

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

- 十五週年!!!
- Prerequisite: Computer Programming, **Linux/Unix**, C/C++, and Data Structure and Algorithms.
 - **Enjoy playing classical board games!**
 - **Heavy programming projects!**
- 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/2021>

About this course

- Time and Place: Every Thursday from 2:20pm to 5:20pm at Room 105 (NTU CSIE building): **on-lined** for the first 3 weeks, the rest is unknown now.

	Sep				23	30
	Oct	7	14	21	28	
■ Dates:	Nov	4	11	18	25	
	Dec	2	9	16	23	30
	Jan		6	13	20	

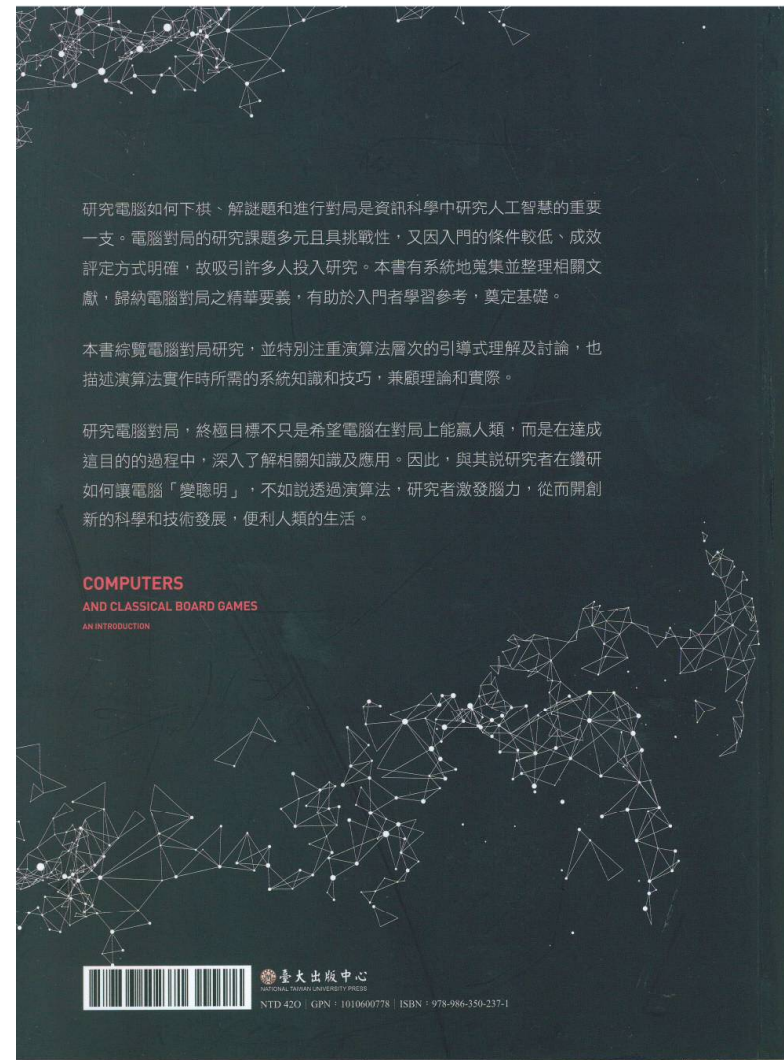
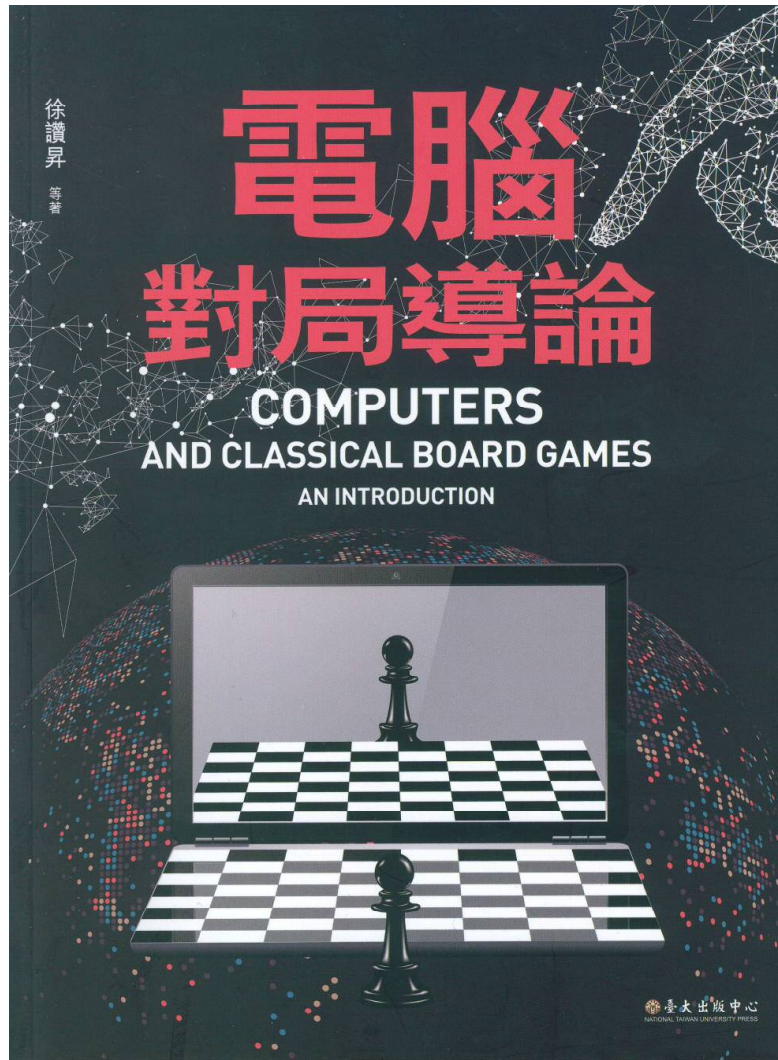
- Format:

- Lectures.
- Presentations for homework projects (optional).
- Invited lectures: TBA.

- Class materials

- textbook: 電腦對局導論, 臺大出版中心, June 2017 ; ISBN: 978-986-350-237-1; **required!!**
- Class notes
- Collection of papers

Textbook



勘誤表: <http://www.iis.sinica.edu.tw/~tshsu/tcg/errata20210824.pdf>

電腦對局導論

Computers and classical board games: An Introduction

2017年6月一版

勘誤表

August 23, 2021

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。
圖目錄之 2.4	混合雙佇列實作佇列之示意	混合雙佇列實作佇列之示意圖
圖目錄之 4.4	六貫棋性質證明：連接黑方棋子	六貫棋性質證明：連接各行中的黑方棋子
圖目錄之 5.7	位在中央的騎士	騎士的影響
圖目錄之 5.14	栓鏈的範例	栓鏈
圖目錄之 5.19	欠行局例	欠行
圖目錄之 7.4	斥候演算法搜尋的節點數比 Alpha-Beta 切捨演算法拜訪的節點數多的例子	斥候搜尋時 TEST 拜訪的節點數比 Alpha-Beta 切捨多的例子
圖目錄之 7.8	斥候演算法拜訪最少的節點數的例子	斥候演算法拜訪最少節點數的例子
演算法目錄之15	15 $F'(position\ p)$	15 $F'(position\ p, integer\ depth)$
演算法目錄之16	16 $G'(position\ p)$	16 $G'(position\ p, integer\ depth)$
演算法目錄之17	17 $F(position\ p)$	17 $F(position\ p, integer\ depth)$
演算法目錄之18	18 $F_2^2(position\ p, value\ alpha, value\ beta)$	18 $F_1^1(position\ p, value\ alpha, value\ beta)$
演算法目錄之19	19 $G_2^2(position\ p, value\ alpha, value\ beta)$	19 $G_1^1(position\ p, value\ alpha, value\ beta)$
演算法目錄之20	20 $F_2(position\ p, value\ alpha, value\ beta)$	20 $F_2(position\ p, value\ alpha, value\ beta, integer\ depth)$
演算法目錄之21	21 $F_2(position\ p, value\ alpha, value\ beta)$	21 $F_2(position\ p, value\ alpha, value\ beta, integer\ depth)$
演算法目錄之29	29 IDAS(position p , integer $limit$, integer $threshold$)	29 IDAS(position p , integer $limit$, value $threshold$)
演算法目錄之30	30 IDAS'(position p , integer $limit$, integer $threshold$)	30 IDAS'(position p , integer $limit$, value $threshold$)
演算法目錄之36	36 $F_{4.4}(position\ p, value\ alpha, value\ beta, integer\ depth, Boolean\ do_null)$	36 $F_{4.4}(position\ p, value\ alpha, value\ beta, integer\ depth, Boolean\ in_null)$
演算法目錄之37	37 $F_{4.5}(position\ p, value\ alpha, value\ beta, integer\ depth, Boolean\ do_lmr)$	37 $F_{4.5}(position\ p, value\ alpha, value\ beta, integer\ depth, Boolean\ in_lmr)$
演算法目錄之45	45 MCTS	45 MCTS

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 - Classes of 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019 and 2020.
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 - Jessica Lin (class of 2011)
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 - 陳冠伶
 - 許祐程
 - 張紘睿
 - 樂正
 - 鍾詠先
 - 陳約廷
 - 郭麗莎

Evaluation (1/3)

■ Homework (50%)

● One homework project about alpha-beta search (25%)

- ▷ *About alpha-beta search, single-person project, C/C++;Linux/Unix knowledge is **required**.*
- ▷ *A special Chinese Dark Chess game where there are no dark pieces and cannons.*
- ▷ *Your program plays against a baseline program. on a set of benchmarks. Your score is compared with the score of a good CDC program playing on the same set of test data.*
- ▷ *Implement a set of required techniques learned from the class and submit a written report.*

● One homework project about Monte-Carlo simulation (25%)

- ▷ *A single-person project, C/C++;Linux/Unix knowledge is **required**.*
- ▷ *A special Chinese Dark Chess game where there are no dark pieces.*
- ▷ *Your program plays against a baseline program. on a set of benchmarks. Your score is compared with the score of a good CDC program playing on the same set of test data.*
- ▷ *Implement a set of required techniques learned from the class and submit a written report.*

Evaluation (2/3)

- **Final coding project (30%)**
 - An alpha-beta based computer game program for the original version of 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 15th NTU-TCG Cup.
 - The competition will be held during the 17th week of the semester in about 3 non-consecutive days.
- **Final written report (20%):** during the 18th week of the semester.
 - Document for the final project
 - Study notes.
 - Open-booked questions.
 - ...
- **Class participation**
 - Bonus for good participation
 - Students being recorded as not attending the classes will be penalized
 - More rules will be announced during the lectures

Evaluation: Backup plans (3/3)

- In case of unexpected circumstances due to COVID-19 or others.
- Possible options:
 - A written final exam.
 - Off-line competition.
 - ▷ *Code submitted and then executed by TA.*
 - ▷ *Game logs are provided.*
 - ▷ *Multiple runs.*
- For students that are falling behind during the semester, we will invite them to do extra work to make up the score.

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 (chapter 1): an A.I. oriented overview
- Single-player games: **lectures are skipped**, topics for self study except chapter 2.2.6.
 - Basic techniques
 - Advanced techniques
- Two-player perfect information games
 - Survey (chapter 4): **chapter 4.5 will be skipped.**
 - Introduction from Chess's point of view (chapter 5)
 - Alpha-beta and its extensions (chapters 6 and 7)
- **Homework I**: announce at the 5th week and is due at the 8th week.
- Two-player perfect information games
 - Monte-Carlo based method (chapters 9 and 10)
- **Homework II**: announce at the 9th week and due at the 12th week.

Course at a glance (2/2)

- **Practical considerations**
 - Transposition tables (ch. 8.1–8.3)
 - Advanced pruning techniques (ch 8.4–8.9)
- **Advanced topics**
 - Parallelization (ch. 11) (?)
 - Endgame (ch. 12) (?)
 - The graph-history interaction (GHI) problem (ch 13.2)
 - Opponent model(ch 13.3)
 - Searching chance nodes (ch 13.4)
- **Concluding remarks (ch 14)**
 - Timing control
 - Software and hardware enhancements
 - Conclusion
- **Final project:** announce 13th week and due at the 17th week.
- **Final report:** 18th week.

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)*
 - ▷ *2018 at New Taipei City, Taiwan (21th)*
 - ▷ *2019 at Macau, China (22th), co-located with IJCAI*
 - ▷ *2020 (23th) is on-lined due to COVID-19.*
 - ▷ *2021 (24th) is on-lined due to COVID-19.*

Resources (2/6)

- **TCGA web site**
 - Taiwan Computer Games Association
 - Since 2011.
 - <http://tcga.ndhu.edu.tw>
 - Annual May/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)

▷ 2019 at Macau, China (16th)

▷ 2021 (online) (17th)

■ 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), 2018 (10th; New Taipei City, Taiwan), 2020 (cancelled)

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, August 20th, 2017.
 - 2018 (7th), Sweden
 - Not sure about it after 2018

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
 - Since, 2017, IEEE Transactions on Games.

Collection of papers

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