AI for Games

Doron Nussbaum

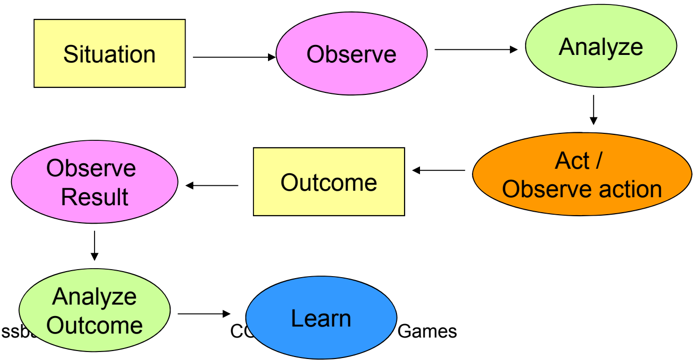
- Introduction
- Movement and path planning
- Games and trees
  - MinMax
  - Decision trees
- Finite State Machines
- Agents
- Other

Intelligence Definition

- “The ability to acquire and apply knowledge and skills” (Oxford dictionary)
- Ability to understand, reason, grasp issues and complex problems/ideas as well as ability to learn from experience of self and others
- Artificial Intelligence
  - An attempt by machines (computers) to be intelligent

Humans and Intellegence

- We have the ability to:
  - Learn → look at a situation and react



Situation

Observe

Analyze

Act / Observe action

Outcome

Observe Result

Analyze Outcome

Learn

AI

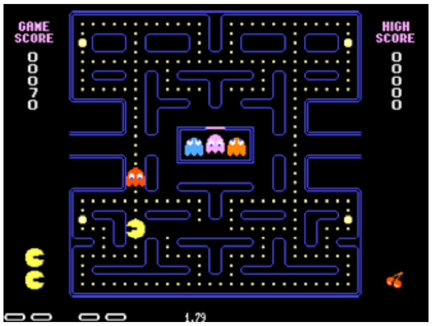
- In Academia – understanding intelligence (theory)
  - Thought process
    - Behaviour prediction
  - Comprehension
    - Machine vision
  - Natural language –
    - understanding semantics
    - Carry out a conversation
- Engineering – Use AI to solve real problems
  - Searching (Google)
  - Stock market predictions

Are we there yet?

- Not Yet!
- Large number of applications
  - Machine vision
  - Speech recognition
  - Stock market prediction
  - …
- Spectrum of domain is hard to achieve
- Some specific areas are promising
  - Chess
  - Carrying out a conversation on specific topics (e.g., whether, daily activities)
- What is in the way
  - Unscripted actions
  - Not always logical
  - Emotions

What about Game AI?

- Game AI is different
  - Provide entertainment
  - Attract the player
  - Should be realistic
- PACMAN
  - Is it AI?
- AI in games provides
  - Interaction with the player
  - Level of unpredictability
  - Somewhat no repetition in the game



http://free-extras.com/images/pacman_game-1973.htm

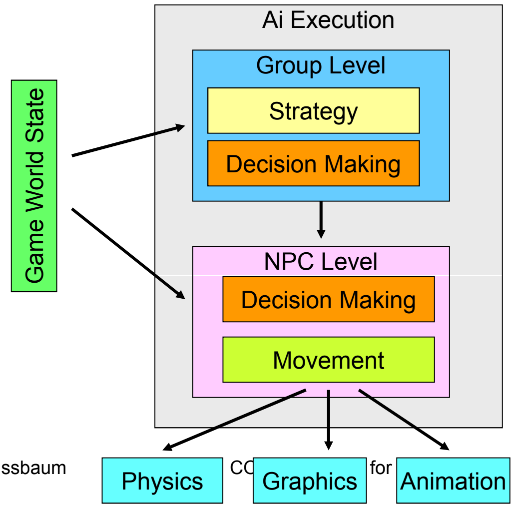
What Should Game AI Be

- Should be good
  - Cannot be too smart – should have some built in flaws
  - Provide fun
- Provide good perception (no obvious flaws)
  - Should not look dumb
  - No unintended flaws – cannot be defeated using a “secret path”t
- Must be fast (real time)
- If possible configurable
  - Not hard coded by programmer
- Can adjust to different level of players

What about Game AI?

- Must be smart, but purposely flawed
    - Lose in a fun, challenging way
- No unintended weaknesses
    - No “golden path” to defeat
    - Must not look dumb
- Must perform in real time (CPU)
- Configurable by designers
    - Not hard coded by programmer
- “Amount” and type of AI for game can vary
    - RTS needs global strategy, FPS needs modeling of individual units at “footstep” level
    - RTS most demanding: 3 full-time AI programmers
    - Puzzle, street fighting: 1 part-time AI programmer
    - All of project 2. ☺

AI Model

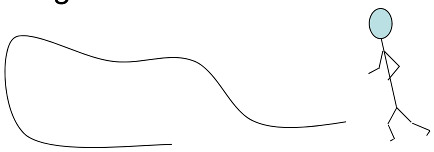


Movement

- Movement is to the way an NPC moves in the world
  - Wander
  - Seek
  - Chase / home in / zoom to target
  - Flee

Wander

- NPC moves in the world
  - Without a particular goal
  - Usually aimlessly (no logic in movement)
  - Scouts an area (not exploring)
    - Guarding
    - Cleaning



wander

- Address motion
- Address orientation

- Set up a target
  - Set up a path
  - Path can be a sequence of short line segments.

- Update the motion
  - Speed
  - Velocity
  - Orientation

- Use regular motion equations (distance, speed, velocity)

Seek

- Similar to wander (something in mind)
- Searching for something
  - Treasure
  - Enemy
  - Weapon

- Create constraints – (when is the target visible?)
  - Distance constraints
  - Visibility – colour, size, text
  - Type – searching for a box, target is a sphere

Seek

- Address motion
- Address orientation

- Set up a search pattern
  - Wander
  - Logical scan – in circles, side to side, moving in a maze

- Update the motion
  - Speed
  - Velocity
  - Orientation

Chase

- Target is visible
  - Known location of target
  - Target may be stationary or in motion

- Realistic actions
  - Change of direction is affected by speed
  - Cannot change direction on the spot (e.g., a car)

- Issues
  - Overshooting the target

Chase

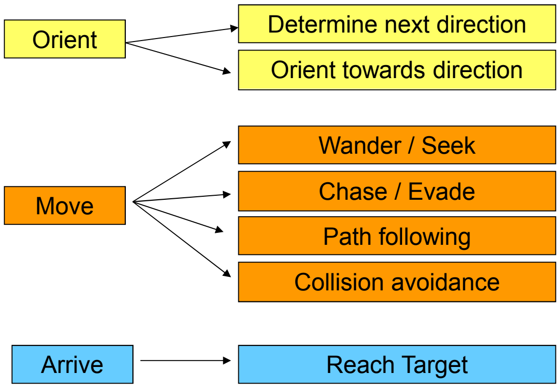
- Address motion
- Address orientation

- Set up a static path
  - Path can be direct
  - Path needs to avoid obstacles

- Set up a chase path (dynamic path)
  - Follow the path
  - Zoom in on current location
  - Prediction of future location

- Update the motion
  - Speed
  - Velocity
  - Orientation

Steering



- Orient
  - Determine next direction
  - Orient towards direction
- Move
  - Wander / Seek
  - Chase / Evade
  - Path following
  - Collision avoidance
- Arrive
  - Reach Target

Path Planning

- Determine how to move in space
  - Wander – move aimlessly
  - Seek – move to a particular location

- What does one have
  - Start point
  - Target point
  - Obstacles
  -

Path Planning

- What is missing?

- Free space!!!
  - Space in which one can move freely

- This may not be trivial
  - Object has area/volume (2D/3D)

Path Planning

- Motion –
  - Assume that object is a point →
  - Move a point in the free space
- Creating free space
  - Convert object to a point
  - Enlarge obstacles accordingly (e.g., Minkowski sums)

Path Planning

- How to move in free space?
  - Hard – not knowing where to go, when to turn
- Visibility
  - Move in a shortest path “notion”
- Attempt to convert the space into a graph

Path Planning

- Types of problems that may be of interest
- Guards placement
  - How many guards are needed to guard area
  - Where to position guards so that the guarded area is covered
- Guarding path
  - Is there a path that a guard can see the guarded area
    - All the time
    - At least once during the motion
  - How many guards are needed?
  - What should the paths be?
- Gaming –
  - Each guard is an autonomous object
  - Place less guards then needed – give the player a chance

Path Planning

- Most of the time path planning is to reach a goal.
  - Shortest path
  -
- What is the meaning of shortest path?

Path Planning

- Input:
  - a graph
    - Vertices
    - Edges
    - Weights
  - Start point
  - End point (in most cases)
- Output: a path (possible ∅)

- Algorithm?
  - Path traversing algorithms?

Path traversing Algorithms

- Breadth First Search (BFS)
  - Explore closest neighbourhood first

- Depth First Search (DFS)
  - Explore furthest neighbourhood first

Path Planning

- Algorithms for path planning
  - Best first
  - Dijkstra shortest path
  - A*
  - Hierarchical shortest path

Constructing Graphs

- Depending on the world
  - Grid (cell based)
    - Four connected
    - Eight connected (3x3)
    - 16 connected (5x5)
  - Vector based
    - TIN
    - Obstacles
    - Free space

Best First

- Usually used on a grid based graphs
- Idea
  - Attempt to move as “fast” as possible to the target (Greedy algorithm)
  - Attraction to the target/goal position

Dijkstra Shortest Path

- Search for the target around the start point until target is found.
  - No relation to the target point
- Algorithm properties
  - Triangle inequality $cost(\pi(u,w)) <= cost(\pi(u,v)) + cost(\pi(v,w))$
  - $\delta(u)$ is the minimum $cost(\pi(u,v))$

Dijkstra Shortest Path

- Let (v,u) be an edge in G
  - $\delta(u) <= \delta(v) + \text{weight}(u,v)$
- If $v_0,v_1,\ldots,v_k$ be a shortest path from v_0 to v_k then $v_i,\ldots,v_j$ is a shortest path from v_i to v_j where $0<= i,j <= k$ and $i<j$

- $v_i \leftarrow \infty$
- $s \leftarrow 0$
- Insert all vertices to a priority queue Q
- While $(Q \neq \emptyset)$
  - $u \leftarrow \text{top}(Q)$
  - for all v which are neighbours of u
    - if $\text{cost}(\pi(s,u))+\text{weight}(u,v) < \text{cost}(\pi(s,v))$ then
      - $\text{cost}(\pi(s,v)) \leftarrow \text{cost}(\pi(s,u))+\text{weight}(u,v)$
      - Update parent of u
      - Update Q with new cost of v

What is the "problem" with Dijkstra?

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- A BFS algorithm
- Search everywhere without any relatioship to the target

- Solution ?

What is the “problem” with Dijkstra?

- A BFS algorithm
- Search everywhere without any relatioship to the target

- Solution
  - Combine Best First and Dijkstra

A* Path Algorithm

- A heuristic algorithm
- Attempts to take the best of both worlds
  - The BFS behaviour of Dijkstra
  - The DFS behaviour of Best First

A* Path Algorithm

- Modify the comparison statement of Dijkstra priority queue algorithm
- Instead of extracting u such that cost($\pi(s,u)$) is the minimum in Q
- Use cost($\pi(s,u)$) + Estimate(u,t)

A* Path Algorithm

- What kind of estimate one can use?

Large Graphs

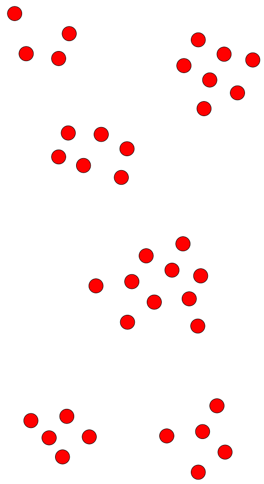
- What can be done with large graphs?
- How can many queries be handled?
- Scalability
  - Domain size
  - Number of players
- Solution
  - Speed up queries
  - Merge queries

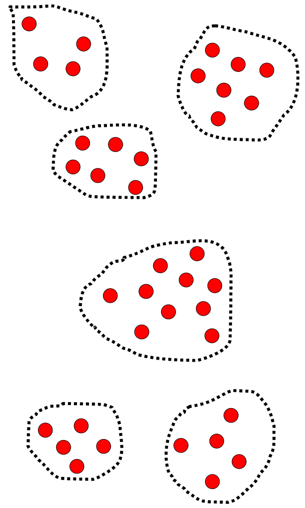
Hierarchical Graphs

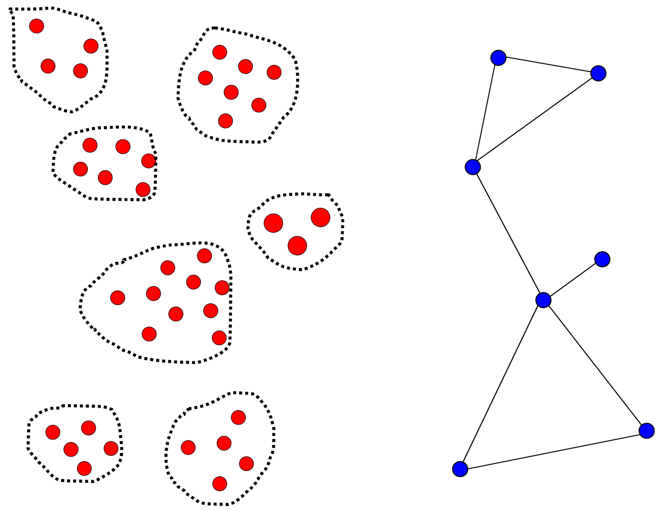
- Create a hierarchy
- Similar to a highway system
  - Neighbourhood roads
  - City roads
  - Regional roads

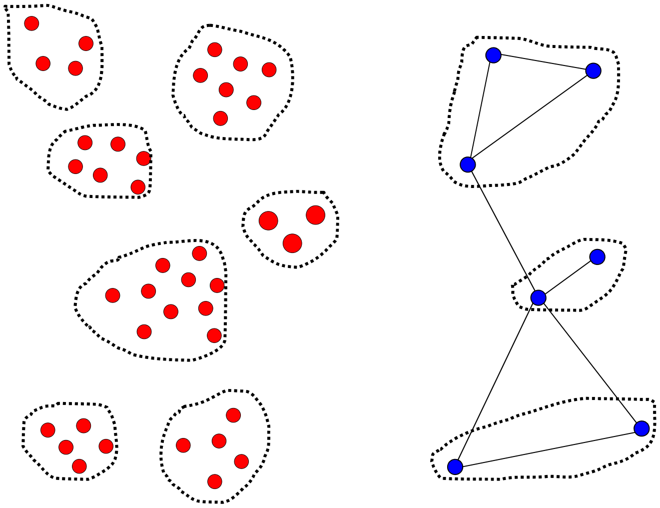
Graph Hierarchy

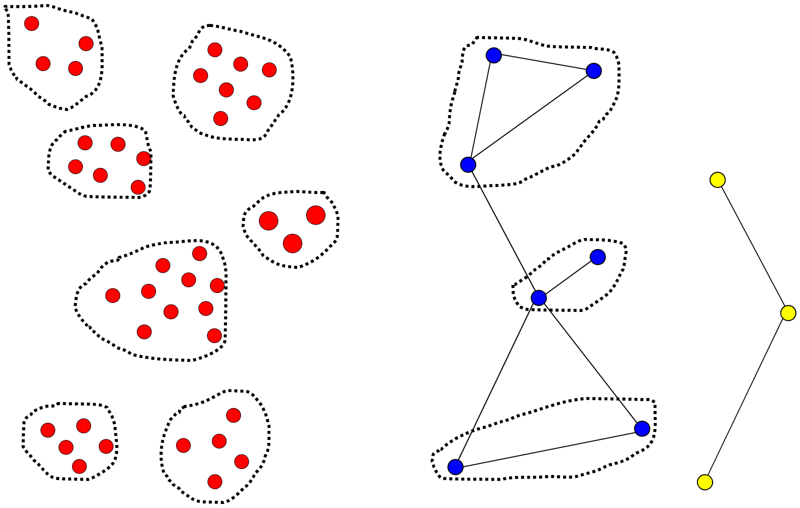
- Designate some paths as “high” level paths (highways)
  - Few connections
  - Few edges
- Create a representation of the space
  - Possibly a sequence of representations G, G^1, G^2…
- Operation
  - Gravitate to a high level representation
  - Find path on high level
  - Convert path back to a low level “real path”

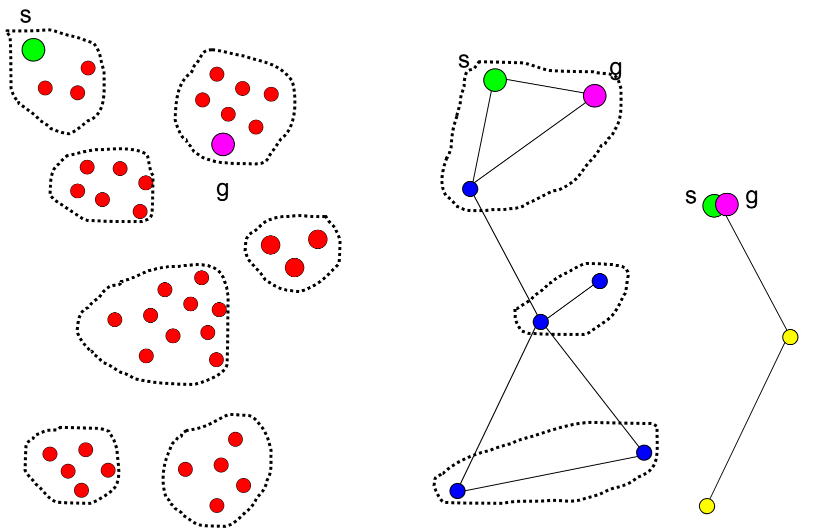












Game Playing Programs

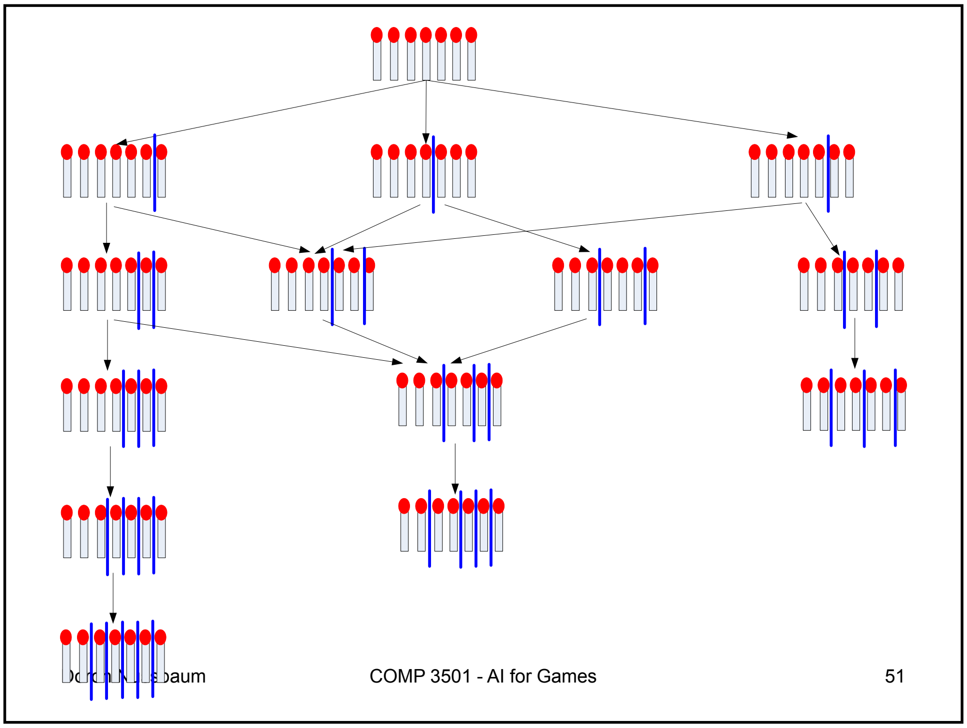
- Game playing programs obey some rules:
  - Visibility – is the board visibile/partial visible
  - Turns – is the game played in order
  - Chance/Luck – what is the nature of a “move”
    - Governed by probability (card game, dice)

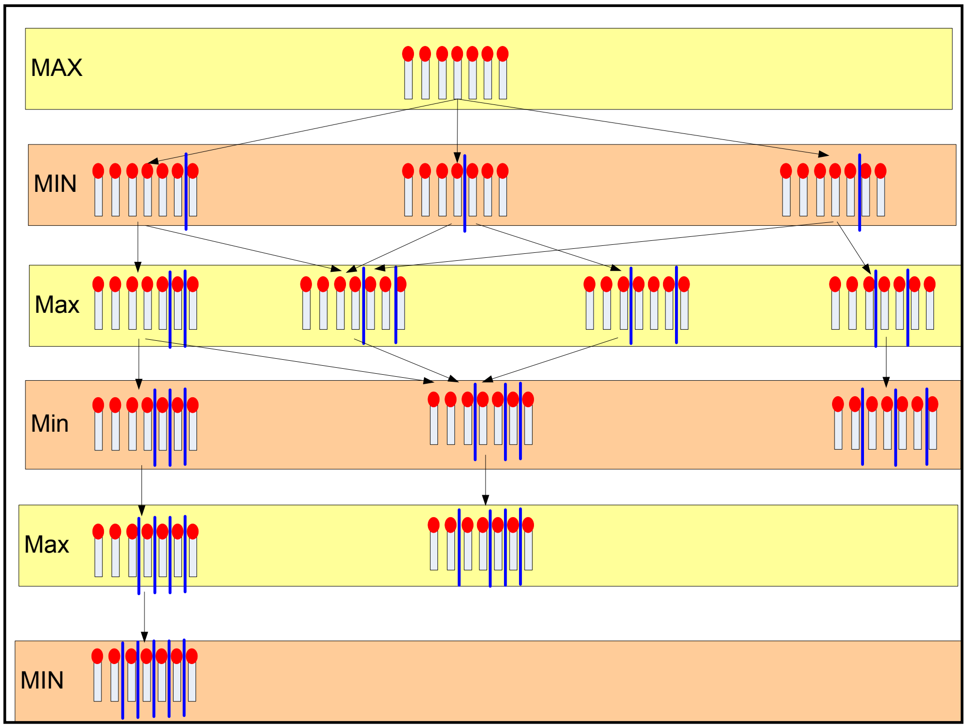
How to play?

- Deterministic game
- Create a tree with all possible moves
- Search the tree for the best move
  - DFS
- Assuming that each player plays for the best move then each try to follow a path that guarantees a “victory”

Division Nim Game

- Given a pile of matches
- Each player in his/her turn takes one pile and divides it into two piles of different size
- Game ends when there is non other option to play
- For example given 6 matches one can divide into
  - 1-5
  - 2-4

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MIN
Max
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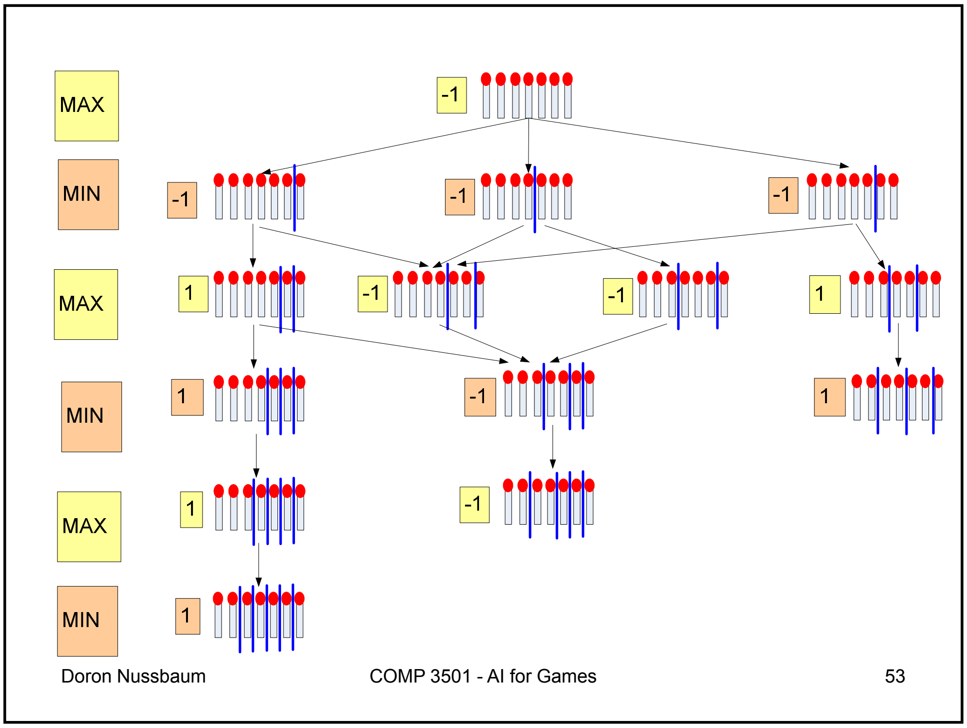
MIN



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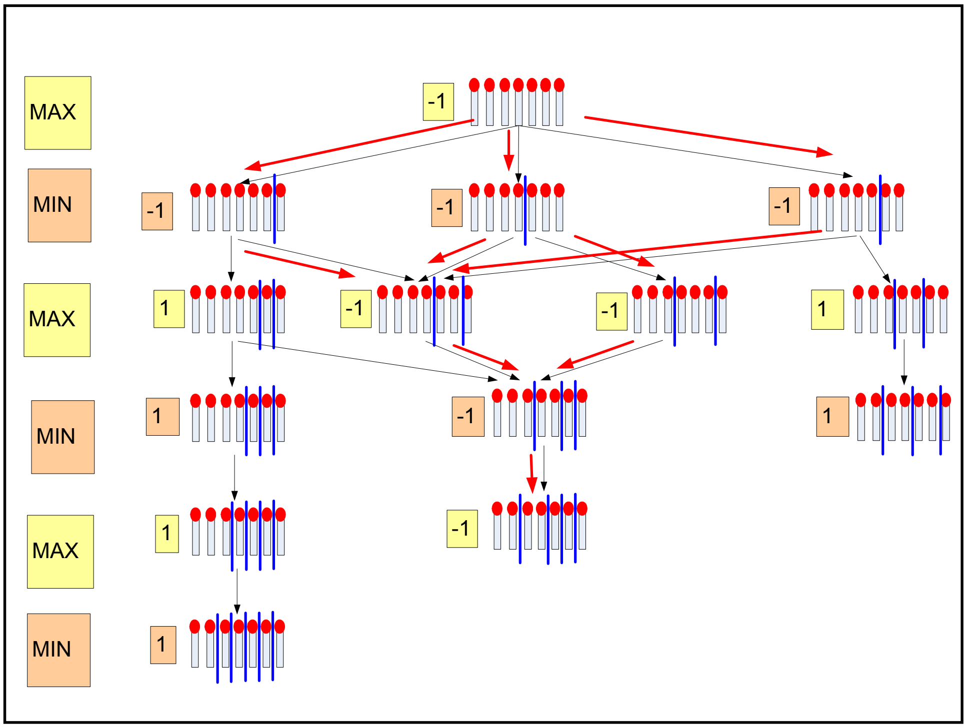


$$\text{minimax}(v) = \begin{cases} \mathit{value}(v) & \text{if } v \text{ is a leaf} \\ \min\limits_{u \in \text{children}(v)} \{\text{minimax}(u)\} & \text{if } v \text{ is a MIN node} \\ \max\limits_{u \in \text{children}(v)} \{\text{minimax}(u)\} & \text{if } v \text{ is a MAX node} \end{cases}$$

```
In: node v in the tree
Out: value of v

MiniMax(v)
if (children(v) = $\emptyset$) then
    return value(v)
else if label(v) = MIN then
    d $\leftarrow +\infty$
    for all u $\in$ children(v) do
        d $\leftarrow$ min{d,MiniMax(u)}
    endfor
    return d
else
    d $\leftarrow -\infty$
    for all u $\in$ children(v) do
        d $\leftarrow$ max{d,MiniMax(u)}
    endfor
    return d
endif
```

Complexity

- Assuming a branching factor is *b* and a depth of the search tree is *k* then the tree size is

$$1+b+b^2+\cdots+b^k = \frac{1-b^{k+1}}{1-b} = \frac{b^{k+1}-1}{b-1}$$

- Need to traverse the tree (DFS/post order)
- $O(b^k)$

MiniMax Trees

- Complete? Yes (if tree is finite)
-
- Optimal? Yes (against an optimal opponent)
-
- Time complexity $O(b^k)$
-
- Space complexity $O(b^k)$ (depth-first exploration)
- For chess, b ≈ 35, m ≈100 for "reasonable" games → exact solution completely infeasible
-

Partial Trees

- At times it is not possible to build a full tree
  - Time complexity $O(b^k)$
  -
  - Space complexity $O(b^k)$
  -
- For example - Chess game
  - Branching factor - b ≈ 35,
  - A reasonable game is k ≈ 100
    - Exact solution completely infeasible
    - $35^{100} \approx 2^{500}$

Evaluation Function

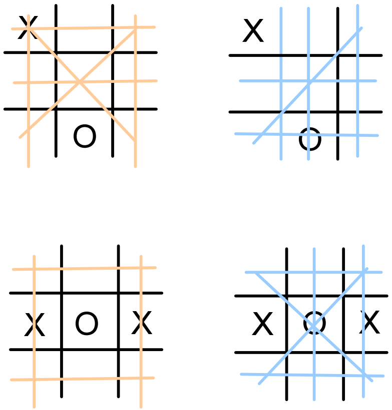
- Solution
  - Build a partial tree
- Question –
  - What value to give a node in the "middle" of the tree?
- Develop an evaluation function to assess the state of the game

Searching

- if search depth limit was reached
  - Evaluate/Compute state of current position
  - Return value
- else
  - if MAX level then
    - apply MiniMax to each child
    - return maximum of results
  - else // MIN level
    - apply MiniMax to each child
    - return minimum of results

Evaluate Tic-Tac-Toe

- Evaluate the number of free moves that are available to win



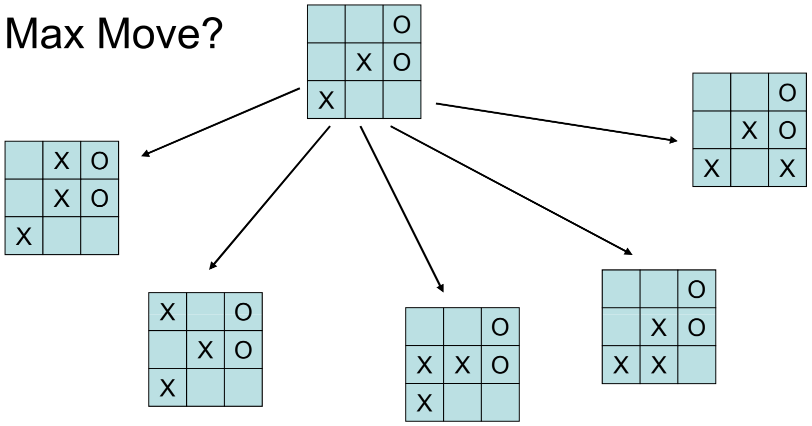
- Eval(p) –

  number of directions for Max - number of directions for Min
- Eval(p) - ∞ if Max wins
- Eval(p) - -∞ if Min wins
- Eval(p) - 6 – 5 = 1

X	O	

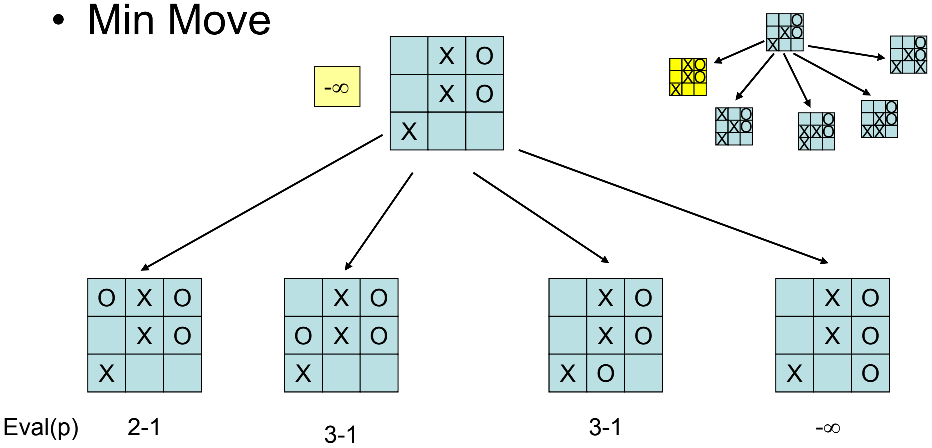
Example – Assume 2 steps ahead

- Max Move?



Example – Assume 2 steps ahead

- Min Move



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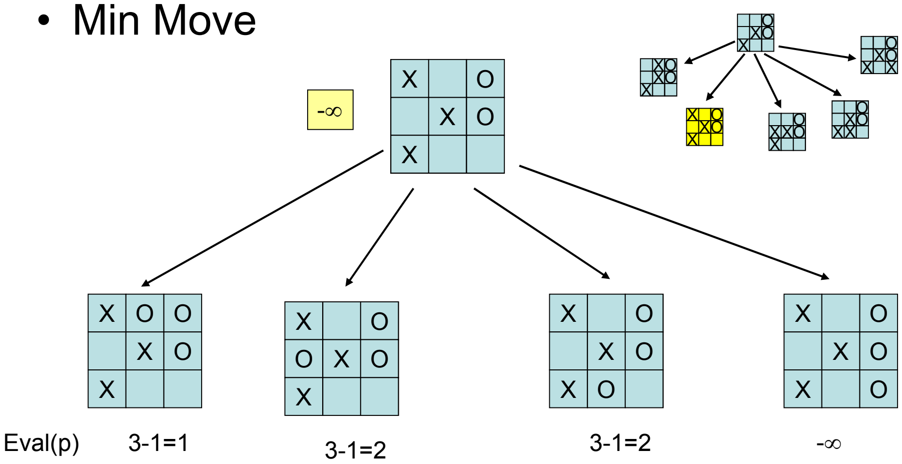

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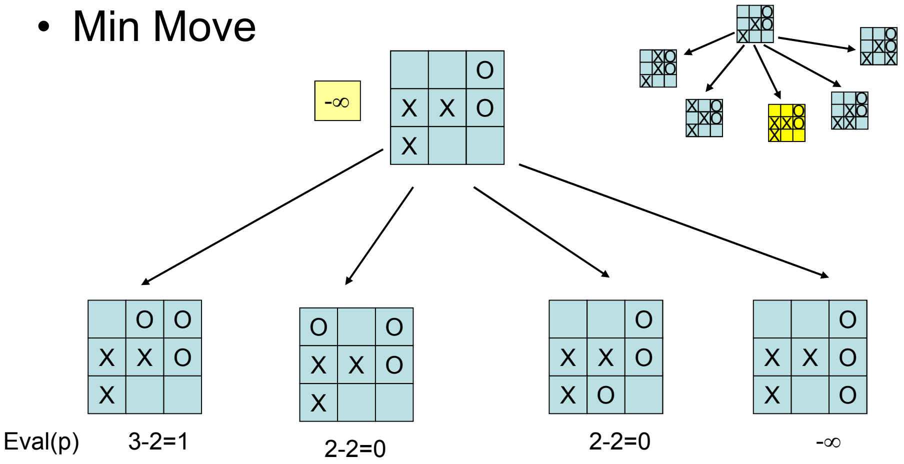

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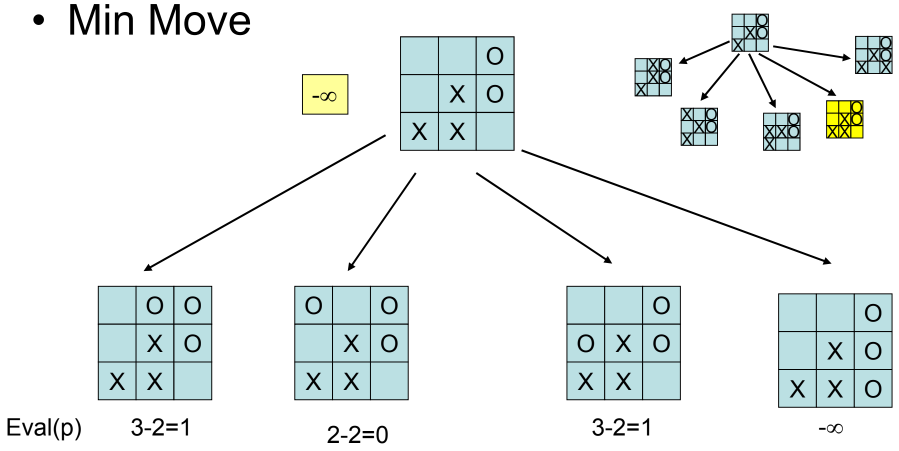

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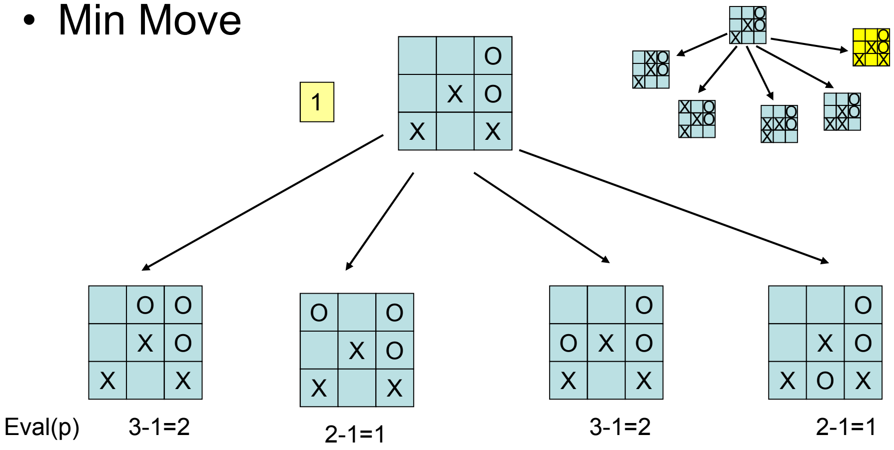
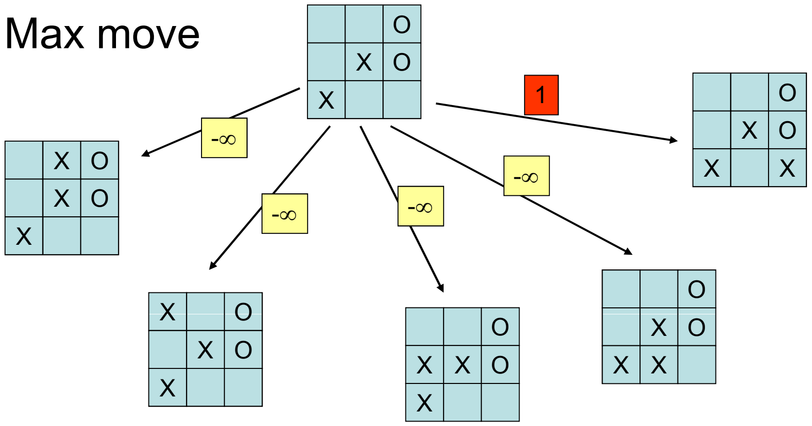


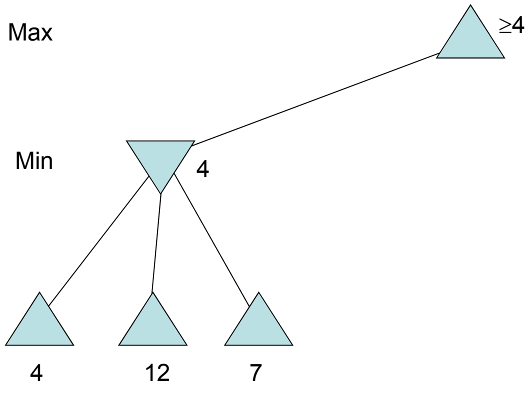
- Max move



Pruning the tree

- Tree can be quite large
  - Evaluation consumes computing cycles
- Trimming the tree → saves work
- Alpha-beta pruning (α-β pruning)

Example



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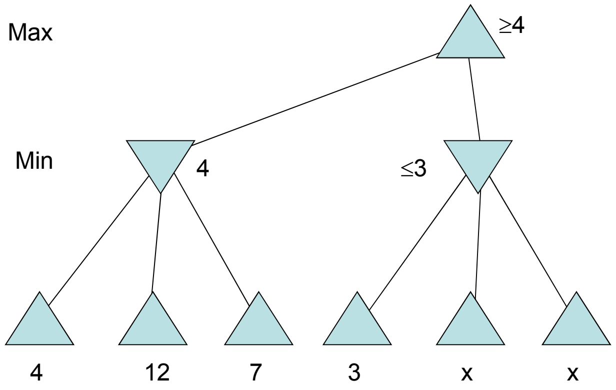

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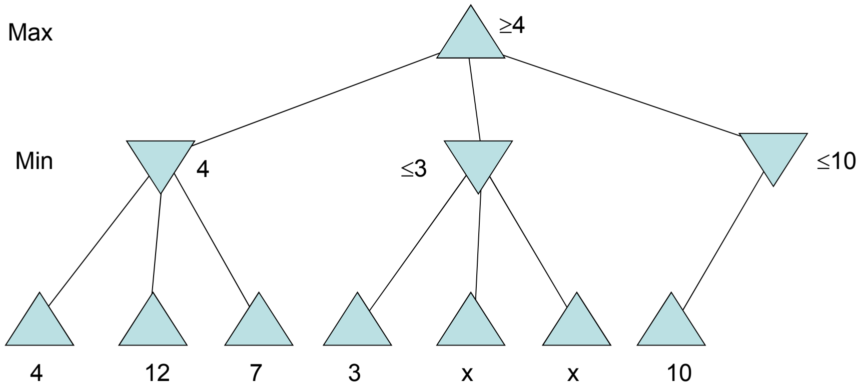

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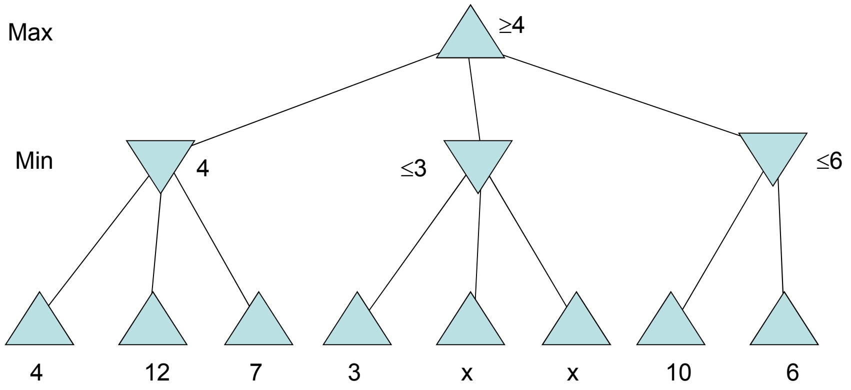

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