

Theory of Computer Games

電腦對局理論

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Goal

- Course name: Theory of Computer Games

電腦對局理論

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- 十週年!!!
- Prerequisite: Computer Programming, and Data Structure and Algorithms.
 - Enjoy playing classical board games!
- Goal: This course introduces techniques for computers to play various games which include Chinese chess and Go.
- Disclaimers:
 - **NOT** yet a course on game theory.
 - **NOT** yet a course on video games.
 - **NOT** yet a course on war game simulations.
- Web page:
<http://www.iis.sinica.edu.tw/~tshsu/tcg/2016>

About this course

- Time and Place: Every Thursday from 2:20pm to 5:20pm at Room 105 (NTU CSIE building).

Sep 15 22 29

Oct 6 13 20 27

- Dates: Nov 3 10 17 24

Dec 1 8 15 22 29

Jan 5 19

- Format:

- Lectures.
- Presentations for homework projects.
- Invited lectures: TBA.

▷ *Chinese chess*

▷ *Go*

▷ ...

- Student presentation: the last few lectures if time allows.

- Class materials

- Class notes: draft of a text book with > 300 pages in Chinese is ready.
- Collection of papers.

Acknowledgements

- Thanks to the students of this course for providing constructive feedbacks on the slides.
 - Classes of 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014 and 2015.
- Special thanks to the following persons.
 - Yuh-Jie Chen (class of 2008)
 - Jennya Chang (class of 2011)
 - Jessica Lin (class of 2011)
 - 許祐程 (TA of the 2012 class)

Evaluation (1/3)

- **Homework (30%)**
 - **One homework project about single-agent search (15%)**
 - ▷ *About single agent search.*
 - ▷ *Implement different techniques learned from the class and compare the results.*
 - **One homework project about Monte-Carlo simulation (15%)**
 - ▷ *A 2-player game with a strong Monte Carlo flavor.*
 - ▷ *Your program against TA's program.*
- **Written exam: midterm exam (30%)**

Evaluation (2/3)

- **Final project (40%)**
 - **A computer game program for Chinese Dark Chess.**
 - ▷ *A sample code with GUI will be provided.*
 - ▷ *The usage of this sample code is restricted for anything related to this course only.*
 - **The 10th NTU-TCG Cup.**
 - **Submitted package: Code + documents.**
- **Class participation (bonus)**

Evaluation (3/3)

- **Presentation/Report of a research paper on game tree search.**
 - **If we have more than 16 students, then**
 - ▷ *Bonus for selected students who are obviously falling behind.*
 - If we have less than 17 students, then**
 - ▷ *This is required for each student.*
 - ▷ *This will be 10% of your score in which case the two programming homework each take 10%.*
 - **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, a written report.**
 - ▷ *Pick a paper related to the course.*
 - ▷ *Write a report with at least 1000 words in PDF format.*
 - ▷ *Summary of results in the paper.*
 - ▷ *Comments about this paper, its strength, weakness and potential improvements.*

Lecturing format

- **For each topic**
 - **The first and most influential papers are introduced.**
 - **A list of recent and latest papers is provided for further readings and/or topics for presentations.**

Course at a glance (1/2)

- Introduction: an A.I. oriented overview
- Single-player games
- **Homework 1**
- Two-player perfect information games
 - Survey
 - Introduction from Chess's point of view
 - Alpha-beta and its extensions
- **Midterm exam**

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**

Introduction and an A.I. 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]
 - ...

Single-player games

- **Games that can be played by one person [DH09]**
 - combinatorial games such as 15-puzzle or Sudoku
 - 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]**

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

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

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]
- **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.*

Practical considerations (2/2)

- **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 the 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
 - Majon

Concluding remarks

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

Resources (1/5)

■ ICGA web site

- <http://ticc.uvt.nl/icga/>
- Formally as ICCA (International Computer Chess Association)
 - ▷ *Between 1977 and 2001.*
- International Computer Games Association
 - ▷ *Since 2002.*
- Host of Computer Olympiad
 - ▷ *International competition of games played by computers*
 - ▷ *1989 at London, United Kingdom (1st)*
 - ▷ *...*
 - ▷ *2004 at Ramat-Gan, Israel (9th)*
 - ▷ *2005 at Taipei, Taiwan (10th)*
 - ▷ *...*
 - ▷ *2011 at Tilburg, the Netherlands (16th)*
 - ▷ *2013 at Yokohama, Japan (17th)*
 - ▷ *2015 at Leiden, the Netherlands (18th)*
 - ▷ *2016 at Leiden, the Netherlands (19th)*

Resources (2/5)

- **TCGA web site**
 - Taiwan Computer Games Association
 - Since 2011.
 - <http://tcga.ndhu.edu.tw>
 - Annual June conference and tournaments
- **TAAI game tournaments**
 - Taiwan AI Association
 - ▷ <http://www.taai.org.tw/TAAI/>
 - Annual conference since 2001
 - Annual November game tournament since 2009

Resources (3/5)

■ Proceedings of IJCAI

- International Joint Conference on Artificial Intelligence
- Covers all areas of A.I.
- Computer games occupy only a small session now
- Since 1969, odd numbered of years

■ Proceedings of AAAI

- Association for the Advancement of A.I.
- Covers all areas of A.I.
- Computer games occupy only a small session now
- Since 1980

Resources (4/5)

- **Proceedings of the ACG conference**
 - Advances in Computer Games International Conference
 - Every (if possible) odd numbered of year
 - ▷ ...
 - ▷ 1999 at Paderborn Germany (9th)
 - ▷ 2003 at Graz, Austria (10th)
 - ▷ 2005 at Taipei, Taiwan (11th)
 - ▷ 2009 at Pamplona, Spain (12th)
 - ▷ 2011 at Tilburg, the Netherlands (13th)
 - ▷ 2015 at Leiden, the Netherlands (14th)

- **Proceedings of the CG conference**
 - Computers and Games International Conference
 - Since 1998, **almost** even numbered of years
 - ▷ 1998 (1st), 2000, 2002, 2004, 2006, 2008, 2010 (7th), 2013 (8th), 2016 (9th)

- **Proceedings of IEEE CIG**
 - Computational Intelligence and Games International Conference
 - Since 2005, every year.
 - Video game, classical games, ...

Resources (5/5)

- **Artificial Intelligence**
 - Flagship journal
 - Since 1970
- **ICGA journal**
 - Quarterly publication since 1977
- **The A.I. magazine**
 - Journal for AAAI
 - Since 1980
- **IEEE Transactions on Computational Intelligence and A.I. in Games**
 - An IEEE journal
 - Quarterly publication since 2009

Collection of papers

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