Lecture 30: How can computation... Win games against you?

Chess: Mechanical Turk

Automaton Chess Player
- Chess-playing machine 1770-1854
- Play strong game of chess against human opponent
- Arms move chess pieces
- Gears shown off inside

The Turk won most games
- Europe and the Americas
- Defeated many challengers (Napoleon Bonaparte and Benjamin Franklin)

The Turk: a mechanical illusion
- Human chess master hiding inside to operate the machine
- Revealed in 1820s

Chess: Deep Blue

Feb 1996: first machine to win chess game vs. reigning world champion
  - Garry Kasparov under regular time controls
  - Deep Blue loses match
May 1997: Upgrade wins match
  - Search 6-8 moves ahead (up to 20 moves)
  - Kasparov said saw “deep intelligence and creativity” in machine’s moves
    - Claimed person was directing Deep Blue
    - Change between games to fix weaknesses

Today’s Question

What type of algorithms are used to win strategy games?

Does computer need “insight” to win difficult games against humans?
What is a Strategy Game?

Requirements:
• No chance involved (no dice or card games)
• Both players have complete information
  – No hidden information (no Stratego or Magic)
• Two players alternate moves
  – No simultaneous moves
  – One player can pass...
• Identify ending condition as Win, Tie, or Lose:
  – Game ends in a pattern, capture, by the absence of moves

Examples
• Tic-Tac-Toe, Connect 4, Othello, Checkers, Chess

Today’s Exercise

Play strategy game to help you analyze your “strategy”

Want a strategy game you have no prior experience with... (not tic-tac-toe!)

Want you to blindly search for winning strategy
• Enumerate all possible moves
• Record whether each leads to win or loss

Exercise: Variation of Nim (Subtraction Game)

Rules:
• 2 players, 7 objects
• Take turns removing 1, 2, or 3
• Winner: Takes last object

In order to record states:
• Fill in 7 slots (instead of remove)
• Use X (player 1)
• Use 0 (player 2)

Example:
X, X000, X000XXX → X wins

Play multiple times (try to enumerate all), alternate who goes first
If solve for 7 objects, try with different numbers of starting pieces

Strategies?

Exhaustive search
• Record every possible move for X and O
• Which ones lead to winning? Do those next game...

Random
• Just pick 1, 2, or 3 at random!

Insight
• Remove 1,2, or 3 such that remaining N mod 4 = 0
Exhaustively Analyze all Possibilities

7 Empty slots
Possibility 1: Initial move of 3 Xs

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<thead>
<tr>
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<th>O</th>
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</table>

Conclusion: X can always win if it places 3 (given 7 initially)
Leaving 4 squares is good...

Nim Game Trees: Empty Board - 2 moves

Nodes: Game positions or states
Edges: Moves or transitions

Exhaustively Analyze all Possibilities

Possibility 2: Initial move of 2 Xs

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No matter what X does, O can win

X may not win if it takes 2 (given 7 initially)
Leaving 5 is bad...

Nim Game Tree: 3 X’s for first move

Leaf node: Winner
Purple: X Wins
Red: O Wins

3 Xs good move: All paths can lead to X winning
No matter what O does, X can win
Always assume O is smart - will do best move for itself
**Computer Chess**

**Slideshow**

**Great website**
http://www.computerhistory.org/chess/

**Interactive Demo:**
http://www.computerhistory.org/chess/interact/index_content.html

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**Minimax Algorithm: Game Tree**

Associate values:
- 0: tie
- 1: computer win
- -1: opponent win

**Strategy**
- Assume each makes best move for itself
- Pick path to victory!

**Algorithm**
- Start at leaves
- Propagate max value before computer turn
- Propagate min value up before opponent turn
- Choose max path down

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**Nim Game Tree: 3 X’s for first move**

Leaf node: Winner
Purple: X Wins
Red: O Wins

3 X’s good move: All paths can lead to X winning

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**Nim Game Tree: 3 X’s for first move**

Leaf node: Winner
Purple: X Wins
Red: O Wins

Conclusion: Player 1 can always win with 7 objects by initially taking 3
**Strongly Solve?**

Nim and tic-tac-toe have relatively few board positions
- Can exhaustively search every possibility
- Can determine best strategy ahead-of-time and hard-code solution

Chess: too many board positions to exhaustively search
- Can only search few moves ahead and/or some possibilities at each move
- Determine strategy as play, based on observed positions

**Today’s Summary**

**Game Strategies for searching thru possibilities**
- Construct game tree to determine best moves
  - Minimax algorithm: Assume each makes best moves for self

**Reading**
- On-line interactive materials

**Announcements**
- Code for homework 6 posted
- No homework next week, no new content next week
- Exam 2 next Friday
  - Lists: Linear O(N) and binary O(log N) search, opt, viz
  - Running processes (single CPU, share CPU and mem, races)
  - Prediction: Probability trials, simulation, game trees
- Project 2 available soon: Trivia Game with Lists