Theory of Computer Games

電腦對局理論

Tsan-sheng Hsu

徐讖昇

tshsu@iis.sinica.edu.tw

http://www.iis.sinica.edu.tw/~tshsu
Goal

- **Course name:** Theory of Computer Games
  電腦對局理論

- **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:**
About this course

- **Time and Place:** Every Thursday from 2:20pm to 5:20pm at Room 105 (NTU CSIE building).
  
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- **Format:**
  - Lectures.
  - Presentations for homework projects.
  - Invited lectures: TBA.
  - 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.

Special thanks to the following persons.
- Yuh-Jie Chen (class of 2008)
- Jennya Chang (class of 2011)
- Jessica Lin (class of 2011)
- 許佑程 (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%)
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)
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.
  - \( \leq 30 \) slides in PDF format.
  - 10–15 minutes of Q & A.
  - Each student asks \( \geq 1 \) 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 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 [Bea90]
  - Quiescence search [Sch89] [AN77] [Hsu91]
  - Move ordering and other 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 \([\text{Zob70}]\)
- **Open-game \([\text{Hy99}]\) \([\text{Bur99}]\) and endgame databases \([\text{Tho86}]\)  
  \([\text{Tho96}]\) \([\text{WLH06}]\)
  - Off-line collecting of knowledge
  - Computation done in advance
- **Parallelization**
  - Parallel alpha-beta based game tree search \([\text{Bro96}]\) \([\text{FMM94}]\) \([\text{HM02}]\)  
    \([\text{HSN89}]\) \([\text{Hy97}]\) \([\text{Man01}]\)
  - Parallel Monte-Carlo game tree search \([\text{CJ08}]\) \([\text{CWvdH08}]\)
- **The graph-history interaction (GHI) problem \([\text{Cam85}]\)  
  \([\text{BvdHU98}]\) \([\text{WHH05}]\)
  - 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 [Hy84] [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

- **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
References


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


