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

- **Prerequisite:** Computer Programming, and Data Structure and Algorithms.

- **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/2015
About this course

- **Time and Place:** Every Thursday from 2:20pm to 5:20pm at Room 105 (NTU CSIE building).
  
  Sep      17  24  
  Oct      1   8   15  22  29 

- **Dates:**
  
  Nov      5   12  19  26  
  Dec      3   10  17  24  31  
  Jan      7   21  

- **Format:**
  
  - Lectures.
  - Presentations for homework projects.
  - Invited lectures: Thursday Dec. 10, 2015
    - Chinese chess
    - Go
    - . . .
  - Student presentation: the last few lectures if time allows.

- **Class materials**
  
  - Class notes.
  - Collection of papers.
Acknowledgements

- Thanks to the students of this course for providing constructive feedbacks on the slides.

- Special thanks 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.
    - Pick your own game, implement, and then present the result.
  - One homework project about Monte-Carlo simulation (15%)
    - About 2 player games.
    - 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 9th 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.
Topics

- **Introduction**: an A.I. oriented overview
- **Single-player games**
  - Homework 1
- **Two-player perfect information games**
  - Introduction
  - Alpha-beta and extensions
    - Midterm exam
  - Monte-Carlo based methods
    - Homework 2
- **Practical considerations**
  - Memorizing knowledge
  - Advanced pruning techniques
  - Parallel
  - The graph-history interaction (GHI) problem
  - Opponent model
  - Timing control
  - Hardware enhancements
    - 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]
  - ...
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]
Two-player perfect information games (1/2)

- A survey of current status [vdHUvR02]


- 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

- Parallel alpha-beta based game tree search [Bro96] [FMM94] [HM02] [HSN89] [Hya97] [Man01]
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 \([ST09]\) \([HCL10a]\)
  - Parallel Monte-Carlo game tree search \([CJ08]\) \([CWvdH08]\)

- Case study:
  - Computer Chinese chess \([YCYH04]\)
  - Computer Chinese dark chess \([CSH10]\) if time allowed
Other games – if time allowed

- Games with imperfect information and stochastic behaviors [FBM98]
  - Backgammon
  - Bridge
- Multi-player games [Stu06]
  - Poker
  - Majon
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 [Hy"a99] [Bur99] and endgame databases [Tho86] [Tho96] [WLH06]**
  - Off-line collecting of knowledge
  - Computation done in advance

- **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** [Hyao84] [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]
- **Parallelization** [Bro96] [Man01]
Concluding remarks

- Search chance nodes
- How to put everything together
- How to test your implementation
Resources (1/5)

- **ICGA web site**
  - [http://ticc.uvt.nl/icga/](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)*
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

- **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
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[SBB⁺07] Jonathan Schaeffer, Neil Burch, Yngvi Bjornsson, Akihiro Kishi-


