Course Form for PKU Summer School International 2018

Course Title	Computational Game Theory
	计算对弈游戏理论
Teacher	Dan Garcia
First day of classes	July 31, 2018
Last day of classes	August 10, 2018
Course Credit	2 credits

Course Description

Objective
This course will explore the fertile ground of computational game theory, i.e., the use of computers to solve abstract strategy games via computational brute force. We blend ideas from artificial intelligence, combinatorics, human-computer interface design, parallel and distributed computing and software engineering. Students will learn the mathematical foundations of abstract strategy games and the special case of combinatorial games, including surreal numbers. They will learn how to calculate the upper bounds of the size of a game tree, will author a simple recursive solver for loop-free games, and a retrograde solver to handle loopy games. They will extend their retrograde solver to work in a distributed environment using the Apache Spark™ API. For their final project, students will work in teams to choose and encode an abstract strategy game, solve it, author a graphical interface that will allow the system to play perfectly, and use it to perform analysis.

Pre-requisites /Target audience
Data Structures and Algorithms, Discrete Mathematics, Python language fluency Senior undergraduate students and graduate students

Proceeding of the Course
Data structures

Assignments (essay or other forms)
Reading, Assignment and Programming

Evaluation Details
Attendance, Participation and Reading: 20% Programming Project: 50% Final Report: 30%

REQUIRED Text Books and Reading Materials

1. Jonathan Schaeffer, Neil Burch, Yngvi Björnsson, Akihiro Kishimoto, Martin Müller,Robert Lake,Paul Lu, Steve Sutphen, **Checkers Is Solved**. *Science* 14 Sep 2007:Vol. 317, Issue 5844, pp. 1518-1522, DOI: 10.1126/science.1144079
2. R.U.Gasser. **Solving Nine Men's Morris** R.J.Nowakowski (Ed.), Games of No Chance, MSRI Publications, 29,Cambridge University Press, Cambridge, MA (1996), pp.101-113
3. H.Jaapvan den Herik, Jos W.H.M.Uiterwijk, Jackvan Rijswijck. **Games solved: Now and in the future**. Artificial Intelligence, Volume 134, Issues 1–2, January 2002, Pages 277-311. https://doi.org/10.1016/S0004-3702(01)00152-7

RECOMMENDED Text Books and Reading Materials

1. Elwyn R. Berlekamp, John H. Conway, Richard K. Guy. **Winning Ways for Your Mathematical Plays: Volume 1 (2nd Edition),** A K Peters/CRC Press; 978-1568811307; January 18, 2001)

Academic Integrity (If necessary)

CLASS SCHEDULE
(Subject to adjustment)

Session 1：*Introduction to Computational Game Theory*	Date:7/31

【**Description of the Session**】(**purpose, requirements, class and presentations scheduling, etc.)** After group introductions, we will provide an overview of the field, motivation and basics of computational game theory. We will also explore many popular abstract strategy games and form classifications.

【**Questions**】

【**Readings, Websites or Video Clips**】
1. H.Jaapvan den Herik, Jos W.H.M.Uiterwijk, Jackvan Rijswijck. **Games solved: Now and in the future**. Artificial Intelligence, Volume 134, Issues 1–2, January 2002, Pages 277-311. https://doi.org/10.1016/S0004-3702(01)00152-7

【**Assignments for this session (if any)**】 Author a recursive backtracking solver in Python for the Nim-like game 10, 9, … 1 (starting with 10 coins, remove one or two on your turn with the goal of removing the last coin) and rudimentary playing system.

Session 2：*Determining the Size of Games*	Date:8/01

【**Description of the Session**】(**purpose, requirements, class and presentations scheduling, etc.**) Using principles from Combinatorics, students will learn how to calculate bounds on the number of positions of games.

【**Questions**】

【**Readings, Websites or Video Clips**】 YouTube "Numberphile: Connect 4"
https://www.youtube.com/watch?v=yDWPi1pZ0Po

1. R.U.Gasser. **Solving Nine Men's Morris** R.J.Nowakowski (Ed.), Games of No Chance, MSRI Publications, 29,Cambridge University Press, Cambridge, MA (1996), pp.101-113

【**Assignments for this session (if any)**】 Determine the number of positions in Connect 4 in closed form. Polish the "game player" from Session 1.

Session 3：*Solvers*	Date:8/02

【**Description of the Session**】(**purpose, requirements, class and presentations scheduling, etc.**) Starting from a simple recursive descent solver, we will understand its limitations, and will first increase its speed significantly through memoization, and then explore the retrograde algorithm to handle loopy games, as well as explore an optimized iterative solver for tier games.

【**Questions**】

【**Readings, Websites or Video Clips**】 https://en.wikipedia.org/wiki/Hare_games

【**Assignments for this session (if any)**】 Author a retrograde solver in Python and test it on a small loopy game (e.g., Hare and Hounds, Chopsticks, etc)

Session 4：*Distributed Solvers*	Date:8/03

【**Description of the Session**】(**purpose, requirements, class and presentations scheduling, etc.**) Students will be introduced to the Apache Spark system and explore how to use it to speed up an iterative solver.

【**Questions**】

【**Readings, Websites or Video Clips**】
1. Jonathan Schaeffer, Neil Burch, Yngvi Björnsson, Akihiro Kishimoto, Martin Müller,Robert Lake,Paul Lu, Steve Sutphen, **Checkers Is Solved**. *Science* 14 Sep 2007:Vol. 317, Issue 5844, pp. 1518-1522, DOI: 10.1126/science.1144079

【**Assignments for this session (if any)**】 Students will choose a game to implement for their final project and begin working on it.

Session 5： *Introduction to Combinatorial Game Theory*	Date:8/07

【**Description of the Session**】 (**purpose, requirements, class and presentations scheduling, etc.**) Starting with Nim and moving quickly through to Kayles and Domineering, students will learn the fundamentals of combinatorial game theory.

【**Questions**】

【**Readings, Websites or Video Clips**】

【**Assignments for this session (if any)**】 Practice with the algorithm for playing Nim perfectly, and continue to work on their final project.

Session 6： *Building a Graphical User Interface*	Date:8/08

【**Description of the Session**】 (**purpose, requirements, class and presentations scheduling, etc.**) Students will be introduced to the principles behind building a graphical user interface for their game.

【**Questions**】

【**Readings, Websites or Video Clips**】

【**Assignments for this session (if any)**】 Begin to add an a graphical user interface onto their final project

Session 7： *Group Project Work Session*	Date:8/09

【**Description of the Session**】 **(purpose, requirements, class and presentations scheduling, etc.)** This session is provided to allow the student groups to finish up their projects with instructor guidance, and do analysis of the games.

【**Questions**】

【**Readings, Websites or Video Clips**】

【**Assignments for this session (if any)**】 Continue working on the final project

Session 8：*Final Project Demonstrations*	Date:8/10

【**Description of the Session**】 **(purpose, requirements, class and presentations scheduling, etc.)** This session is devoted to demonstrations of the student final projects and submissions of their final report.

【**Questions**】

【**Readings, Websites or Video Clips**】

【**Assignments for this session (if any)**】

A CV of 250-300 words and a high-resolution personal photo should also be provided

Title in English: Computational Game Theory
Professor：Dan Garcia

Dan Garcia (ddgarcia@cs.berkeley.edu) is a Teaching Professor in the Computer Science Division of the EECS Department at the University of California, Berkeley, and joined the faculty in the fall of 2000. Dan received his PhD and MS in Computer Science from UC Berkeley in 2000 and 1995, and dual BS degrees in Computer Science and Electrical Engineering from MIT in 1990. He was chosen as an ACM Distinguished Educator in 2012. He won NCWIT's Undergraduate Research Mentoring (URM) Award in 2016.

He has won all four of the department's teaching awards (the Information Technology Faculty Award for Excellence in Undergraduate Teaching in 2004, the Diane S. McEntyre Award for Excellence in Teaching in 2002, the EECS outstanding graduate student instructor award in 1998, and the CS outstanding graduate student instructor award in 1992.). He was also chosen as a UC Berkeley "Unsung Hero" in 2005. He holds the record for the highest teaching effectiveness ratings (6.7/7) in the history of the department's lower-division introductory courses. His research interests are computer science education and computational game theory.