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
- 十七週年!!!
- 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/2023

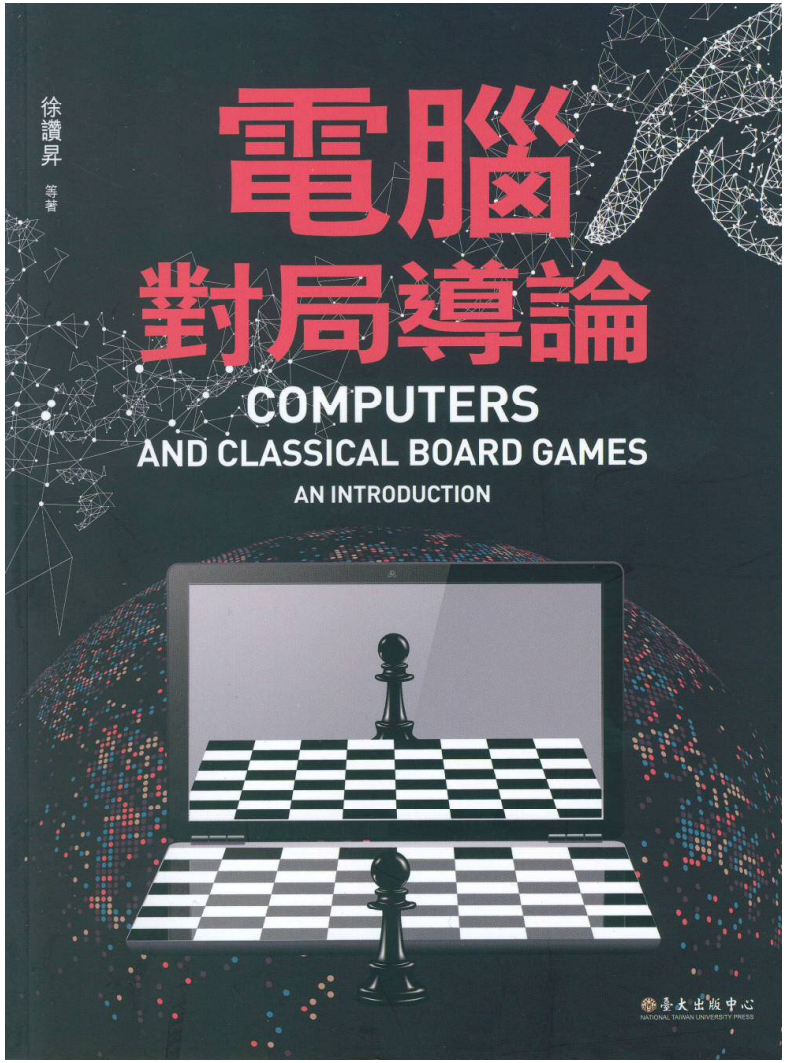
About this course

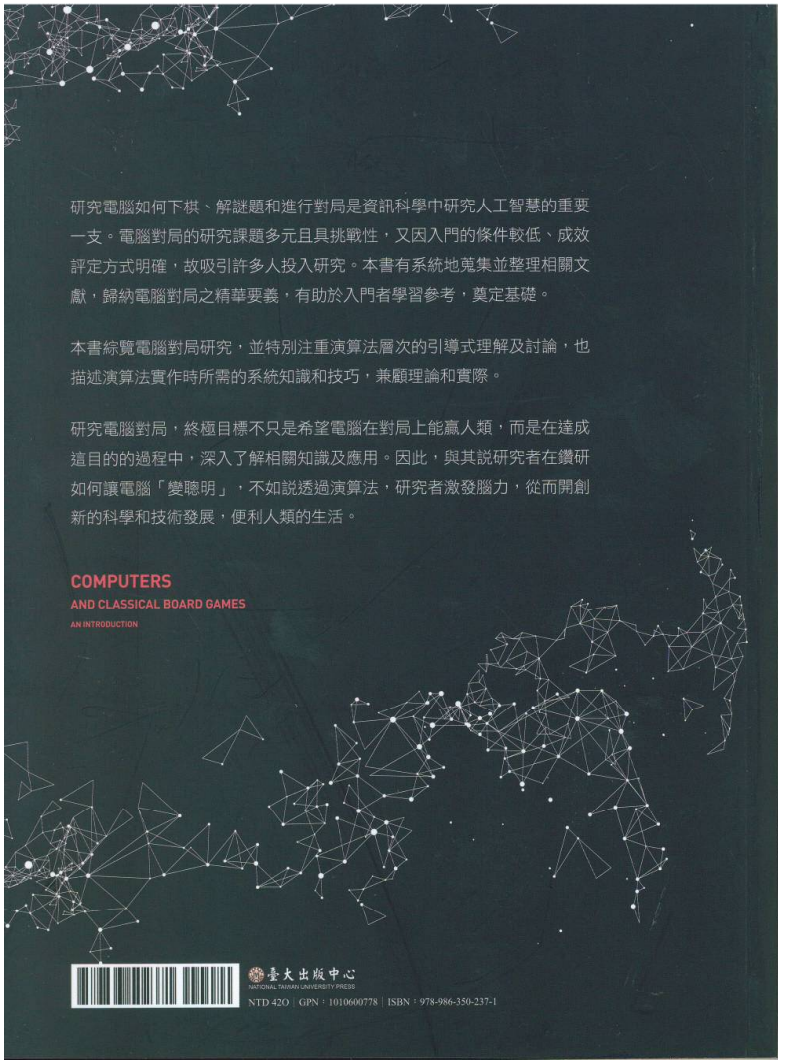
- Time and Place: Every Thursday from 2:20pm to 5:20pm at Room 105 (NTU CSIE building)
- Dates:

Sep		7	14	21	28
Oct	5	12	19	26	
Nov	2	9	16	23	30
Dec	7	14	21	28	
Jan	4				

- 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 F2′(position *p*, value *alpha*, value *beta*)	18 F1′(position *p*, value *alpha*, value *beta*)
演算法目錄之19	19 G2′(position *p*, value *alpha*, value *beta*)	19 G1′(position *p*, value *alpha*, value *beta*)
演算法目錄之20	20 F2(position *p*, value *alpha*, value *beta*)	20 F2(position *p*, value *alpha*, value *beta*, integer *depth*)
演算法目錄之21	21 F2(position *p*, value *alpha*, value *beta*)	21 F2(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 F4.4′(position *p*, value *alpha*, value *beta*, integer *depth*, Boolean *do_null*)	36 F4.4′(position *p*, value *alpha*, value *beta*, integer *depth*, Boolean *in_null*)
演算法目錄之37	37 F4.5′(position *p*, value *alpha*, value *beta*, integer *depth*, Boolean *do_lmr*)	37 F4.5′(position *p*, value *alpha*, value *beta*, integer *depth*, Boolean *in_lmr*)

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  - Jessica Lin (class of 2011)
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  - 陳冠伶
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  - 張紘睿
  - 樂正
  - 鍾詠先
  - 陳約廷
  - 郭麗莎
  - 許嘉銘
  - 詹凱傑

Classroom rules

- No drinking and eating.
- Maintain a proper social distance.
- If you do not feel well, rest at home.
  - Wear a mask effectively.

Evaluation (1/3)

- Homework (34%)
  - One homework project about single-player search (17%)
    - About A* search, single-person project, C/C++;Linux/Unix knowledge is required.
    - A one-player version of the EWN game when pieces can move in 8 directions and with a fixed dice sequence called One-EWN. The goal is to find a schortest moves to the goal.
    - Your score is compared with the score of a good heuristic 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 (17%)
    - A single-person project, C/C++;Linux/Unix knowledge is required.
    - EWN Kari 3: EWN with a larger board and a fixed dice sequence.
    - Your program plays against a baseline program and other opponents. Your score is compared with the score of a good EWN kari 3 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)

- Written mid-term exam (33%)
- Final coding project (33%)
  - An alpha-beta based computer game program for the original version of EWN.
    - A sample code with GUI will be provided.
    - The usage of this sample code is restricted for anything related to this course only.
  - The 17th NTU-TCG Cup.
  - The competition will be held on-line or physically during the 17th and 18th weeks of the semester in 2 or 3 non-consecutive days.
  - Submitted package: Code + documents.
  - Final written report: during the 18th week of the semester.
    - Document for the final project
    - Study notes.
    - ...
- 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

- Lecturing is entirely done in Mandarin
- 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 (1/3)

- Introduction (chapter 1): an A.I. oriented overview
- Programming tips (chapter 14.2.2)
- Single-player games (chapter 2): lectures for chapter 2.2.1 – 2.2.4 and chapter 3 are skipped
  - Brute-force search
  - A* search
- Homework I: announce before the 5th week and is due at the 7th week.
- Two-player perfect information games
  - Survey (chapter 4)
  - Introduction from Chess's point of view (chapter 5)
  - Alpha-beta search (chapter 6)
  - Basic Monte-Carlo search (chapter 9)
- Mid-term exam: 2:20pm–5:20pm Nov 2 (Thursday)

Course at a glance (2/3)

- Advanced single-player search (chapter 3): skipped
- Two-player perfect information games
  - Advanced Monte-Carlo method (chapter 10)
  - Nega-scout search (chapter 7)
- Homework II: announce at the 11th week and due at the 14th week.
- Practical considerations
  - Transposition tables (ch. 8.1–8.3)
  - Move ordering (ch 8.4–8.5)
- Searching chance nodes (ch 13.4)
- Advanced topics
  - Parallelization (ch. 11) (?)
  - Opengame and Endgame (ch. 12)
  - The graph-history interaction (GHI) problem (ch 13.2) (?)
  - Opponent model(ch 13.3) (?)
- Concluding remarks (ch 14)
  - Timing control
  - Software and hardware enhancements
  - Conclusion

Course at a glance (3/3)

- Final project: announce at the 14th week and due at the 18th week.
  - Live competition during Thursdays of the 17th and 18th weeks.
- 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 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]
- 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]
- Searching chance nodes
- 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)

- Bit board
- Multi-player game tree search and pruning
- 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?

Collection of papers

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