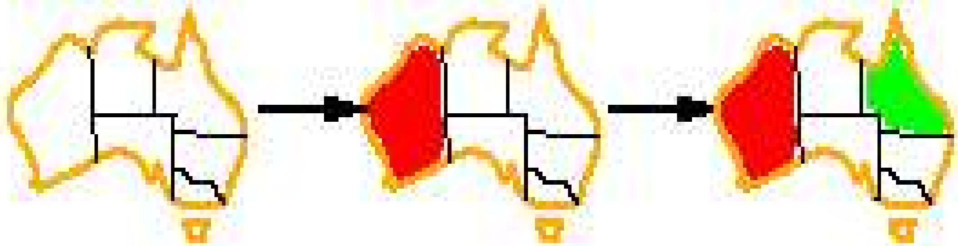
CSC421 Intro to Artificial Intelligence

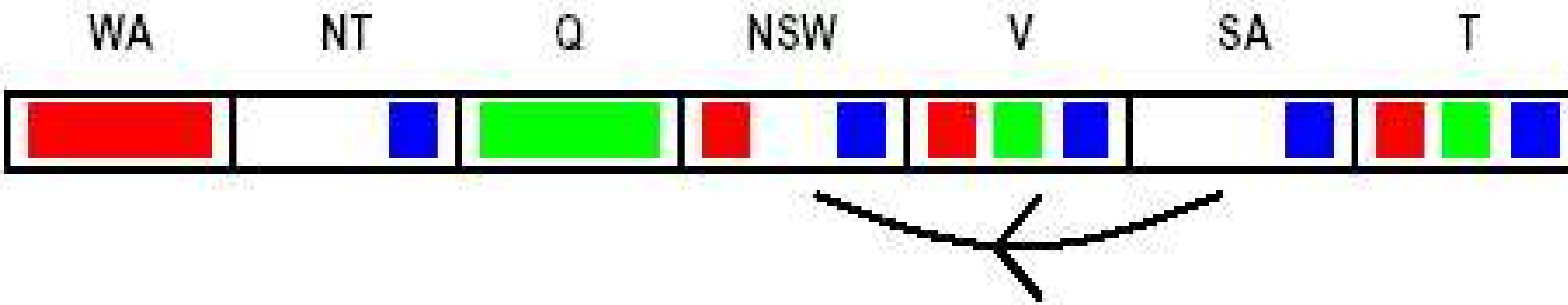
UNIT 07:
Game Playing

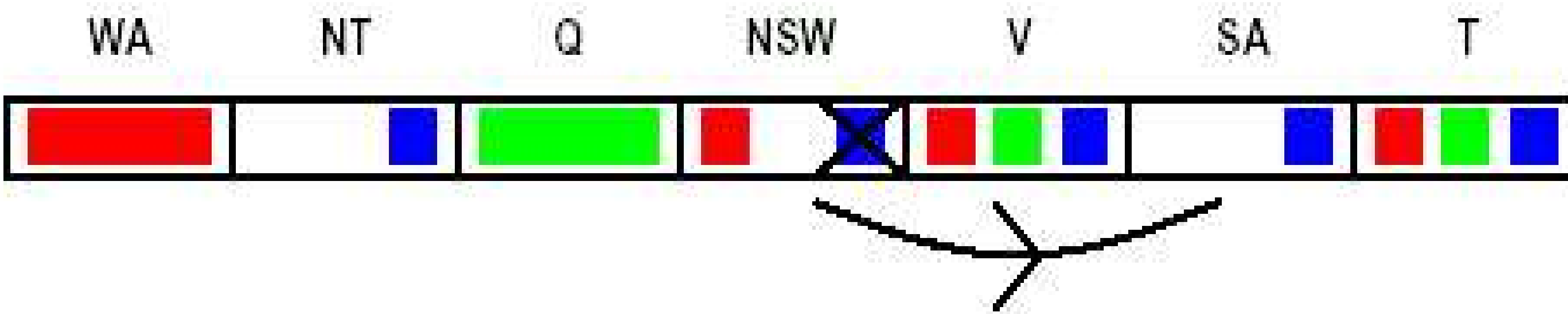
Arc consistency

- Stronger form of constraint propagation than forward checking
- Arc consistent
  - X -> Y is consistent iff for every value x of X there is some allowed value y of Y
- Does X->Y imply Y->X ?

Arc consistency







K-consistency

- Arc consistency either as pre-processor or after every assignment
- Stronger forms k-consistency
- Determining appropriate level of consistency checking is mostly an empirical science
- Special constraints -> special purpose constraint propagation
    - Alldiff
    - Resource constraint – bounds propagation

Problem structure

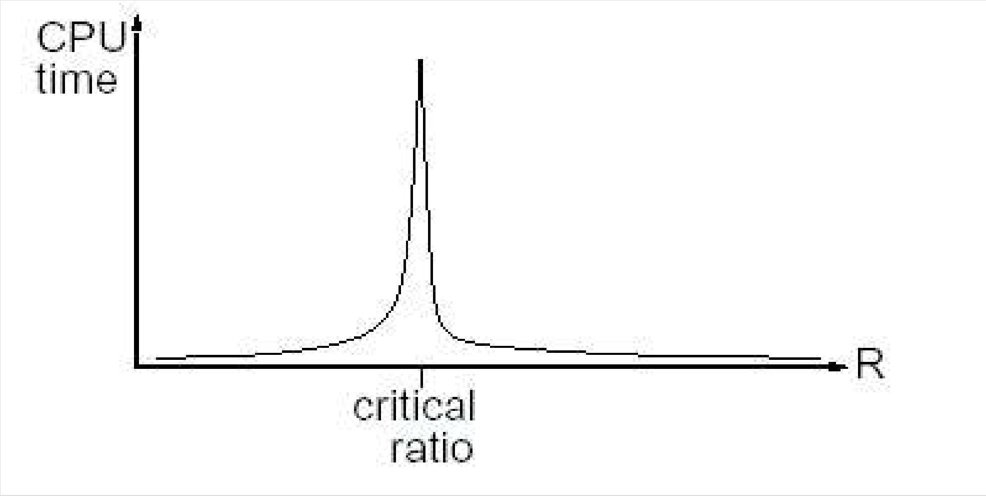
- Connected components
- Tree structured CSP
  - Relation of syntactic restrictions and complexity of reasoning
- Nearly tree-structured CSP
  - Cutstet conditioning

Iterative algorithms for CSP

- Hill-climbing, simulated annealing typically work with "complete" states, i.e. All variables assigned
- To apply to CSPs:
  - Allow states with unsatisfied constraints
  - Operators reassign variable values
- Variable selection: randomly select any conflicted variable
- Value selection: Min-conflict heuristic
  - Choose value that violates the fewest constraints
  - Hill climbing with h(n) = # violated constraints

Performance of min-conflict

- Given random initial state, can solve n-queens in almost constant time for arbitrary n with high probability
- Appears to be true for any randomly generated CSP except narrow range of critical ratio R = # constraints / # of variables



Games vs search

- “Unpredictable opponent” => solution is a strategy specifying a move for every possible opponent reply
- Time limits => unlikely to find goal, must approximate
- Some questions to ponder :
  - Why do humans enjoy playing games ?
  - Why are games important for AI research ?
  - Are the answers to these questions connected ?

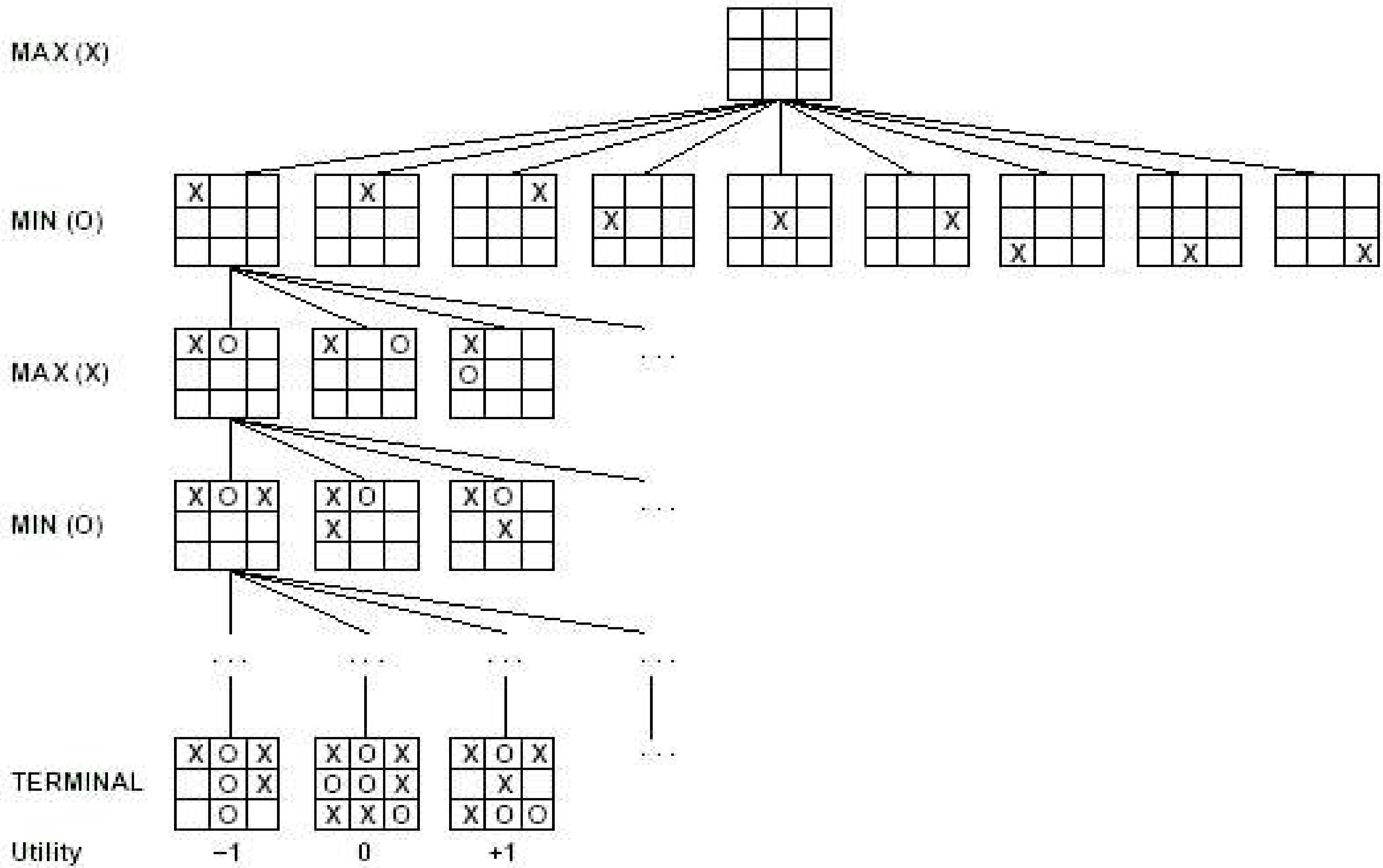
Plan of attack

- Computer considers possible lines of play (Babbage, 1846)
- Algorithms for perfect play (Zermelo 1912, Von Neumann 1944)
- Finite horizon, approximate evaluation (Zuse 1945, Wiener 1948, Shannon 1950)
- First chess program (Turing, 1951)
- Machine Learning to improve accuracy (Samuels, 1952-57)
- Pruning to allow deeper search (McCarthy 1956)

Types of games

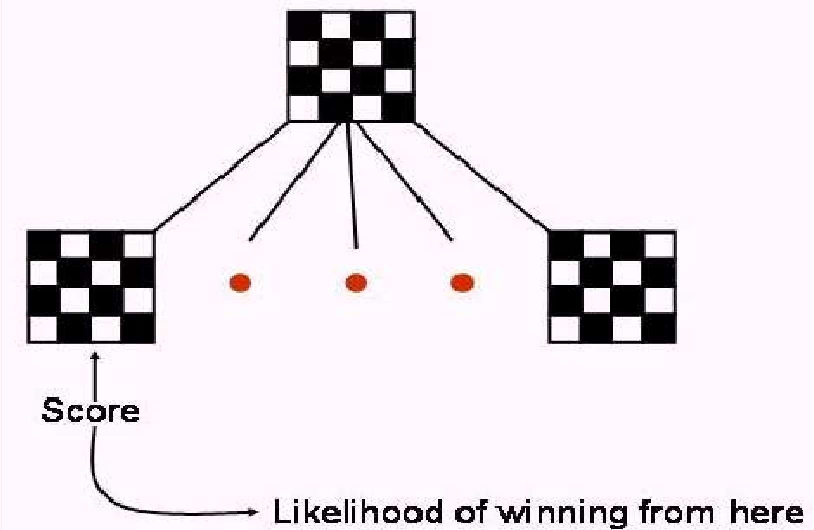
	deterministic	chance
perfect information	chess, checkers, go, othello	backgammon monopoly
imperfect information	battleships, blind tictactoe	bridge, poker, scrabble nuclear war

Game tree



Scoring function

- Scoring function
  - crucial component of any game playing program – numerical value to board position
  - Value captures likelihood of winning from that position
  - One person's win is another's persons loss = same scoring function for both players, simply negating the values to represent the opponent's scores



Concepts

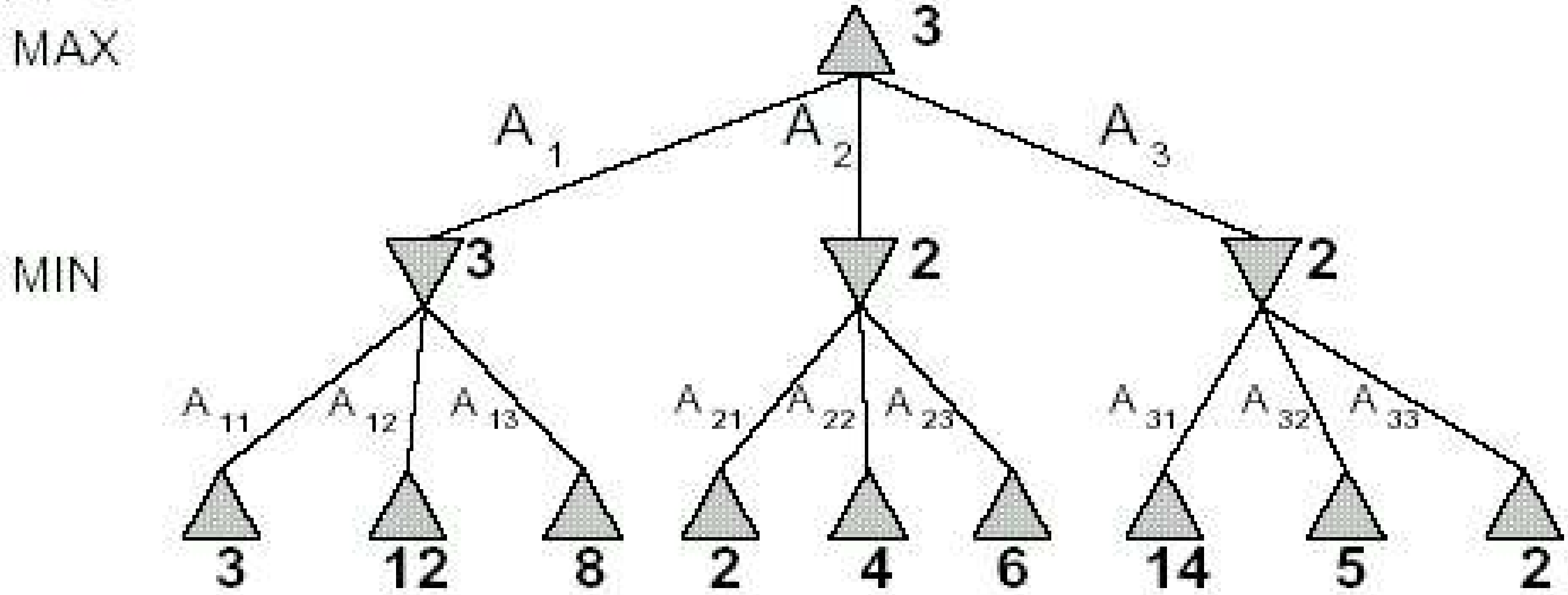
- Utility: +1, -1, 0 (chess), +192 to -192 (backgammon)
- Strategy
  - Max's response to every possible move by Min
- Minimax value of each node
  - Utility of being in the corresponding state, assuming that both players play optimally from the to the end of the game
  - minmax(terminal) = utility
- Minimax-value(n) =
  - Utility(n) if n terminal
  - Max (minimax-value of successors) if n is Max
  - Min (minimax-value of successors) if n is Min

Minimax

- Perfect play for deterministic, full information games
- Idea: choose move to position with highest minimax value = best achievable payoff against best play
- Definition of optimal play assumes that MIN will also play optimally – maximizes worst-case outcome for MAX
- For real games, time cost impractical but serves as basis for mathematical analysis of games and more practical algorithms

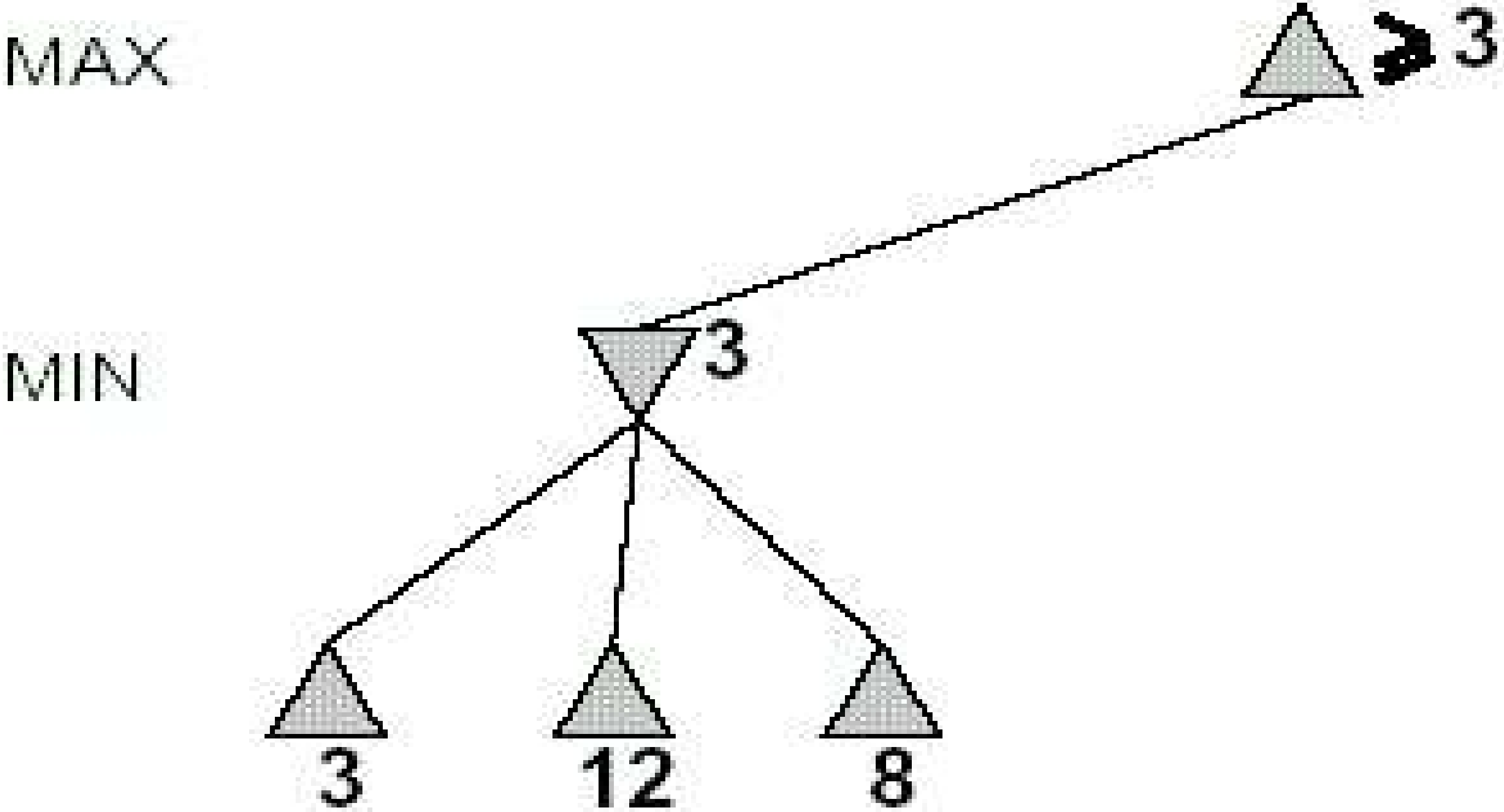
MinMax

E.g., 2-ply game:

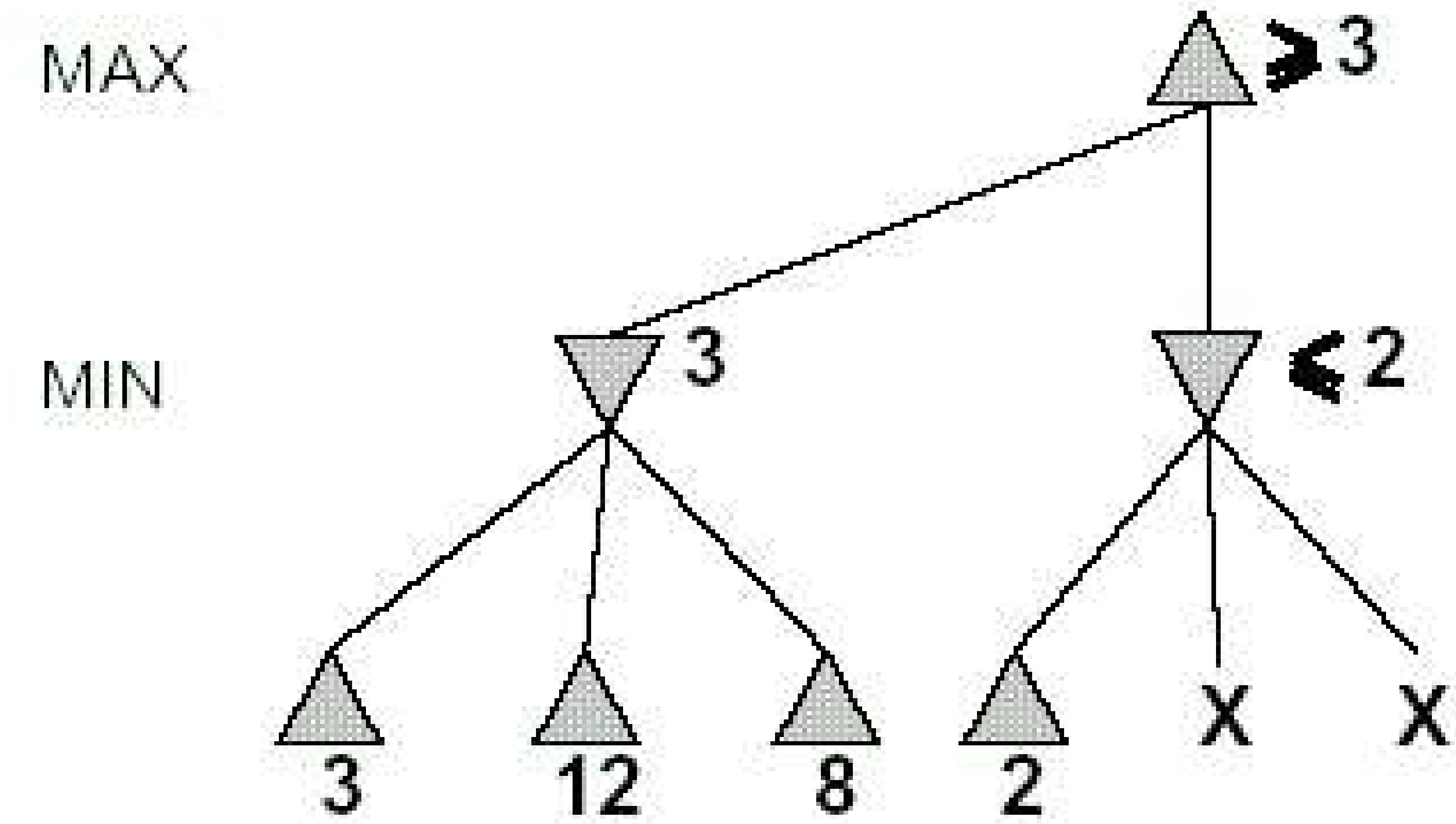


Definition of optimal play for MAX assumes MIN also plays optimally. What if MIN does not play optimally ?

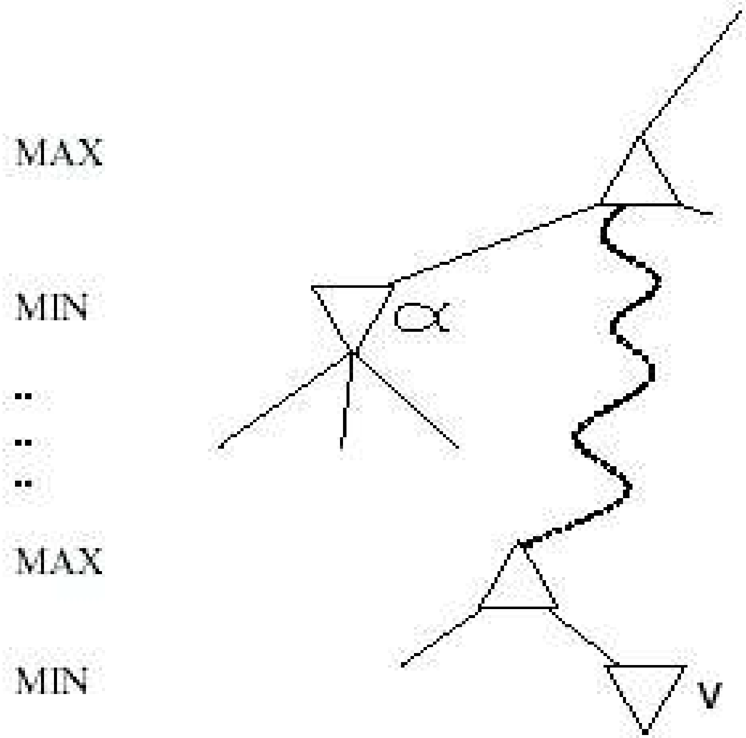
Alpha-Beta Pruning



Alpha-Beta Pruning



Why is it called alpha-beta pruning ?



α is the best value (to MAX) found so far off the current path

If V is worse than α, MAX will avoid it $\Rightarrow$ prune that branch

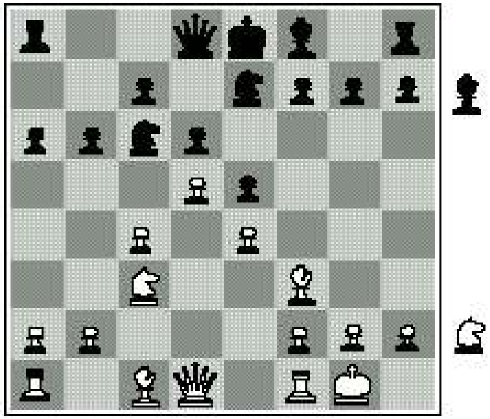
Define β similarly for MIN

Properties of Alpha-Beta Pruning

- Pruning doesn't affect final result
- Good move ordering improves effectiveness of pruning
- With good ordering can double solvable depth
- Examine first succesors that are likely to be best
  - Chess ?

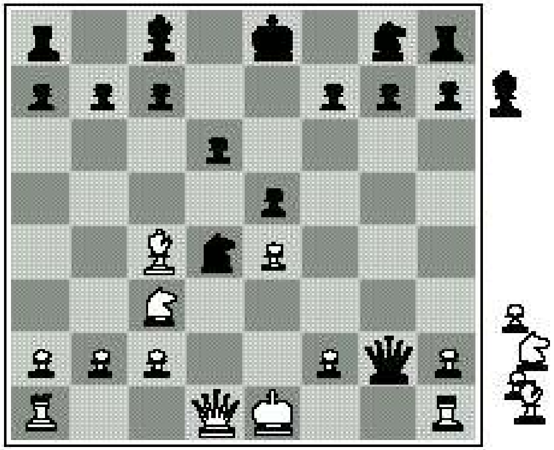
Resource limits

- Standard approach:
  - Use Cutoff-test instead of Terminal-Test
    - e.g. Depth limit
  - Use Eval instead of Utility
    - Evaluation function that estimates desirability of position – in chess weighted linear function



Black to move

White slightly better



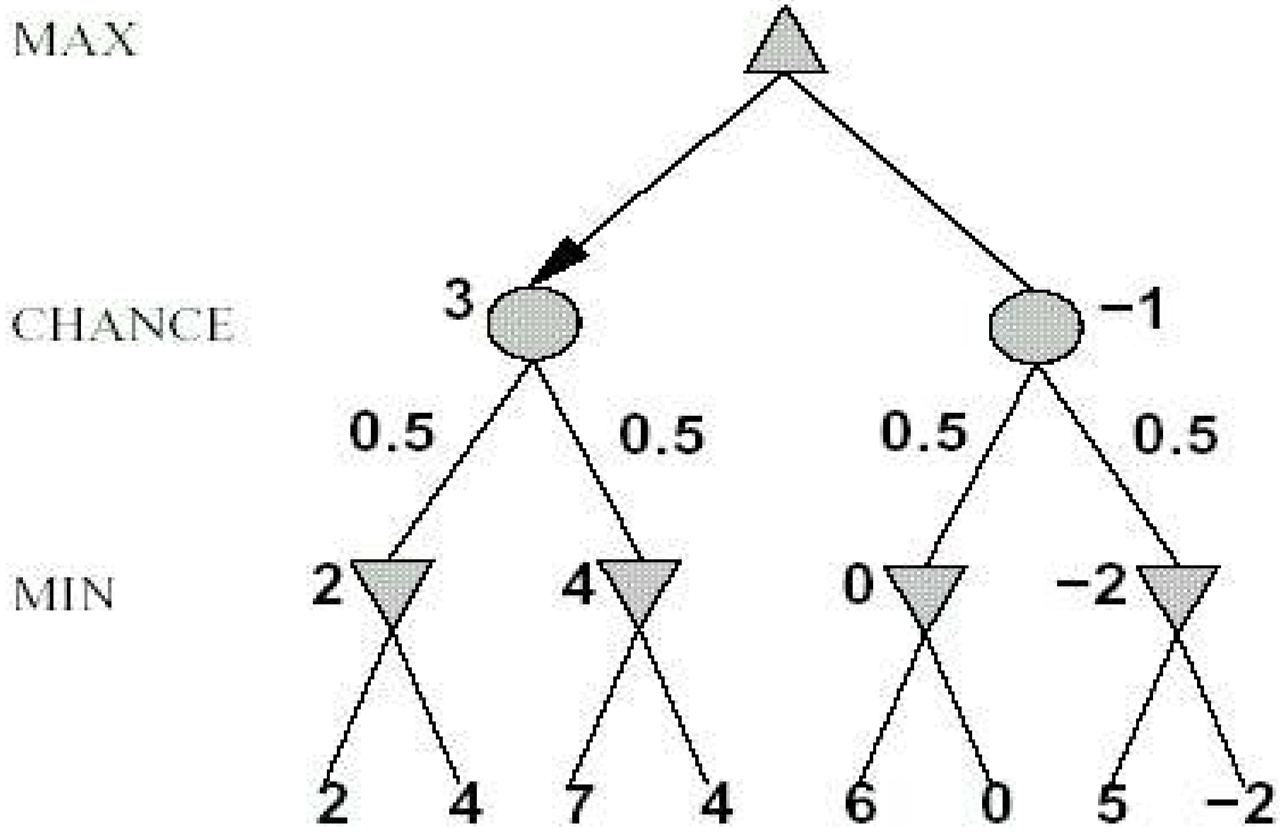
White to move

Black winning

Deterministic games in practice

- Checkers: 1994 ended 40-year reign of human champion Marion Tinsley
- Chess: 1997 Gary Kasparov – Deep Blue 200 milliion positions/second – some lines of search up to 40 ply
- Othello: human champions refuse to compete with computers because they are too good
- Go: Human champions refuse to play with computers, who are too bad. Branching factor b > 300 pattern databases

Non-deterministic games



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...
if state is a MAX node then
    return the highest EXPECTIMINIMAX-VALUE of SUCCESSORS(state)
if state is a MIN node then
    return the lowest EXPECTIMINIMAX-VALUE of SUCCESSORS(state)
if state is a chance node then
    return average of EXPECTIMINIMAX-VALUE of SUCCESSORS(state)
...
```

Like MinMax with addition of CHANCE nodes – gives perfect play

Nondeterministic games in practice

- Dice rolls increase b
- As depth increases, probability of reaching a given node shrinks
- Alpha-beta doesn't help much
- TDGammon – depth-2 search + very good EVAL = world champion level

Summary

- Games are fun to work with
- They illustrate several important points about AI
  - Perfection is unattainable – must approximate
  - Good idea to think about what to think about
  - Uncertainty constraints the assignment of values to states
  - Optimal decisions depend on information state, not optimal state
- Games are to AI as grand prix racing is to automobile design