCA)
    - Between 1977 and 2001
  - ICGA since 2002
  - Host of Computer Olympiad
    - International competition of games played by computers
    - 1989 at London, United Kingdom (1st)
    - ...
    - 2001–2002 at Maastricht, the Netherlands (6–7th)
    - 2003 at Graz, Austria (8th)
    - ...
    - 2005 at IIS, Academia Sinica, Taipei, Taiwan (10th)
    - ...
    - 2018 at CSIE, NTPU, New Taipei City, Taiwan (21st)

Resources (2/5)

- ICGA (2/2)
  - ICGA Journal
    - Quarterly publication since 1977
  - Advances in Computer Games (ACG) International Conference
    - Every (if possible) odd numbered of year
    - 2005 at IIS, Academia Sinica, Taipei, Taiwan (11th)
  - International Conference on Computers and Games (CG)
    - Since 1998, almost even numbered of years
    - 1998 (1st), 2000, 2002, 2004, 2006, 2008, 2010, 2013, 2016 , 2018 (10th)

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Resources (3/5)

- Taiwan Computer Games Association (TCGA)
  - Annual May workshop and game tournaments since 2011
- Taiwanese Association for Artificial Intelligence (TAAI)
  - Annual international conference since 2001
  - Annual November game tournaments since 2009
- Game Programming Workshop (GPW)
  - Annual November workshop and game tournaments in Japan since 1994

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Resources (4/5)

- Artificial Intelligence
  - Flagship journal
  - Since 1970
- International Joint Conference on Artificial Intelligence (IJCAI)
  - Cover all areas of AI
  - Computer Games Workshop (CGW) for classical games
  - Since 1969, odd numbered of years
- Association for the Advancement of Artificial Intelligence (AAAI)
  - Cover all areas of AI
  - AI magazine
  - Computer games occupy only a session in AAAI conferences now.
  - Since 1980

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Resources (5/5)

- IEEE Transactions on Games (IEEE ToG)
  - Formerly as IEEE Transactions on Computational Intelligence and AI in Games (IEEE TCIAIG)
  - Quarterly publication since 2009
- The IEEE Conference on Computational Intelligence and Games (CIG)
  - Since 2005, every year
    - 2015 at Tainan, Taiwan
  - Video game, classical games, ...

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  - `http://www.iis.sinica.edu.tw/~tshsu/tcg/index.html`

Claim

- The slides are used for this course only, not in public. Students in this course or search engines are forbidden to publicize these slides or links over the Internet.