

# UNIT 13A

## AI: Games & Search Strategies

15110 Principles of Computing, Carnegie  
Mellon University

1

## Announcements

- Do not forget to nominate your favorite CA by emailing [gkesden@gmail.com](mailto:gkesden@gmail.com),
- No lecture on Friday, no recitation on Thursday
- No office hours Wednesday, Thursday and Friday. We will resume on Saturday.
- We will announce a review session for Sunday. Stay tuned.

15110 Principles of Computing, Carnegie  
Mellon University

2

## Artificial Intelligence

- Branch of computer science that studies the use of computers to perform computational processes normally associated with human intellect and skill.
- Some areas of AI:
 

Game playing	Knowledge representation	Robotics
Machine learning	Natural language processing	Speech & Vision
- John McCarthy, Marvin Minsky (Stanford, MIT)  
 Allen Newell and Herbert Simon (CMU)  
 General Problem Solver (GPS) in 1957  
 Received the Turing Award in 1975 for  
 "basic contributions to artificial intelligence,  
 the psychology of human cognition,  
 and list processing."



Newell



Simon

15110 Principles of Computing, Carnegie  
Mellon University

3

## A Cynic's View

- AI is the study of how to get computers to do things we don't understand.
  - "thinking", "learning", "creativity", etc.
- When we do understand something, it's no longer AI: it's just programming.

15110 Principles of Computing, Carnegie  
Mellon University

4

## Game Trees

- For most games, the number of possible moves and potential outcomes is HUGE.
- An AI technique used to manage this computation is the use of a game tree.
  - A tree is built with a root node representing the current state of the game.
  - Child nodes are generated representing the state of the game for each possible move.
  - The tree is propagated down, building more child nodes for moves allowed by the next move, etc.
  - Leaves are terminal states of the game.

15110 Principles of Computing, Carnegie Mellon University

5

## Tic Tac Toe

A pencil and paper game for two players, X and O, who take turns marking the spaces in a 3×3 grid. The player who succeeds in placing three respective marks in a horizontal, vertical, or diagonal row wins the game.

The following example game is won by the first player, X:

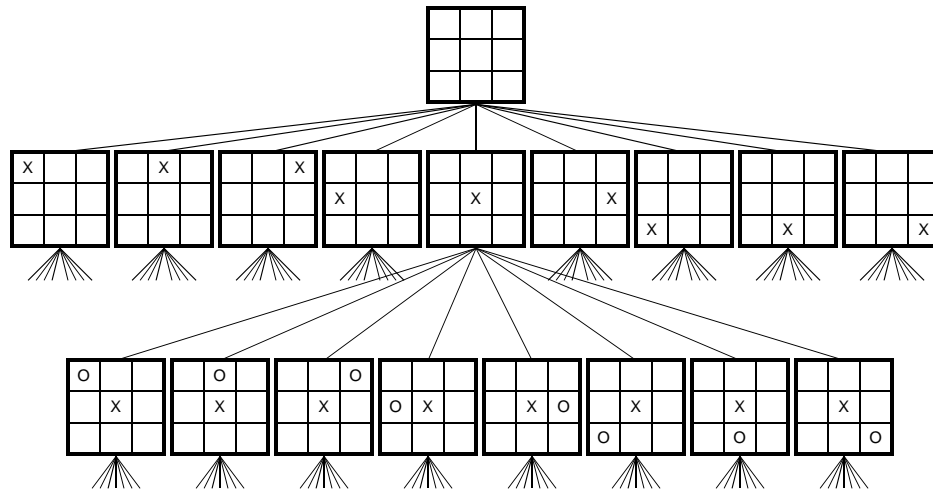


Source: Wikipedia

15110 Principles of Computing, Carnegie Mellon University

6

## Tic Tac Toe (Not Huge)



15110 Principles of Computing, Carnegie  
Mellon University

7

## How Big is the Tic-Tac-Toe Tree?

- Assuming that all nine positions must be filled before the game ends, how big does this tree get? (The number of possible different games)
- Of course, in real Tic-Tac-Toe, a player can win without filling the whole board.
  - What is the first level of the tree where this can occur?
  - How big is this tree up to this level?

15110 Principles of Computing, Carnegie  
Mellon University

8

## How Big is the Tic-Tac-Toe Tree?

- Assuming that all nine positions must be filled before the game ends, how big does this tree get?  
Bounded above by  $9*8*7*6*5*4*3*2*1 = 9! = 362880$
- Of course, in real Tic-Tac-Toe, a player can win without filling the whole board.
  - What is the first level of the tree where this can occur?  
Ending on the 5<sup>th</sup> move. 3Xs, 2 Os
  - How big is this tree up to this level?  
 $9*8*7*6*5$

## More Exact Calculations

- All games should continue until either all nine squares are filled or someone has three in a row (or both), so there must be at least five marks. So all we have to do is find how many games end with five marks, and similarly how many with six, seven, eight, or nine. For nine, there are two possibilities: either someone has won on their ninth move, or it is a draw with no three in a row.
- Furthermore, if board symmetries are taken into account, two games are considered the same if rotating and/or reflecting the board makes one of the games into a copy of the other game.

## Tic-Tac-Toe Is Completely Searchable

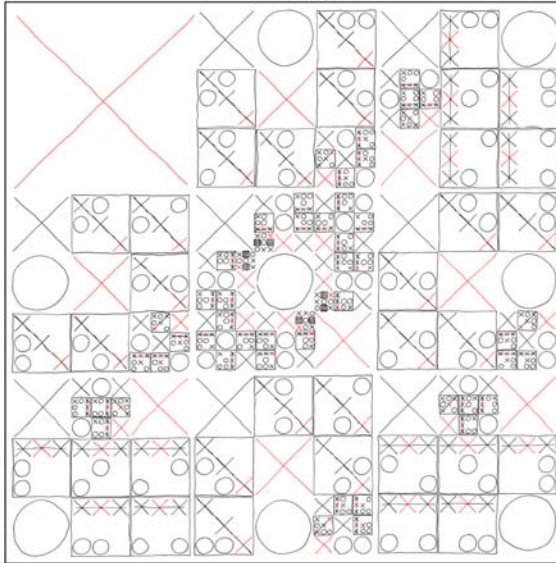
- For the first move, pick a square at random.  
(Always picking the same square would be boring.)
- For subsequent moves:
  - Using recursion, grow the entire game tree with the current board state as the root
  - For each child of the root, count how many games below that child end in a win.
  - Pick the child with the most wins.

## For the Enthusiast

- If you are interested in optimal strategies see the next 9 slides.

# XKCD's Optimal Tic-Tac-Toe

MAP FOR X:



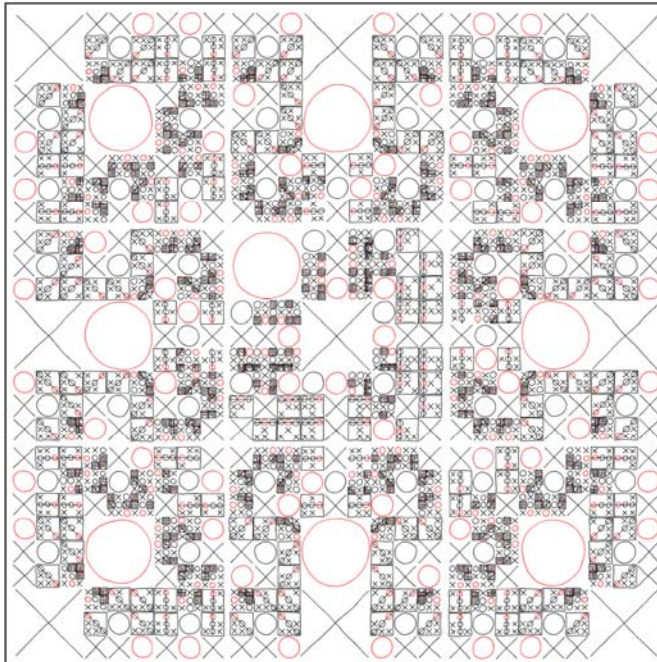
COMPLETE MAP OF OPTIMAL TIC-TAC-TOE MOVES

YOUR MOVE IS GIVEN BY THE POSITION OF THE LARGEST RED SYMBOL ON THE GRID. WHEN YOUR OPPONENT PICKS A MOVE, ZOOM IN ON THE REGION OF THE GRID WHERE THEY WENT. REPEAT.

<http://xkcd.com/832>

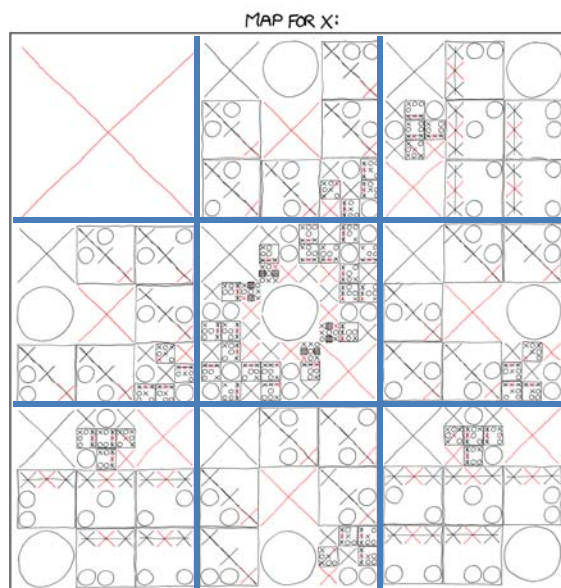
13

MAP FOR O:



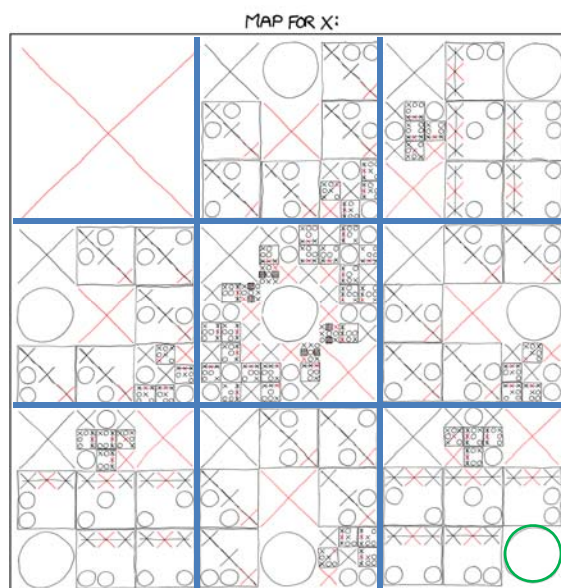
14

## X Move 1



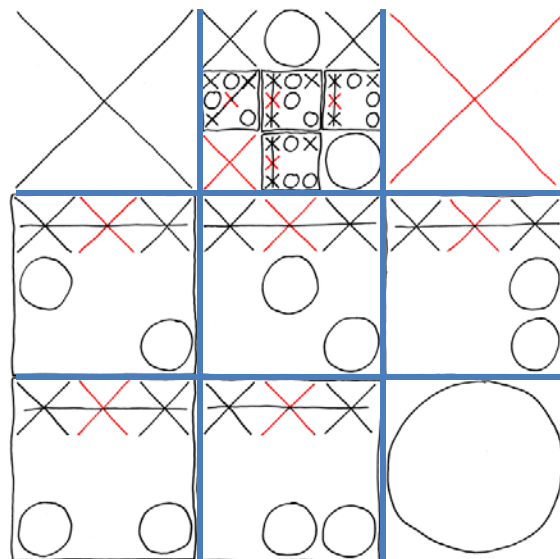
15

## O Move 1



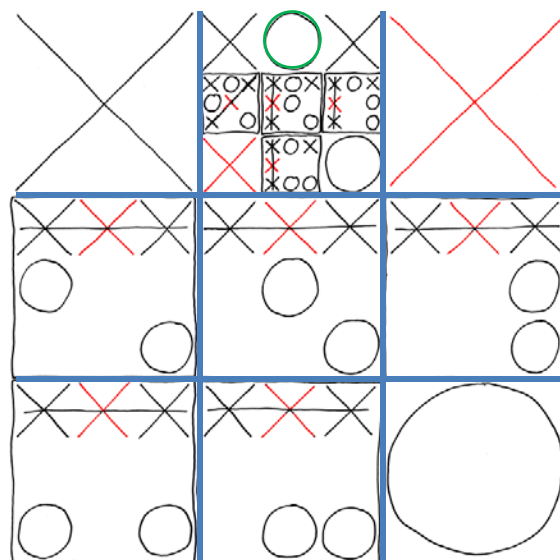
16

## X Move 2



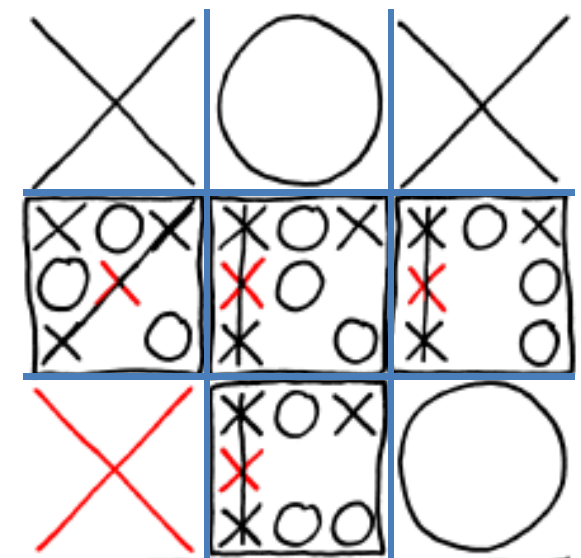
17

## O Move 2



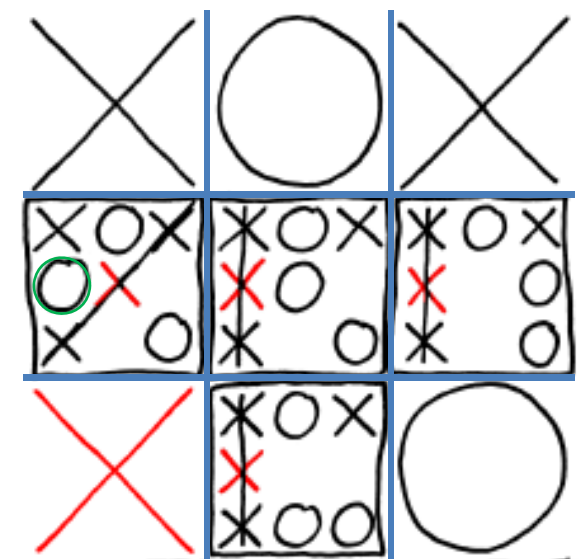
18

## X Move 3



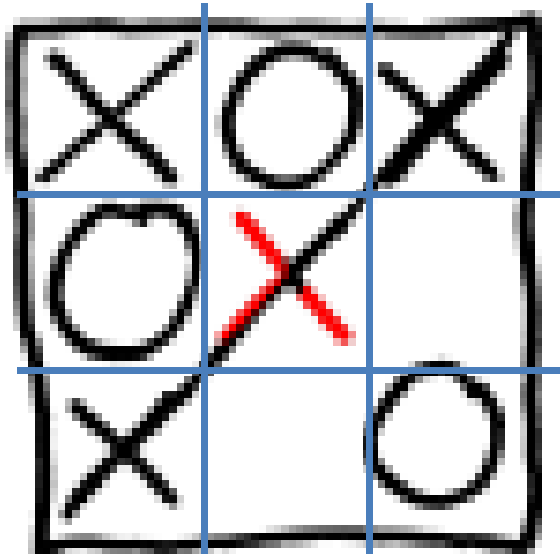
19

## O Move 3



20

## X Move 4 To Win



21

## Dealing With Huge Search Spaces

- How does a computer program that plays chess or go deal with the huge size of the game trees that can be generated?
  - In chess, the average number of possible next moves is around 35, and the average number of moves in a chess game is around 100, so the number of possibilities a computer must check is about  $35^{100}$ , which is beyond hope, even for our fastest computers!
- These programs use heuristics to narrow the search space in the tree that must be examined

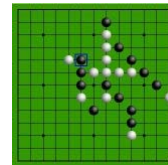
## Heuristics

- Human thought is not purely deductive. It often relies on approximations or analogies.
- A heuristic is a “rule of thumb” that may not always be correct but usually gives useful results.
- Heuristic algorithms are helpful because they can find a reasonably good solution to a problem without requiring excessive search.

15110 Principles of Computing, Carnegie Mellon University

23

## AI Opponents

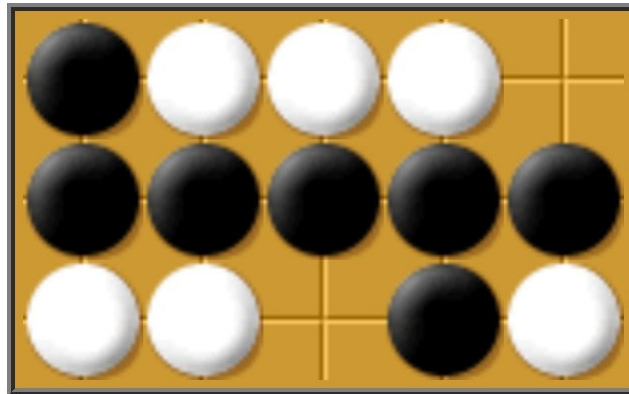


- Consider the game of Pente.
  - Players alternate, placing their stones on the game board at the intersection of lines, one at a time.
  - The object of the game is to be the first player to either get five stones in a straight line or capture 5 pairs of stones of the other player.
  - “Capture” means two adjacent stones surrounded by opponent stones. Captured stones are removed.
  - If we were write a computer program to play Pente against a human player, how does the computer calculate its moves when there are a huge amount of possibilities to consider?

15110 Principles of Computing, Carnegie Mellon University

24

## Black Wins With 5 In A Row

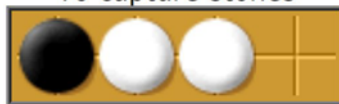


15110 Principles of Computing, Carnegie  
Mellon University

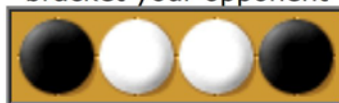
25

## Capture in Pente

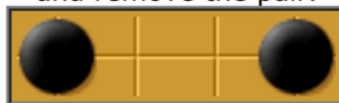
To capture stones



bracket your opponent



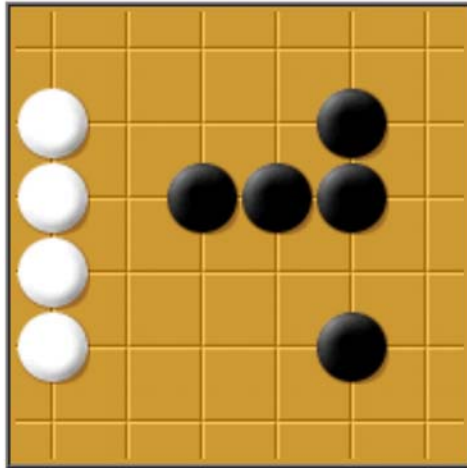
and remove the pair.



15110 Principles of Computing, Carnegie  
Mellon University

26

## Black To Move; White Will Win

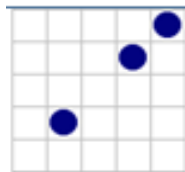


15110 Principles of Computing, Carnegie Mellon University

27

## Heuristics

- Important board features to look for in Pente:
  - Check for x-pieces in a row.
  - Check for capture possibilities.
  - Check for x-pieces in a row for opponent.
  - Check for opponent's potential to make a capture.
- Where is the opponent likely to put a stone?



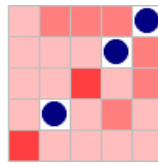
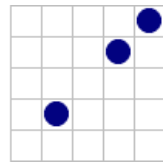
<http://www.generation5.org/content/2000/boardai.asp>

15110 Principles of Computing, Carnegie Mellon University

28

## Heuristics

- Important board features to look for in Pente:
  - Check for x-pieces in a row.
  - Check for capture possibilities.
  - Check for x-pieces in a row for opponent.
  - Check for opponent's potential to make a capture.
- Compute a feature score and choose squares with high value:



0
1
2
3

**Example: threat score.**  
Code each cell based on number of opponent pieces in same row, column and diagonal.

<http://www.generation5.org/content/2000/boardai.asp>

15110 Principles of Computing, Carnegie Mellon University

29

## "Deep Blue"



- IBM's "Deep Blue" computer beats Gary Kasparov in a chess match in 1997.
- Heuristics values:
  - The value of each piece. (1 for pawn up to 9 for queen)
  - The amount of control each side has over the board.
  - The safety of the king.
  - The quickness that pieces move into fighting position.
- For more info:
  - <http://www.research.ibm.com/deepblue/home/html/b.html>
- Is Deep Blue intelligent?



15110 Principles of Computing, Carnegie Mellon University

30

## “Chinook”



- Created by computer scientists from the University of Alberta to play checkers (draughts) in 1989.
- In 2007, the team led by Jonathan Schaeffer announced that Chinook could never lose a game. Checkers had been solved: the best a player playing against Chinook can achieve is a draw.
- Chinook's algorithms featured:
  - a library of opening moves from games played by grandmasters
  - a deep search algorithm
  - a good move evaluation function (based on piece count, kings count, trapped kings, player's turn, “runaway checkers”, etc.)
  - an end-game database for all positions with eight pieces or fewer. and other minor factors.
- Is Chinook intelligent?

15110 Principles of Computing, Carnegie Mellon University

31

## The Imitation Game (Turing Test)

- Proposed by Alan Turing in 1948.
- A human interrogator communicates with two players via teletype.
  - One player is human, the other a machine.
  - Each tries to convince the interrogator that he is the human.
- If the interrogator can't tell which player is human, the machine must be intelligent.

15110 Principles of Computing, Carnegie Mellon University

32

## From Turing's Paper

Shakespeare's  
Sonnet 18



- **Interrogator:** In the first line of your sonnet which reads "Shall I compare thee to a summer's day," would not "a spring day" do as well or better?
- **Computer:** It wouldn't scan.
- **Interrogator:** How about "a winter's day"? That would scan all right.
- **Computer:** Yes, but nobody wants to be compared to a winter's day.

33

- **Interrogator:** Would you say Mr. Pickwick reminded you of Christmas?
- **Computer:** In a way.
- **Interrogator:** Yet Christmas is a winter's day, and I do not think Mr. Pickwick would mind the comparison.
- **Computer:** I don't think you're serious. By a winter's day one means a typical winter's day, not a special one like Christmas.

Dickens character



34

## “Watson”



- IBM's “Watson” computer beats champions Ken Jennings and Brad Rutter in a 2-game match on Jeopardy! in 2011.
- Watson parsed clues into different keywords and fragments.
- Watson had 4TB of data content but was not connected to the Internet during the game.
- Watson executed 1000s of proven language analysis algorithms concurrently. The more algorithms that pointed to the same answer, the more confident Watson was and the more likely it would buzz in.
- Is Watson intelligent?

## Consumer Robotics

- DARPA Urban Challenge
- Google Driverless Car
  - Now legal in Nevada, Florida, and California