Introduction to Artificial Intelligence

Week 4

Learning by Searching

Your Car is Lost in a Carpark

- How would you find it?
- Walk at random
  - No guarantee you will find it
  - Could be lost forever
- Walk down each row
  - Guarantee you will find it
  - Might take a long time
- Walk to the place you think it was last, then expand your search
  - Guarantee you will find it
  - As long as your memory is good – on average it will be less than every row, worst case just as good
- Walk to the place you think it was last, hit the alarm button, then expand search
  - Guarantee you will find it
  - Alarm can be heard from a long way away, and if you press it to no effect the car is not local to you (radius of activation)

Search Space

- Many problems define a set of actions on an environment which can be seen as a search space of states
  - We are at one point in the environment with a destination, there is a list of action states which will bring us to the destination
- Each search type is a method of navigation of the space
- We will rarely want to go to the same point in the search space
  - Represents a cycle in the search, which are not useful in terms of state spaces
- Solution – most searches will avoid this by using tree structures
  - Each node in the tree is a state within the search
  - Search Trees, Game Trees

Types of Searches

Uninformed Search

- Have no sense of the problem domain
- Generally applicable in all cases

Informed Search

- Use a heuristic function developed for the domain
- Applicable in their own domain

Goal-Based Agent

- Four Steps in the Agent:

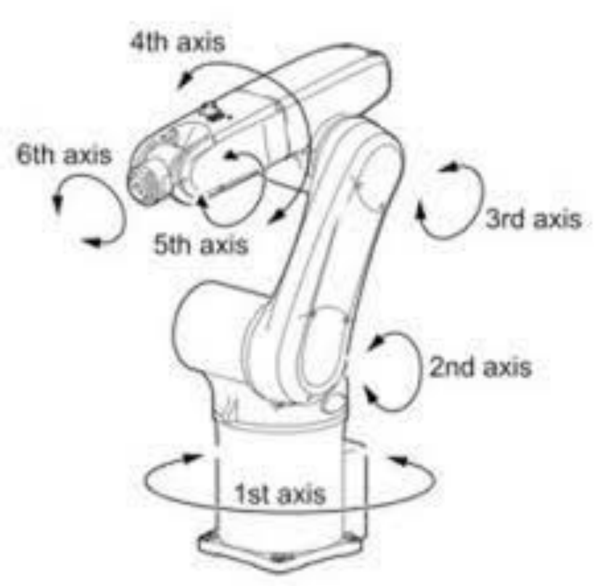
1. Define Goals
   - What are the states which are considered to be satisfying the goal?
2. Problem Formulation
   - What actions are available to move towards the goal?
   - What states are available to move towards the goal?
3. Search
   - Determine the pathway of states in order to meet with the goal
4. Execute
   - Move though the series of states

Example: Painting Robot (simplified)

1. Goal
   - All show surfaces of the part are covered in 1mm of paint
2. Problem Formulation
   - A sequence of points about the part for the robot arm to move into in order to ensure a dispersal about the entire part
3. Search
   - Examine all pathways about the part, taking into account the movements on each part of the arm
   - A pathway is good as long as it covered the part with 1mm of paint
4. Execute
   - The arm moves though the sequence of positions

State Space of the Robot

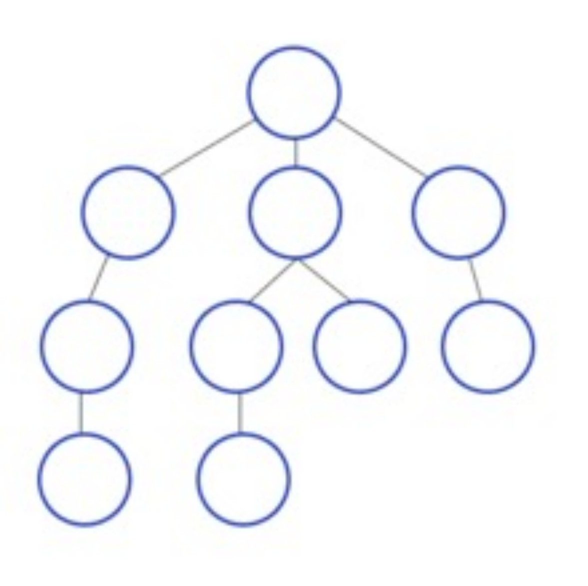
- State space is defined as the location of all moving elements on the robot
  - Relative positioning on all joints from a home position
  - Might also include the rate of spray on the nozzle – from 0 to full
- Transitions of states could be broken down into a sequence of movements in the joints on each rotational axis (hence a 6-axis robot)
  - Move(Elbow, X degrees)



N Queens and Incremental Goals

- Place N queens onto an NxN chess board such that no queen attacks any other queen; a more complicated problem is a Costas Array
- States
  - Place a queen down
- Goal
  - No queen attacks any other queen
  - Hard sometimes to see a good pathway to the goal
- Need a measure in order to see a good pathway
  - Minimize number of queens attacking

Tree Search



- Recursive definition of a tree search as DFS
- SearchTree(State, Move, visited list)
  - Apply Move to the New State
  - If (New State == goal) return TRUE
  - Else
    - If (neighbouring states are empty) return FALSE
    - For each of the MOVE on neighbouring states not in visited list
      - If SearchTree(Neighbouring states, MOVE, visited list + State) return TRUE;

Backtracking Searches

- Move towards the goal, if you reach a position which is going to be less successful – stop and move back up the tree (backtrack, retrace your steps)
- Recursive definition of a depth-first search of a backtrack:
- SearchTreeBacktrack(State, Move, visited list)
  - Apply Move to the New State
  - If (New State == goal) return TRUE
  - If (New State causes an invalid path to goal/or costs too much) return FALSE
  - Else
    - If (neighbouring states are empty) return FALSE
    - For each of the MOVE on neighbouring states not in visited list
      - If SearchTreeBacktrack(Neighbouring states, MOVE, visited list + State) return TRUE;

Sudoku

	1		4		2		5	
5								6
			3		1			
7		5				4		8
2		8				5		9
			9		6			
6								2
	7		1		3		4	

Backtrack on Sudoku

- isValid
  - Check if we have not violated the rules
    - 1-9 in each row
    - 1-9 in each column
    - 1-9 in each box
- Choice at each empty box 1-9
- Multiple Solutions?

5	3	1	2	7	6	8	9	4
6	2	4	1	9	5	2		
	9	8					6	
8				6				3
4			8		3			1
7				2				6
	6					2	8	
			4	1	9			5
				8			7	9

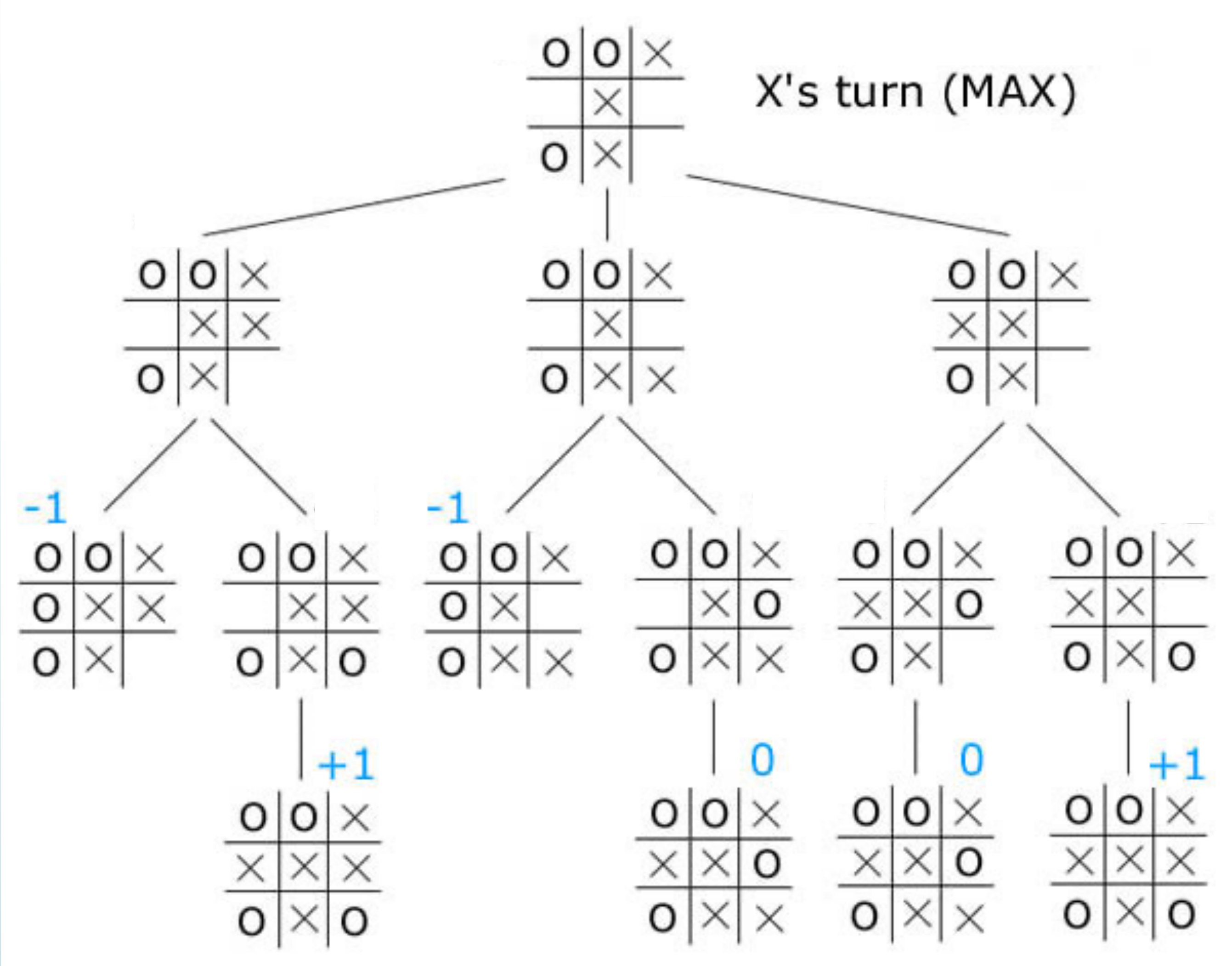
Heuristic Search

- Word comes from the Greek for discovery
- Heuristics use an educated guess on where to move the search next – rules-based movement about a search space
- Not necessarily deterministic – may have stochastic generation methods
- Trial and Error
  - Experimental and Experiential
  - Does not guarantee the most optimal solution
- Examples
  - Greedy and Hill Climbers are heuristics

Minimax

- Opponent goal is to reduce winnings (MINI-Move) and player goal is to increase winnings (MAX-Move)
- Game with a scoring system or win lose condition which can be evaluated
  - GO
  - Chess
- Game Tree
  - Selection of plays in a turn-based game can be reduced to looking at a pathway on a tree
  - Used as part of the theoretical foundations of GAME THEORY

Minimax Example

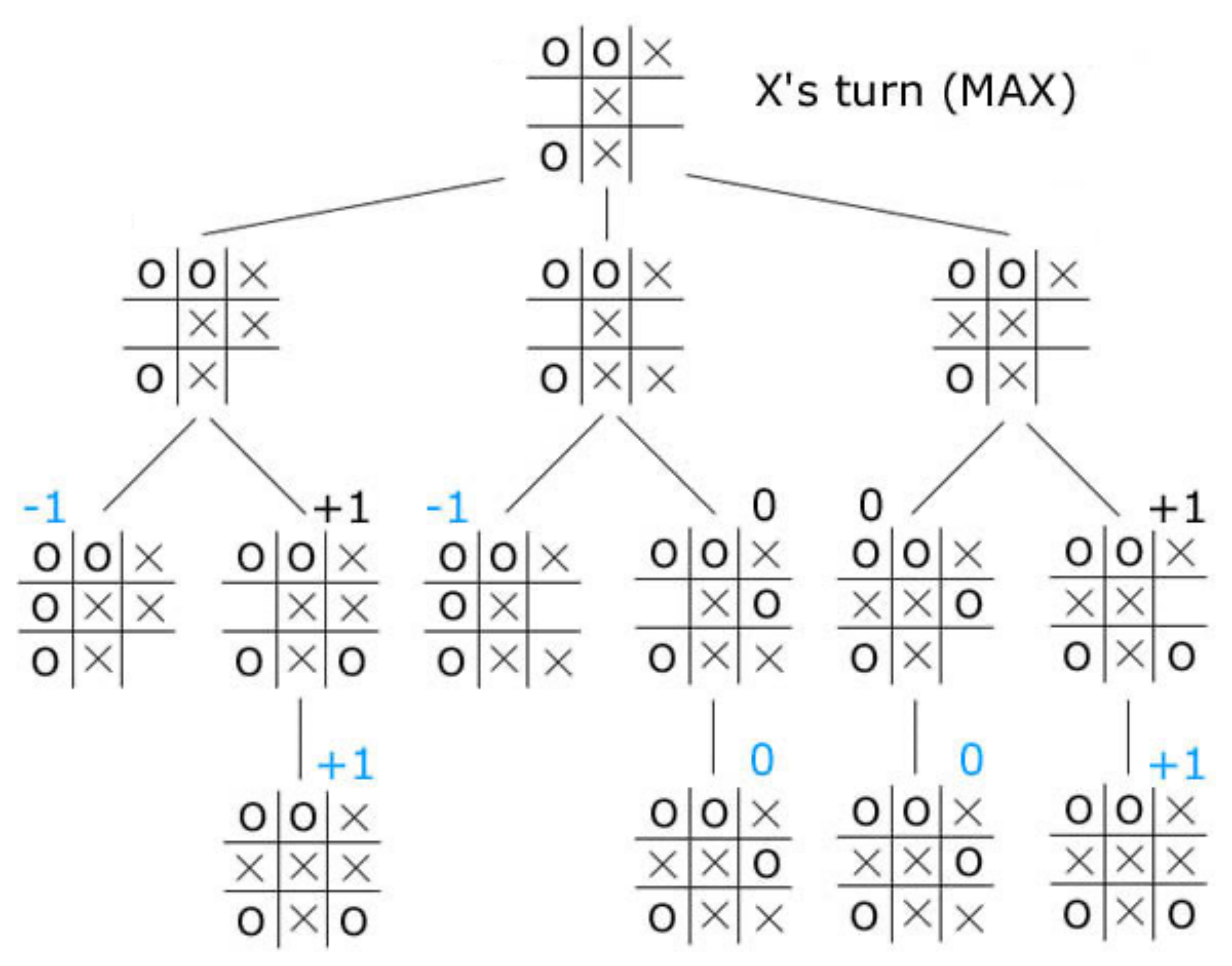


X’s turn (MAX)

0’s turn (MIN)

X’s turn (MAX)

Minimax Example



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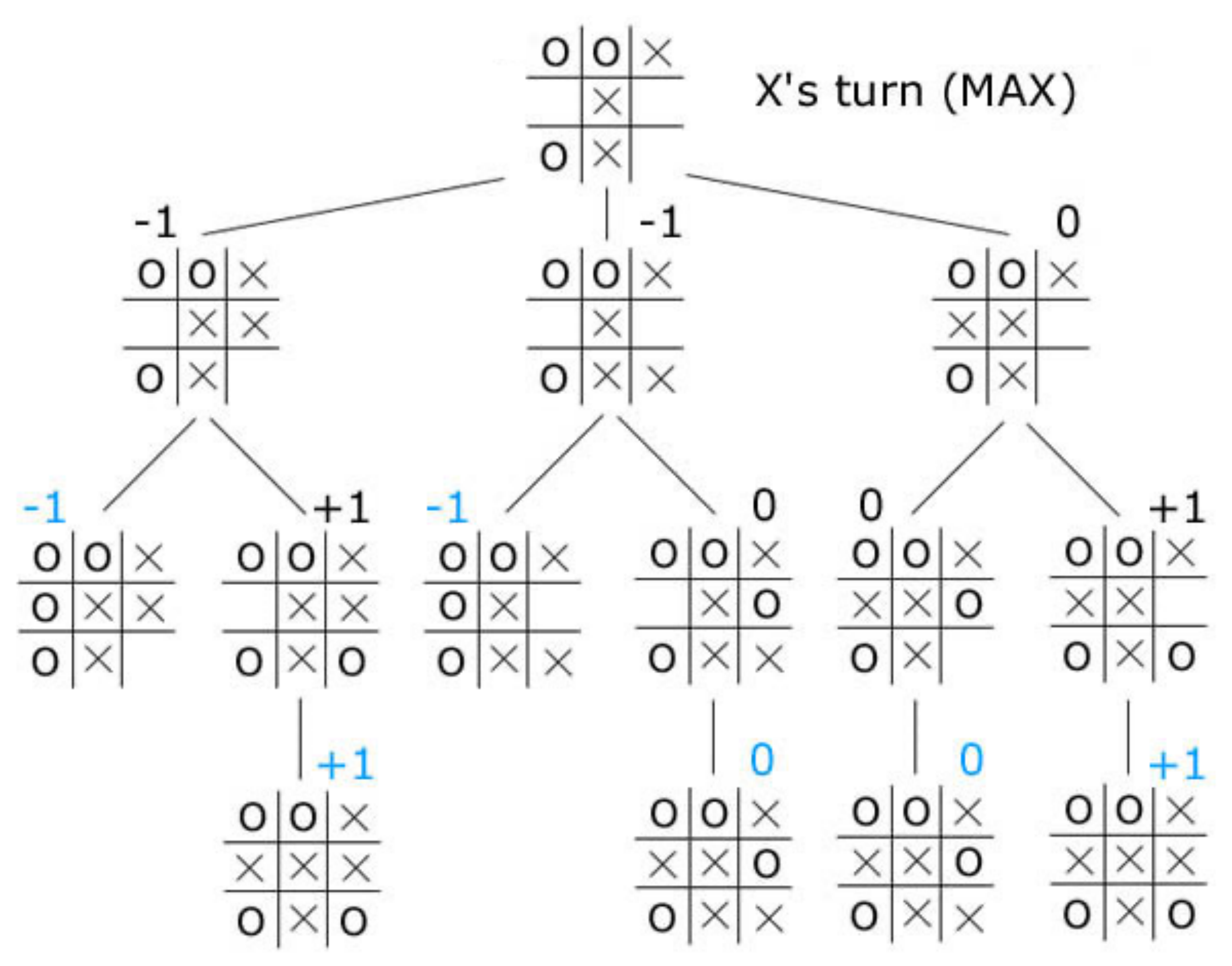

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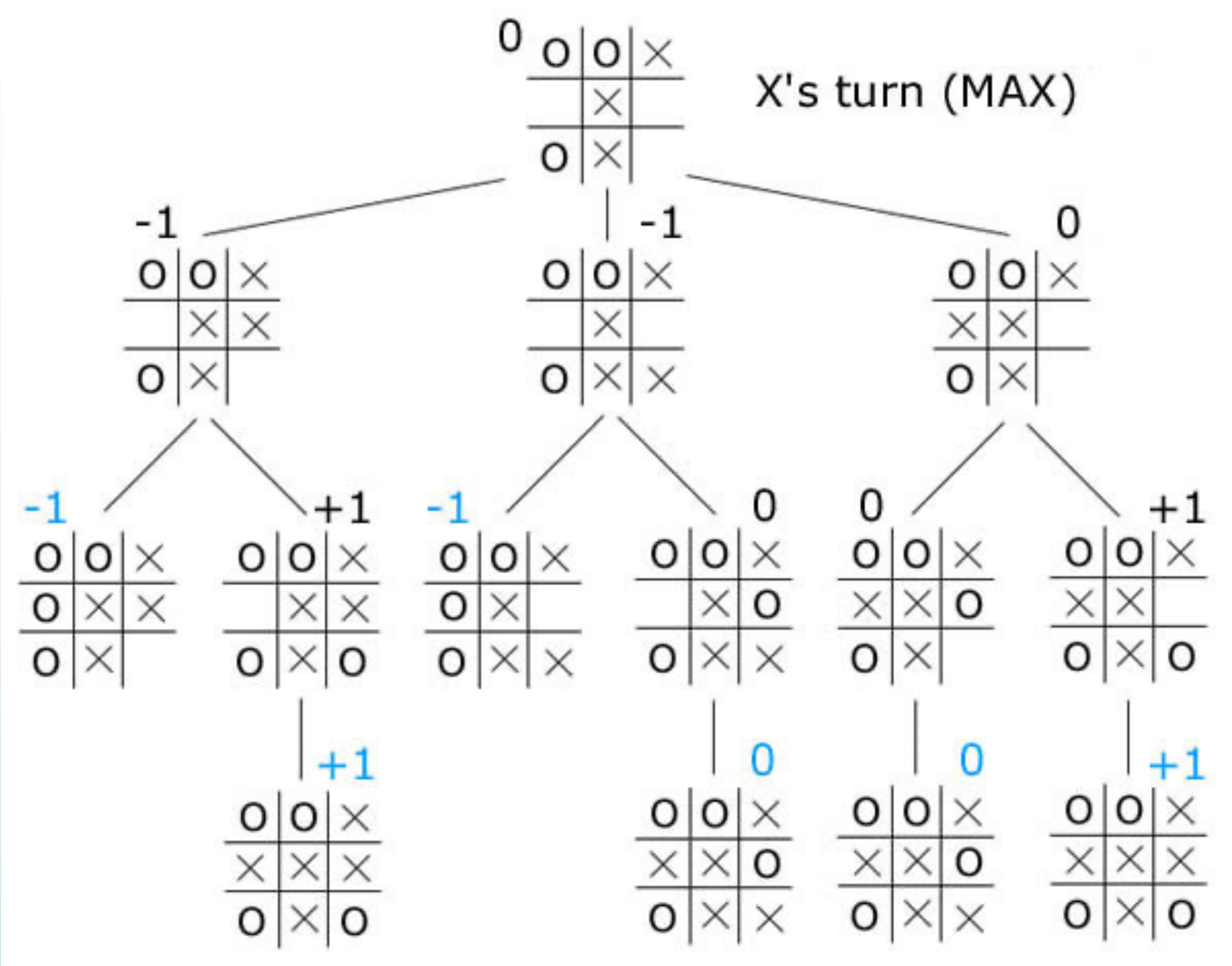
Minimax Example



X’s turn (MAX)

0’s turn (MIN)

X’s turn (MAX)

Backtracking

- Simulate the entire game
- Assume rational/perfect play from the opponent
- Theoretically there is a perfect game play method if we search the entire game
- Solved Games
  - Tic Tac Toe
  - Checkers
  - Two player heads-up limit poker – Recent discovery by researchers in University of Alberta
- Unsolved
  - Chess
  - Go

Backtracking with Alpha Beta Cuts

- Heuristic search based on backtracking
- Used in situations where there is a value to the solution at each point to allow for an evaluation
- Applied for Game Trees
- Alpha Cut
  - Maximum lower bound (Max Plays - Black)
- Beta Cut
  - Minimum upper bound (Min Play - Red)

Cut Examples