CHECKERS SOLVED IN 2007!
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!

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
  - ...}

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 & Napoleon!
- Burned in an 1854 fire
- Chessboard saved.

Deep Blue vs Garry Kasparov (1997)

- Kasparov World Champ
- 1996 Tournament
  - 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
  - GK wins game 1
  - GK resigns game 2
  - even though it was drawn!
  - DB & GK draw games 3-5
  - Game 6: 1997-05-11 (May 11th)
    - Kasparov wins 7, loses in 10 moves. Losses tournament 3½ - 2½
    - GK accuses DB of cheating. No rematch.
- Defining moment in AI history
What is “Game Theory”?

- Combinatorial
  - Sprague and Grundy's 1939
  - Mathematics and Games
  - Nim, Domineering, dots and boxes
  - Find (last year in Manxenbad)
  - Complete info, alternating moves
  - Goal: Last move

- Computational
  - R. C. Bell's 1948
  - 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: Maximize payoff

- 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

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 & 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 (1 losing child)
      - Losing (1 child losing)
      - Root
      - Draw (can’t force a win or be forced to lose)
    - Remoteness
      - How long before game ends?

GamesCrafters

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

What did you mean “strongly solve“?

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 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 a 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
- Misère is tricky
  - 3-in-row LOSES
  - Pair up and play now, then swap who goes first

Tic-Tac-Toe Answer Visualized!

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

GamesCrafters

- Undergraduate Computational Game Theory Research Group
- 300 students since 2001
  - We now average 20/semester!
  - They work in teams of 2+
- Most return, take more senior roles (sub-group team leads)
  - Maximization (bottom-up solve)
  - DeepBlue (parallelization)
  - GUI (graphical interface work)
  - Team (GUI refactoring)
  - Architecture (code)
  - New/ice Games (add / refactor)
  - Documentation (games & code)

Connect 4 Solved, Online!

- We've 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

Future

- Board games are exponential in nature
  - So has been the progress of the speed / capacity of computers!
  - Therefore, every few years, we only get to solve one more "ply"
- One by one, we're going to solve them and/or beat humans
  - We'll never solve some
    - E.g., hardest game: Go