

# 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, A.I.
- 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/tcg2011>

# About this class

- **Time and Place:** Every Thursday from 2:20pm to 5:20pm at Room 310 (CSIE building).

	Sep			15	22	29
	Oct	6	13	20	27	
■ <b>Dates:</b>	Nov	3	10	17	24	
	Dec	1	8	15	22	30
	Jan	5		19		

- **Format:**

- Lecturing: for the first 12 – 14 lectures.
- Presentations for homework projects.
- Occasional invited lectures.

- ▷ *Go*

- ▷ *Connect6*

- ▷ ...

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

- **Class materials**

- Class notes.
- Collection of papers.

# Acknowledgements

- **Thanks to the students of this class for providing feedbacks on the slides.**
  - **Classes of 2007, 2008, 2009, 2010, and 2011.**
- **Special thanks to the following persons.**
  - **Jenny Chang (class of 2011)**
  - **Jessica Lin (class of 2011)**

# Evaluation (1/2)

- **One programming homework project (15%)**
  - About single agent search.
  - Pick your own game, implement, and then present the result.
- **Written exam (25%)**
- **Presentation/Report of a research paper (20%)**
  - 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 1000 words in PDF format.*
    - ▷ *Summary of results in the paper.*
    - ▷ *Comments about this paper, its strength, weakness and potential improvements.*

# Evaluation (2/2)

- **Final project (30%)**
  - **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 usage at this class only.*
  - **The 5th NTU-TCG Cup.**
  - **Submitted package: Code + documents. semester.**
- **Class participation (10%)**

# 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 and an AI oriented overview
- Single-player games
- Two-player perfect information games
- Other games
- Practical considerations
  - Memorizing knowledge
    - ▷ *Transposition tables*
    - ▷ *Endgame databases*
  - The graph-history interaction (GHI) problem
  - Hardware enhancements
  - Timing control
  - Opponent model



# 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] [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
  - 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] [Pea80]
- Enhancements to the classical approaches
  - ▷ *Quiescence search* [Bea90]
  - ▷ *Move ordering and other techniques* [Sch89] [AN77] [Hsu91]
  - ▷ *Further pruning* [SP96]
  - ▷ *Proof-number search* [AvdMvdH94]
- 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 idea [Bru93]
  - Pruning techniques
    - ▷ *Online knowledge* [BH04] [YYK<sup>+</sup>06]
    - ▷ *offline knowledge – Simulating balancing* [ST09] [HCL10a]
  - Parallel Monte-Carlo game tree search [CJ08] [CWvdH08]
- **Case study:**
  - Computer Chinese chess [YCYH04]
  - Computer Chinese dark chess [CSH10]

# Other games

- **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.

# 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 AAAI**
  - Covers all areas of AI
  - Computer game is only a small session now
  - Since 1980
- **Proceedings of IJCAI**
  - Covers all areas of AI
  - Computer game is only a small session now
  - International Joint Conference on Artificial Intelligence
  - Since 1969, every odd numbered of year

# Resources (3/4)

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

# Resources (4/4)

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

# Collection of papers

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