

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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- 十一週年!!!
- 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/2017>

About this course

- Time and Place: Every Thursday from 2:20pm to 5:20pm at Room 111 (NTU CSIE building).

Sep 14 21 28

Oct 5 12 19 26

- Dates: Nov 2 9 16 23 30

Dec 7 14 21 28

Jan 4 18

- Format:

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

▷ *Chinese chess*

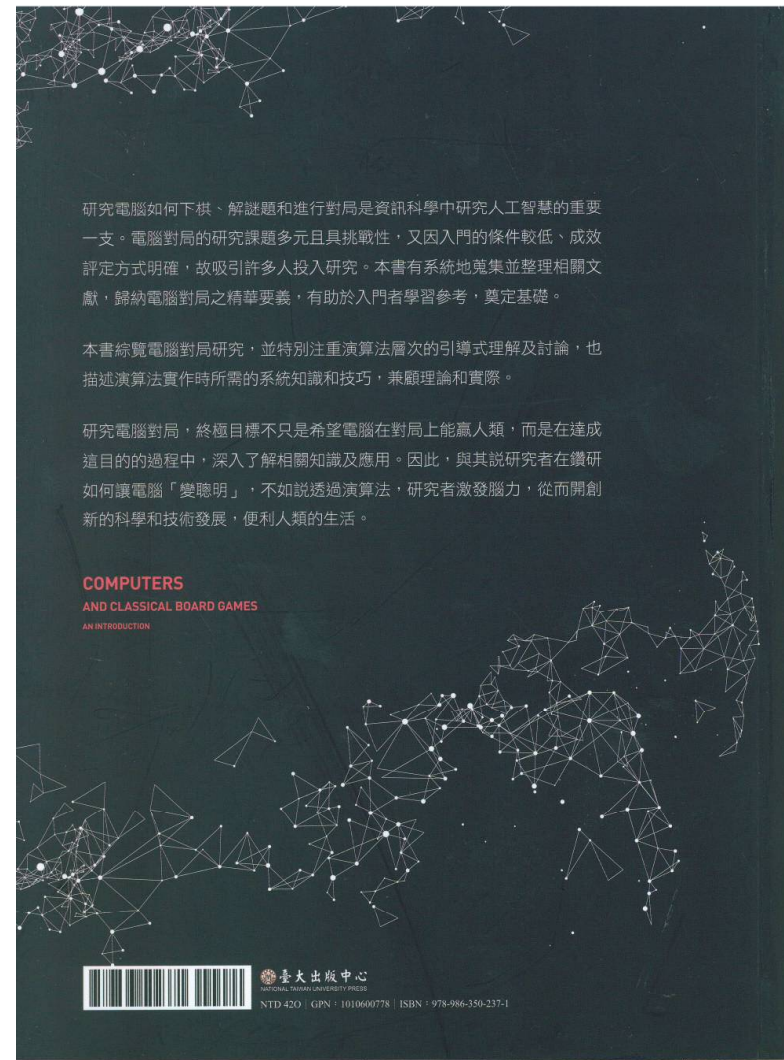
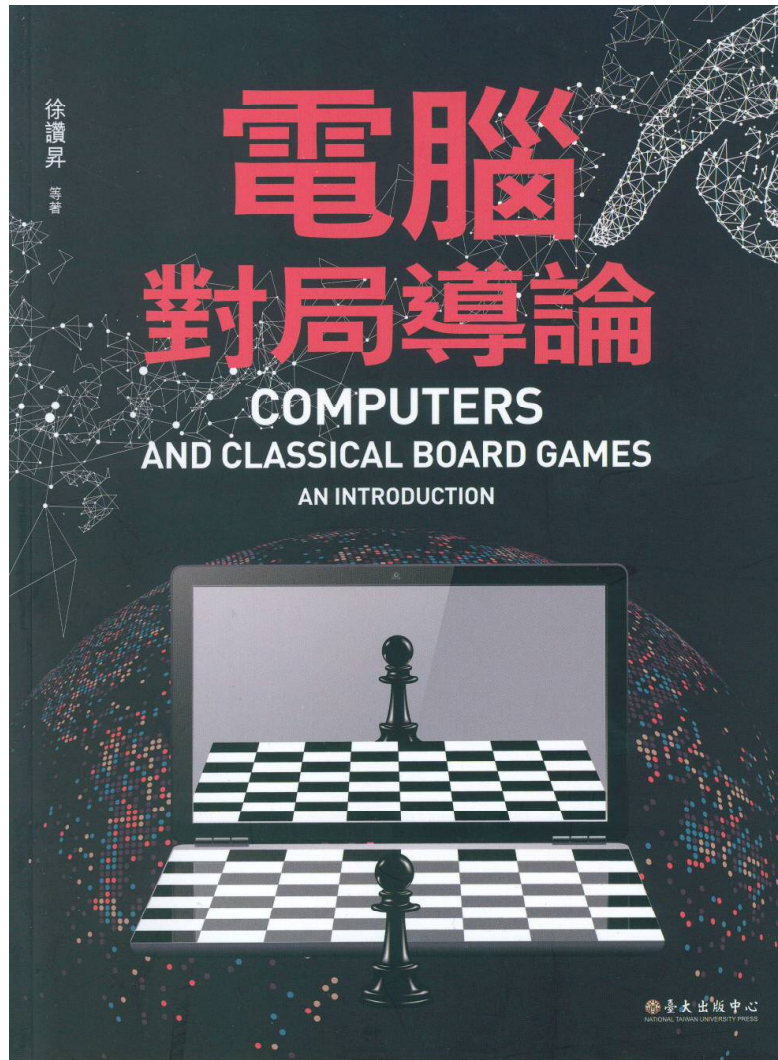
▷ *Go*

▷ ...

- Class materials

- textbook: 電腦對局導論, 臺大出版中心, June 2017
- Class notes
- Collection of papers.

Textbook



勘誤表: <http://www.iis.sinica.edu.tw/~tshsu/tcg/errata.pdf>

電腦對局導論

Computers and classical board games: An Introduction

2017年 6月 一版

勘誤表

日期：2017年 8月 18日

頁碼/位置	內容	
	修改前	修改後
p. I 序一的第二段	預官退伍之後，讚昇出國到美國德州奧斯汀大學深造，專攻演算法研究。	預官退伍之後，讚昇出國到美國德州大學奧斯汀校區深造，專攻演算法研究。
p. I 序一的第三段	2005年8月，讚昇與我共同主辦第十屆國際電腦奧林匹亞大賽和 CG2005 電腦對局國際會議，開啓 ICGA 國際電腦對局學會在亞洲地區舉辦活動的新頁。	2005年8月，讚昇與我共同主辦第十屆國際電腦奧林匹亞大賽和 CG2005 電腦對局國際會議，開啓 ICGA 國際電腦對局學會在亞洲地區舉辦活動的新頁。
p.11 的 1.5.2 節	目前觀察到一個謎題 <u>謎題</u> 必須至少要有 NP 完備的難度才會耐玩。	目前觀察到一個謎題必須至少要有 NP 完備的難度才會耐玩。
p.61 的 4.3 節	<u>1900</u> 年預測 2000 年電腦對局程式的發展。	<u>1990</u> 年預測 2000 年電腦對局程式的發展。
p.253 的 10.3.2 節	接下來，我們會以 AlphaGo 使用卷積神經網路加強蒙地卡羅樹搜尋擴展階段的方法為中心，來說明在擴展階段結合離線學習知識的方法。	接下來，我們會以圍棋程式如何使用卷積神經網路加強蒙地卡羅樹搜尋擴展階段的方法為中心，來說明在擴展階段結合離線學習知識的方法。
p.256 的 10.3.2.2 節	同時，我們也用同樣的資料一前面章節所用提到的 BT 模型建立模擬階段用的 <u>模擬策略模型</u> p_π 。	同時，我們也用同樣的資料一前面章節所用提到的 BT 模型建立模擬階段用的 <u>模擬策略網路 (rollout policy network) 模型</u> p_π 。

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, 2015 and 2106.
- 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, and against all other students.*
- **Written exam: midterm exam (30%)**

Evaluation (2/3)

■ Final project (40%)

- An alpha-beta based 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 11th 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, submit 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
 - Basic techniques
 - Advanced techniques
- **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 (1/6)

■ 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)*
 - ▷ *2015–2017 at Leiden, the Netherlands (18–20th)*

Resources (2/6)

- **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 (3/6)

■ 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 (4/6)

■ 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, 2017 at Leiden, the Netherlands (14th,15th)

■ 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)

Resources (5/6)

- **Proceedings of IEEE CIG**
 - Computational Intelligence and Games International Conference
 - Since 2005, every year.
 - Video game, classical games, ...
- **Proceedings of the Computer Games Workshop (CGW)**
 - Since 2012, every year.
 - Classical games, 2017 with IJCAI at Melbourne, Sunday August 20th, 2017.

Resources (6/6)

- **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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