

GAME PLAYING

CHAPTER 6

Outline

- ◇ Games
- ◇ Perfect play
 - minimax decisions
 - α - β pruning
- ◇ Resource limits and approximate evaluation
- ◇ Games of chance
- ◇ Games of imperfect information

Games vs. search problems

“Unpredictable” opponent \Rightarrow solution is a **strategy**
specifying a move for every possible opponent reply

Time limits \Rightarrow unlikely to find goal, must approximate

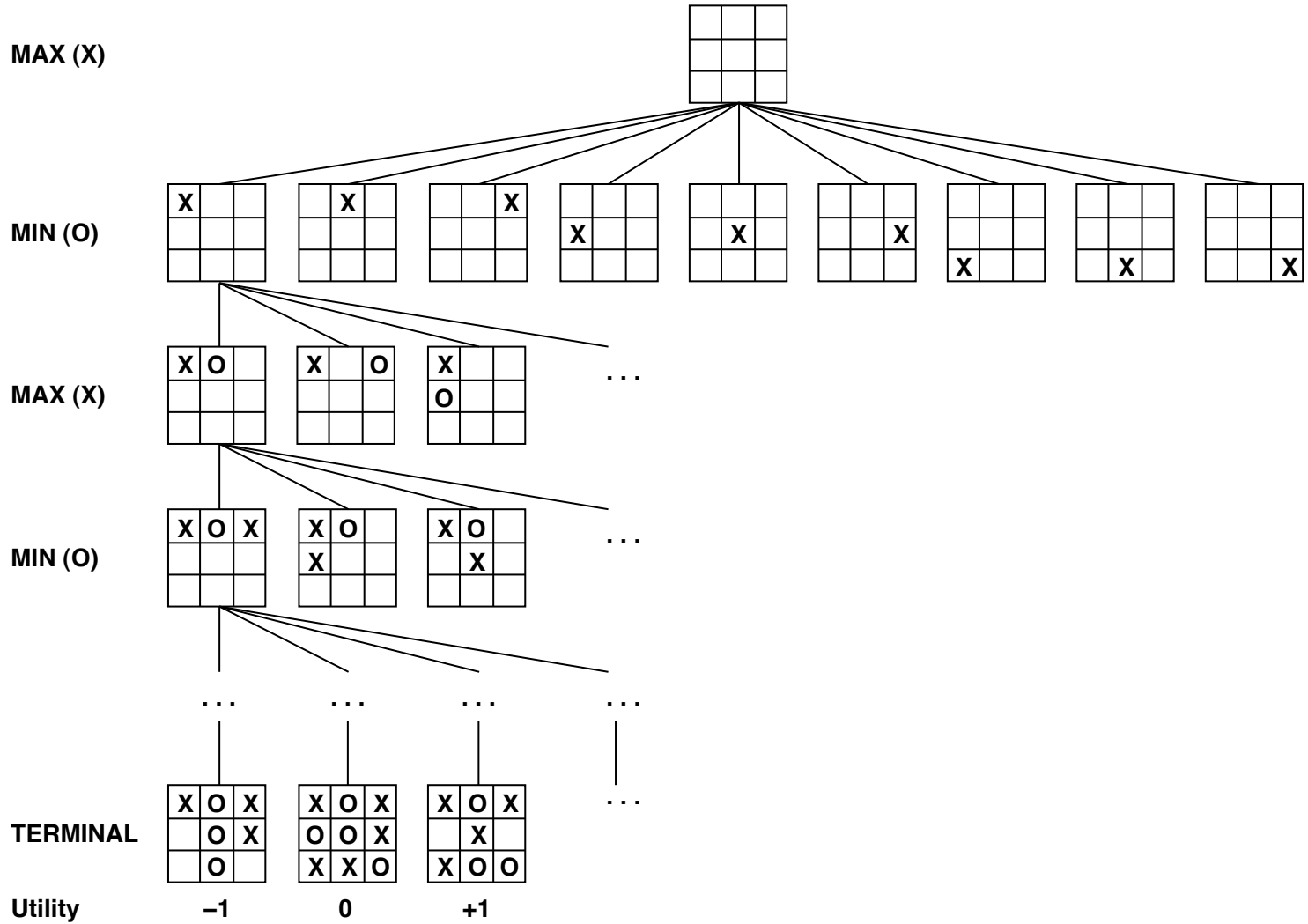
Plan of attack:

- Computer considers possible lines of play (Babbage, 1846)
- Algorithm 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 evaluation accuracy (Samuel, 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 (2-player, deterministic, turns)

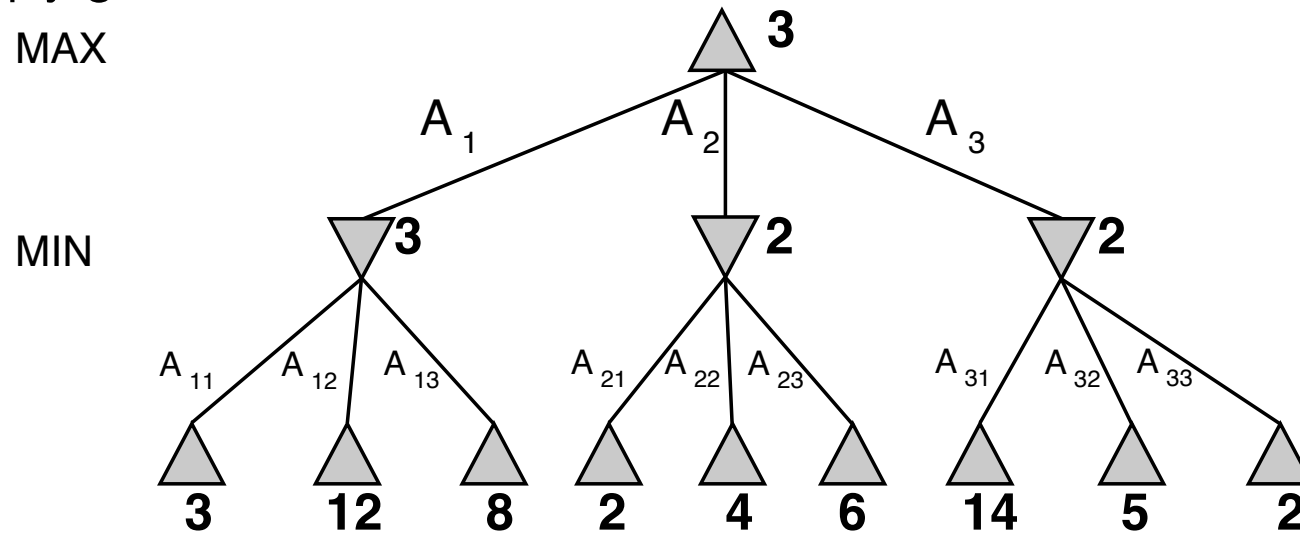


Minimax

Perfect play for deterministic, perfect-information games

Idea: choose move to position with highest **minimax value**
= best achievable payoff against best play

E.g., 2-ply game:



Minimax algorithm

function MINIMAX-DECISION(*state*) **returns** *an action*

inputs: *state*, current state in game

return the *a* in ACTIONS(*state*) maximizing MIN-VALUE(RESULT(*a*, *state*))

function MAX-VALUE(*state*) **returns** *a utility value*

if TERMINAL-TEST(*state*) **then return** UTILITY(*state*)

$v \leftarrow -\infty$

for *a, s* in SUCCESSORS(*state*) **do** $v \leftarrow \text{MAX}(v, \text{MIN-VALUE}(s))$

return *v*

function MIN-VALUE(*state*) **returns** *a utility value*

if TERMINAL-TEST(*state*) **then return** UTILITY(*state*)

$v \leftarrow \infty$

for *a, s* in SUCCESSORS(*state*) **do** $v \leftarrow \text{MIN}(v, \text{MAX-VALUE}(s))$

return *v*

Properties of minimax

Complete??

Properties of minimax

Complete?? Only if tree is finite (chess has specific rules for this).
NB a finite strategy can exist even in an infinite tree!

Optimal??

Properties of minimax

Complete?? Yes, if tree is finite (chess has specific rules for this)

Optimal?? Yes, against an optimal opponent. Otherwise??

Time complexity??

Properties of minimax

Complete?? Yes, if tree is finite (chess has specific rules for this)

Optimal?? Yes, against an optimal opponent. Otherwise??

Time complexity?? $O(b^m)$

Space complexity??

Properties of minimax

Complete?? Yes, if tree is finite (chess has specific rules for this)

Optimal?? Yes, against an optimal opponent. Otherwise??

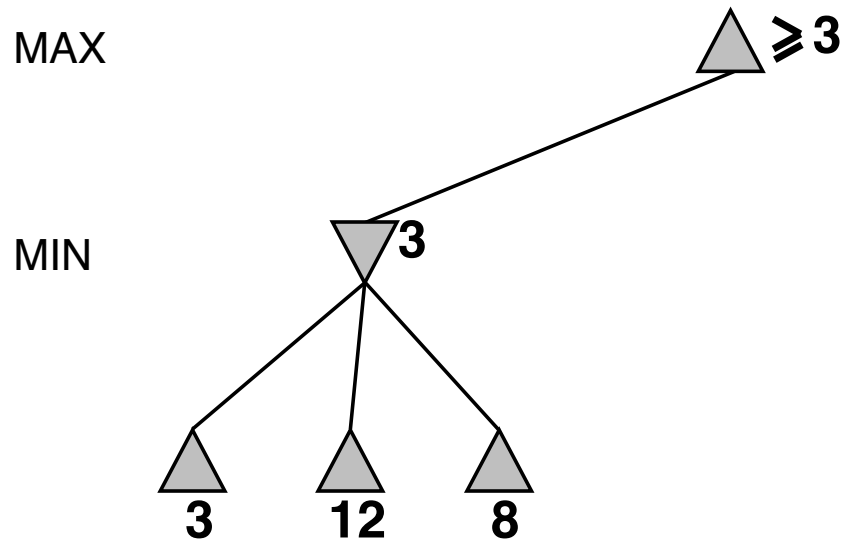
Time complexity?? $O(b^m)$

Space complexity?? $O(bm)$ (depth-first exploration)

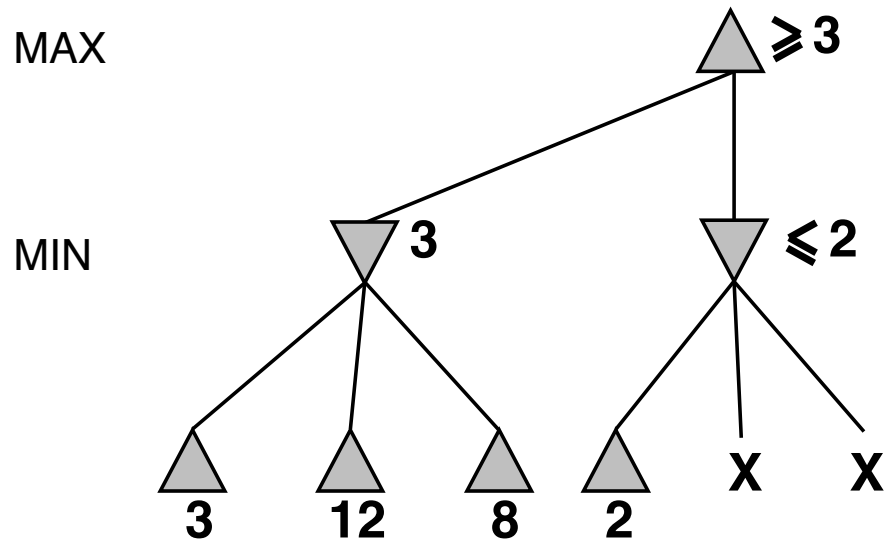
For chess, $b \approx 35$, $m \approx 100$ for “reasonable” games
⇒ exact solution completely infeasible

But do we need to explore every path?

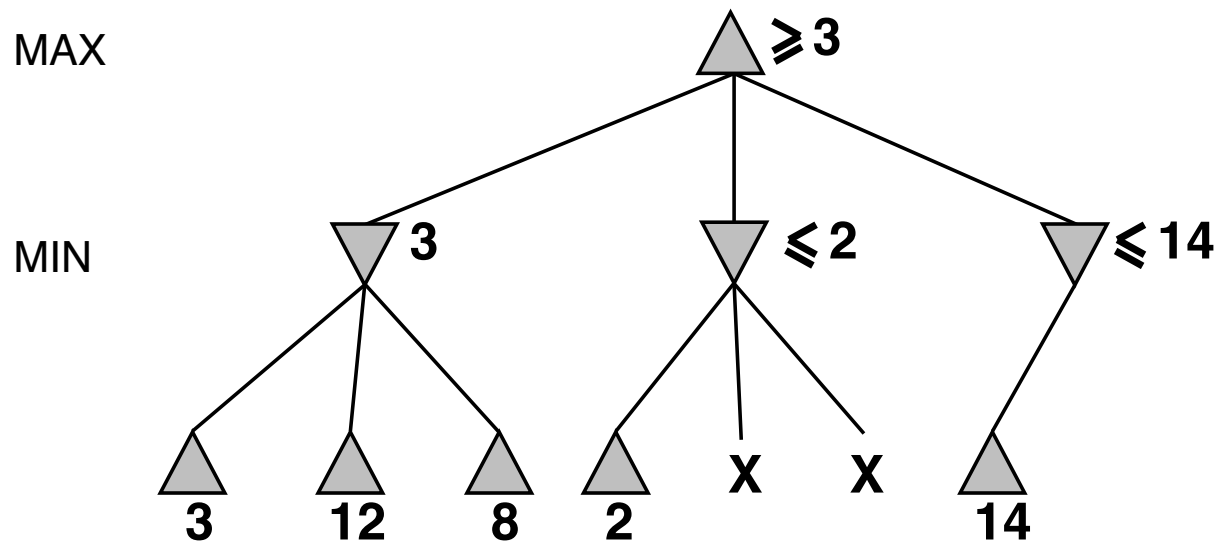
α - β pruning example



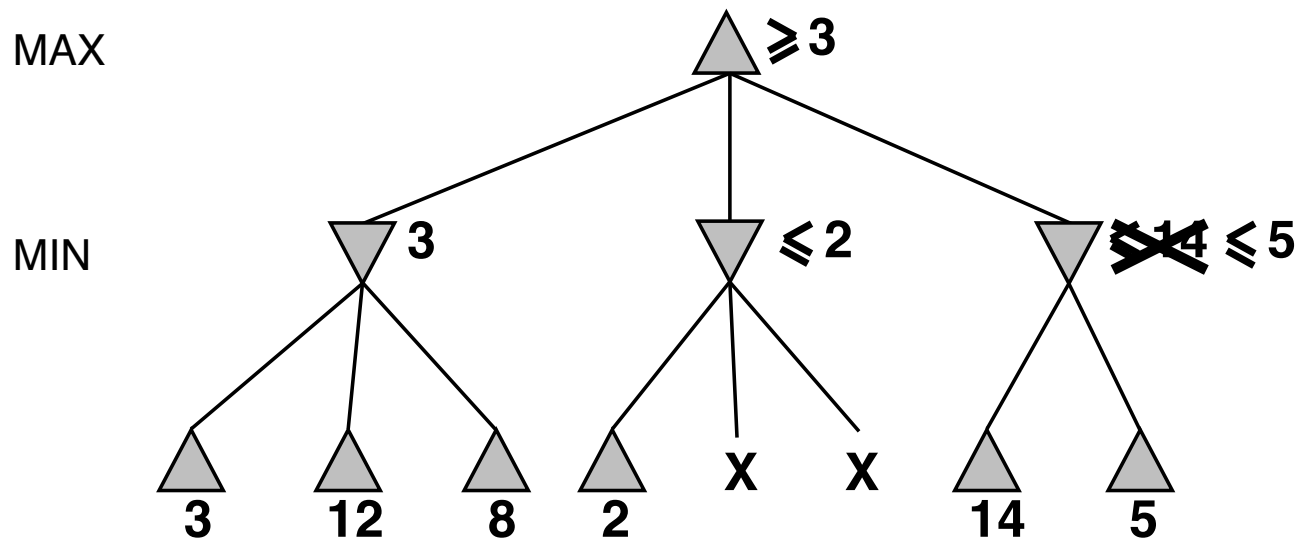
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