CHECKERS SOLVED!
A 19-year project led by Prof Jonathan Schaeffer, he used dozens (sometimes hundreds) of computers and AI to prove it is, in perfect play, a ... draw! This means that if two Gods were to play, nobody would ever win!

www.cs.ualberta.ca/~chinook/

Computer Science ... A UCB view

- CS research areas:
  - Artificial Intelligence
  - Biosystems & Computational Biology
  - Computer Architecture & Engineering
  - Database Management Systems
  - Graphics
  - Human-Computer Interaction
  - Operating Systems & Networking
  - Programming Systems
  - Scientific Computing
  - Security
  - Theory
  - ...

Claude Shannon’s Paper (1950)

- “Father of Information Theory”
  - Digital computer and digital circuit design theory
  - Defined fundamental limits on compressing/storing data
  - Wrote “Programming a Computer for Playing Chess” paper in (1950)
  - All chess programs today have his theories at their core
  - His estimate of # of Chess positions called "Shannon #" 😇
    - Now proved < 2^64 😇

Computational Game Theory

- History
- Definitions
  - Game Theory
  - What Games We Mean
  - Win, Lose, Tie, Draw
  - Weakly / Strongly Solving
- Gamesman
  - Dan’s Undergraduate R&D Group
  - Demo!!
- Future

The Turk (1770)

- A Hoax!
- Built by Wolfgang von Kempelen
  - To impress the Empress
- Could play a strong game of Chess
  - thanks to Master inside
- Toured Europe
  - Defeated Benjamin Franklin
  - Defeated Napoleon
  - Burned in an 1854 fire
  - Chessboard saved.

Deep Blue vs Garry Kasparov (1997)

- Kasparov World Champ
- 1996 Tournament – Deep Blue
  - First game DB wins a classic!
  - But DB loses 3 and draws 2 to lose the 6-game match 4-2
  - In 1997 Deep Blue upgraded, renamed "Deeper Blue"
- 1997 Tournament – Deeper Blue
  - GK wins game 1
  - GK wins game 2
  - even though it was draw!
  - DB & GK draw games 3-5
  - Game 6: 1997-05-11 (May 11th)
  - Kasparov makes move 7, black in 10 moves.
  - Loses Tournament: 6-4... 2-2
  - GK accuses DB of cheating. No remark.
- Defining moment in AI history

www.eecs.berkeley.edu/Research/Areas/


**What is “Game Theory”?**

- **Combinatorial**
  - Sprague and Grundy's 1939 Mathematics and Games
  - Nim, Domineering, dots and boxes
  - Film: Last Year in Marienbad
  - Complete info, alternating moves
  - Goal: Last move

- **Computational**
  - P. C. Bells 1998 Board and Table Games from many Civilizations
  - Board games
  - Tic-Tac-Toe, Chess, Connect 4, Othello
  - Film: Searching for Bobby Fischer
  - Complete info, alternating moves
  - Goal: Varies

- **Economic**
  - von Neumann and Morgenstern's 1944 Theory of Games and Economic Behavior
  - Matrix games
  - Prisoner's dilemma, auctions
  - Film: A Beautiful Mind (about John Nash)
  - Incomplete info, simultaneous moves
  - Goal: Maximize payoff

- **Matrix games**
  - Prisoner's dilemma
  - Auctions

- **Simultaneous moves**
  - Goal: Maximize payoff

- **Game Theory**
  - A subfield of Mathematics

- **Board and Table Games**
  - Nim
  - Chess
  - Connect 4
  - Othello
  - Film: Searching for Bobby Fischer

- **Combinatorial**
  - Nim
  - Chess
  - Connect 4
  - Othello
  - Film: Searching for Bobby Fischer

- **Goal**
  - Maximizing payoff

**What “Board Games” do you mean?**

- No chance, such as dice or shuffled cards
- Both players have complete information
  - No hidden information, as in Stratego or Magic
- Two players (Left & Right) usually alternate moves
  - Repeat & skip moves ok
  - Simultaneous moves not ok
- The game can end in a pattern, capture, by the absence of moves, or ...

**What's in a Strong Solution**

- For every position
  - Assuming alternating play
  - Value
    - for player whose turn it is
    - Winning (3 losing child)
    - Losing (all children winning)
    - Losing (3 losing child, but 3 losing child)
    - Drawing (can't force a win or be forced to lose)
  - Remoteness
  - How long before game ends?

**GamesCrafters**

- A group that strongly solves abstract strategy games and puzzles
  - 70 games / puzzles in our system
  - Allows perfect play against an opponent
  - Ability to do a post-game analysis

**Weakly Solving A Game (Checkers)**

- Master: main line of play to consider
- Workers: positions to search
- Endgame databases (solved)

**Log of Search Space Size**

- Thanks to Jonathan Schaeffer @ U Alberta for this slide...
Strong Solving Example: 1,2,…,10

- Rules (on your turn):
  - Running total = 0
- Rules (on your turn):
  - Add 1 or 2 to running total
- Goal
  - Be the FIRST to get to 10
- Example
  - Ana: “2 to make it 2”
  - Bob: “1 to make it 3”
  - Ana: “2 to make it 5”
  - Bob: “2 to make it 7” → photo
  - Ana: “1 to make it 8”
  - Bob: “2 to make it 10” WIN!

Example: Tic-Tac-Toe

- Rules (on your turn):
  - Place your X or O in an empty slot on 3x3 board
- Goal
  - If your make 3-in-a-row first in any row / column / diag, win
  - Else if board is full with no 3-in-a-row, tie
- Mise is tricky
  - 3-in-row LOSES
  - Pair up and play now, then swap who goes 1st

Tic-Tac-Toe Answer Visualized!

- Recursive Values Visualization Image
- Misère Tic-tac-toe
  - Outer rim is position
  - Inner levels moves
  - Legend
    - lose
    - Te
    - Win

GamesCrafters (revisited)

- Undergraduate Computational Game Theory Research Group
- 300 students since 2001
  - They work in teams of 2
  - Most return, take more senior roles (sub-group team leads)
    - Minimax bottom-up search
    - DeepBlue (parallelization)
    - GUI (graphical interface work)
    - Beta (GUI refactoring)
    - Architecture (core)
    - New/ice Games (add / refactor)
    - Documentation (games & code)

Connect 4 Solved, Online!

- Just finished a solve of Connect 4!!
- It took 30 Machines x 8 Cores x 1 weeks
- Win for the first player (go in the middle!)
  - 3,5 = tie
  - 1,2,6,7 = lose
- Come play online!

Future

- Board games are exponential
  - So has been the progress of the speed / capacity of computers
  - Therefore, every few years, we only get to solve more "ply"
- One by one, we're going to solve them and/or beat humans
  - E.g., checkers, Go
- Strongly solving (GamesCrafters)
  - We visit EVERY position, and know value of EVERY position
  - E.g., Connect 4
- Weakly solving (Univ Alberta)
  - We know game's value by only visiting SOME positions, so we only know value of SOME positions
  - E.g., Checkers