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

About this course

- **Time and Place: Every Thursday from 2:20pm to 5:20pm at Room 110 (NTU CSIE building).**
- **Dates:**

Sep			13	20	27
Oct	4	11	18	25	
Nov	1	8		22	29
Dec	6	13	20	27	
Jan	3	10	17		

- **Format:**
  - **Lectures.**
  - **Presentations for homework projects.**
  - **Invited lectures.**
    - *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.**
  - **Classes of 2007, 2008, 2009, 2010, and 2011.**
- **Special thanks the following persons.**
  - **Yuh-Jie Chen (class of 2008)**
  - **Jennya Chang (class of 2011)**
  - **Jessica Lin (class of 2011)**

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 6th NTU-TCG Cup.**
  - **Submitted package: Code + documents.**
- **Class participation (bonus)**

Evaluation (3/3)

- **Presentation/Report of a research paper on game tree search.**
  - **Bonus for selected students who are obviously falling behind.**
  - **If time allows, 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.**

Topics

- **Introduction: an A.I. oriented overview**
- **Single-player games**
- **Two-player perfect information games**
- **Practical considerations**
  - **Memorizing knowledge**
    - ▷ *Transposition tables*
    - ▷ *Endgame databases*
  - **The graph-history interaction (GHI) problem**
  - **Hardware enhancements**
  - **Timing control**
  - **Opponent model**

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] [Sha50]**
  - **The Turk, a chess playing "machine" at 1780's**
  - **The endgame playing machine at 1910's**
  - **C. E. Shannon (1950) and A. Samuel (1960)**
- **Games that machines have beaten human champions [SvdH02] [Sch00]**
  - **Chess**
  - **Othello**
  - **Checker**
  - ...

Single-player games

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

Two-player perfect information games (1/2)

- **A survey of current status [vdHUvR02]**
- **The original Computer Chess paper by C.E. Shannon [Sha50] 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] if time allowed [Pea80]*
- **Enhancements to the classical approaches**
  - *Quiescence search [Bea90]*
  - *Move ordering and other techniques [Sch89] [AN77] [Hsu91]*
  - *Further pruning techniques [SP96]*
  - *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**
  - **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]**

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 [Hya99] [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)

- **Hardware enhancements [DL04]**
- **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].*
- **Opponent model [CM96]**
  - **How to take advantage of knowing the playing style of your opponent.**

Resources (1/4)

- **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*
    - ▷ *Hold every year since 2000*
    - ▷ *1989 at London, United Kingdom (1st)*
    - ▷ *2004 at Ramat-Gan, Israel (9th)*
    - ▷ *2005 at Taipei, Taiwan (10th)*
    - ▷ *2011 at Tilburg, the Netherlands (16th)*
- **TCGA web site**
  - **Taiwan Computer Games Association**
  - **Since 2011.**
  - **http://tcga.ndhu.edu.tw**

Resources (2/4)

- **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 (3/4)

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

Resources (4/4)

- **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**
  - **A new IEEE journal**
  - **Quarterly publication since 2009**

Collection of papers

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