

Künstliche Intelligenz

Game Playing

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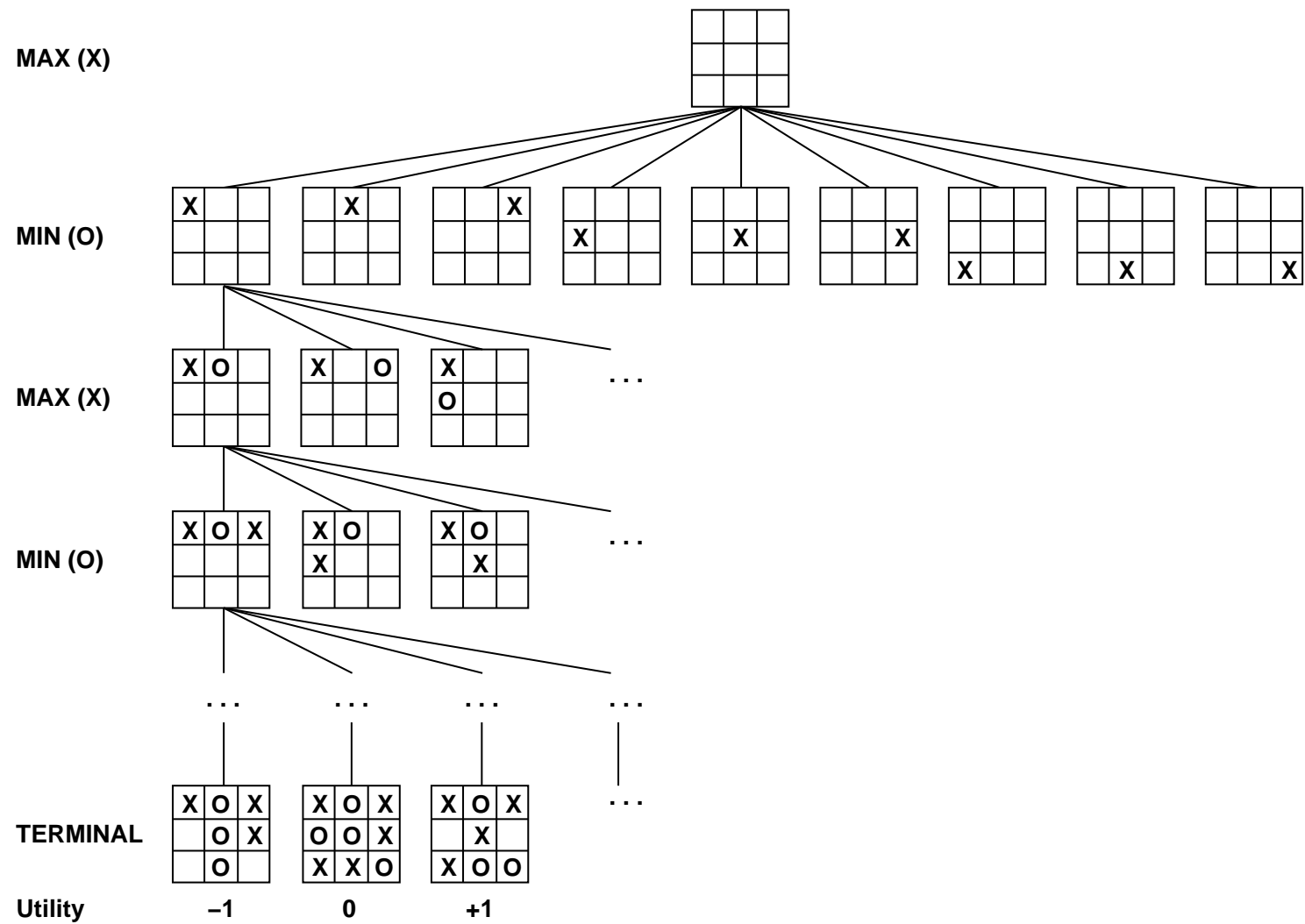
Spiele vs. Suchprobleme

- Spiele unterscheiden sich von “normalen” Suchproblemen:
 - “Unvorhersehbare” Aktionen des Gegners
 - Müssen daher für jede mögliche Aktion des Gegners einen Spielzug parat haben
 - Zeitlimits: Können nicht immer optimale Lösung berechnen

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)

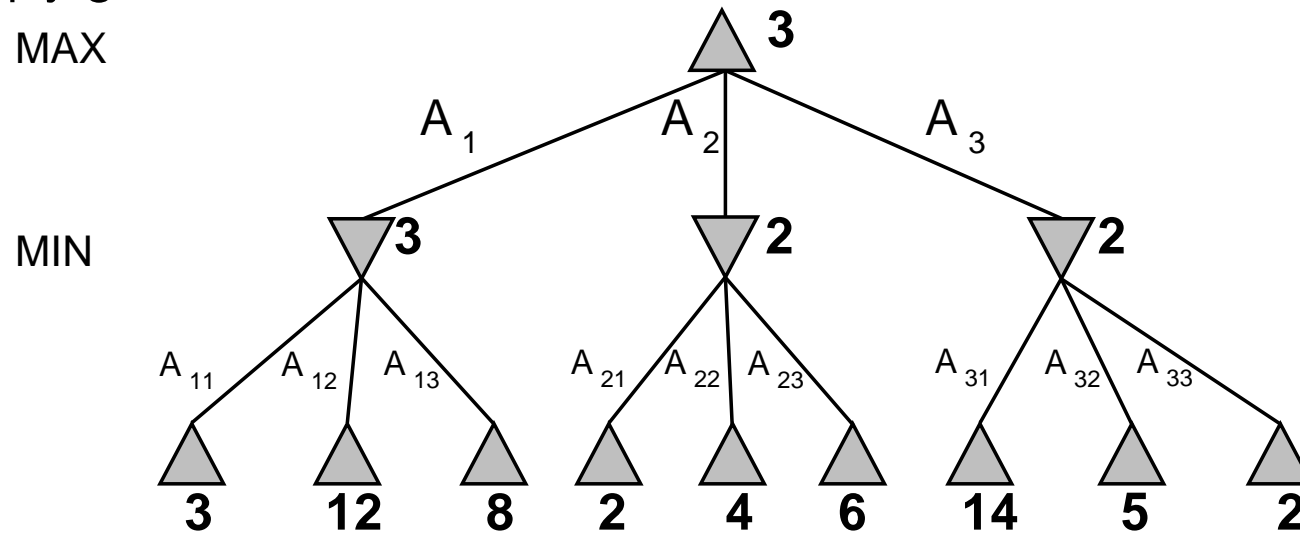


Minimax

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*

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$v \leftarrow \infty$

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??

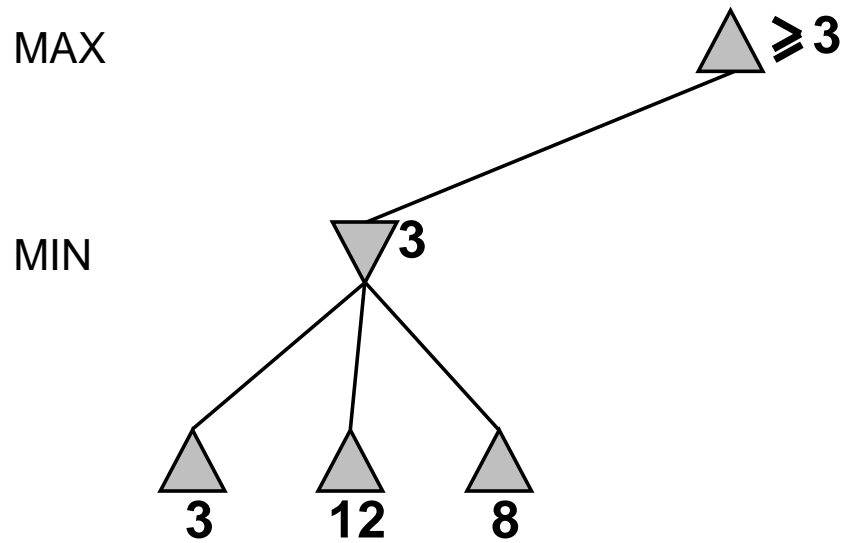
Time complexity?? $O(b^m)$

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

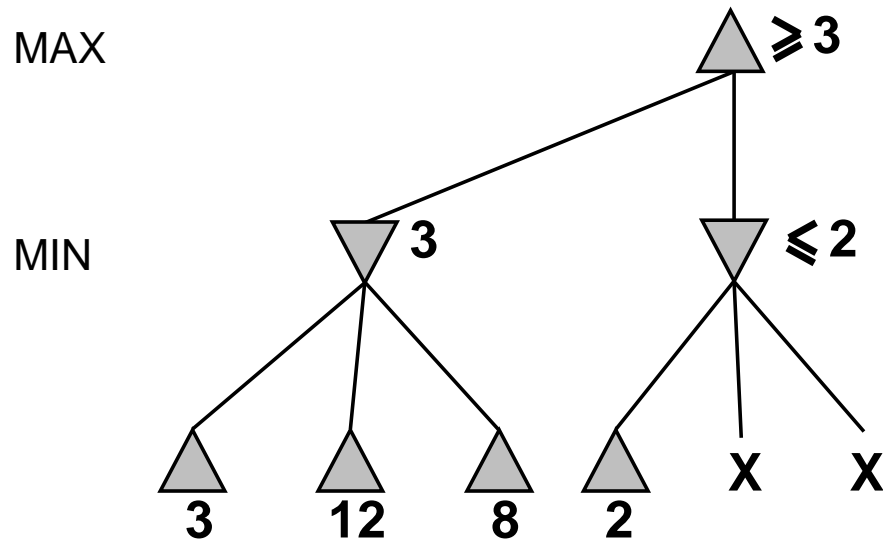
For chess, $b \approx 35$, $m \approx 100$ for “reasonable” games
 \Rightarrow exact solution completely infeasible

But do we need to explore every path?

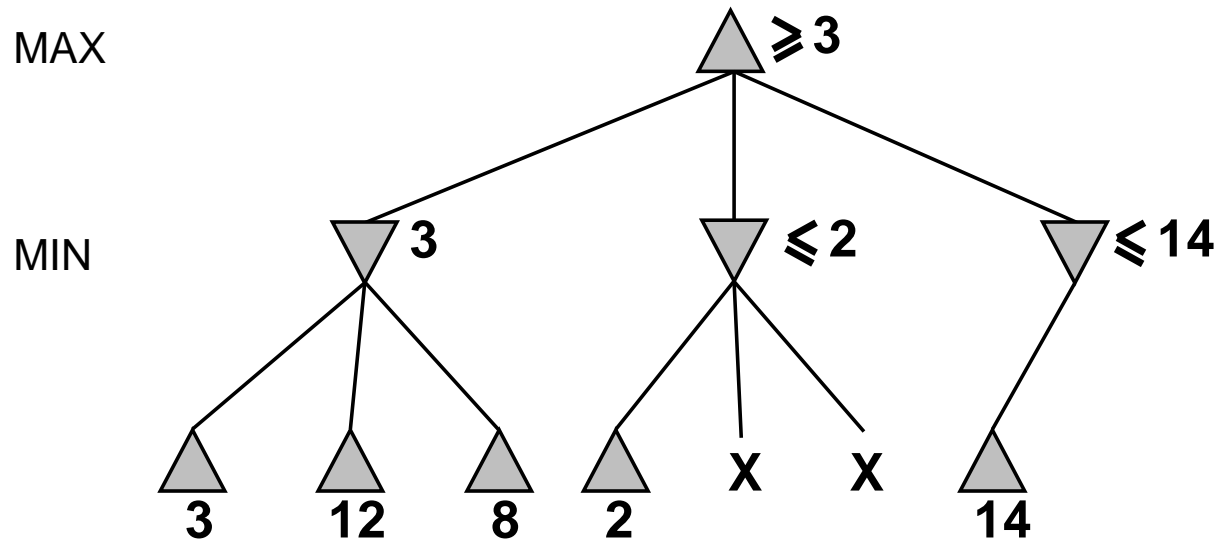
α - β pruning example



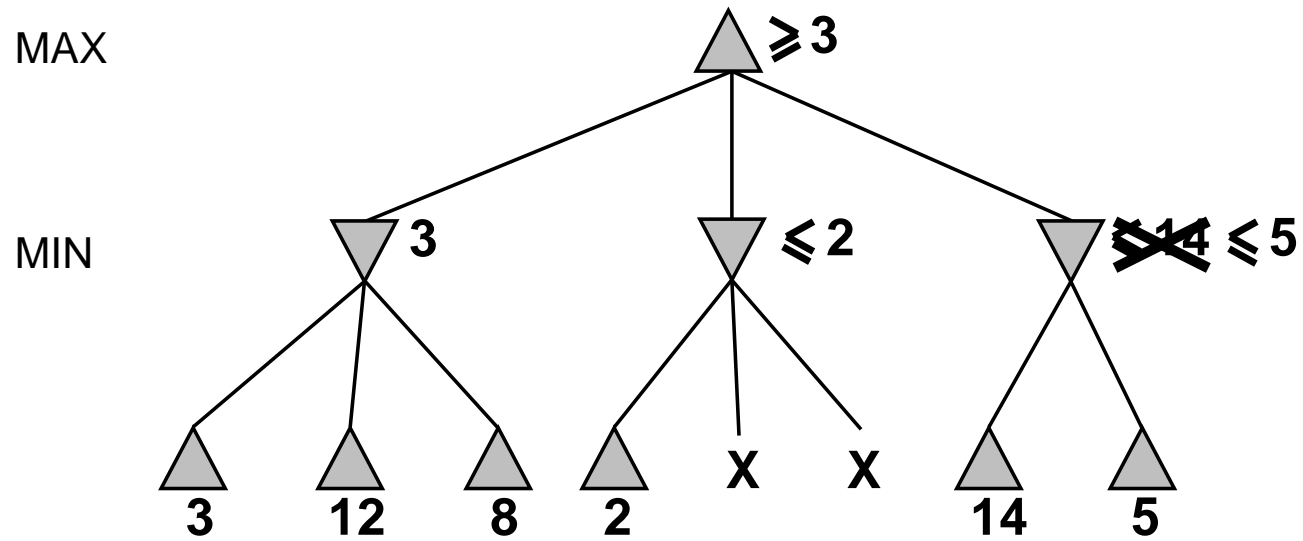
α - β pruning example



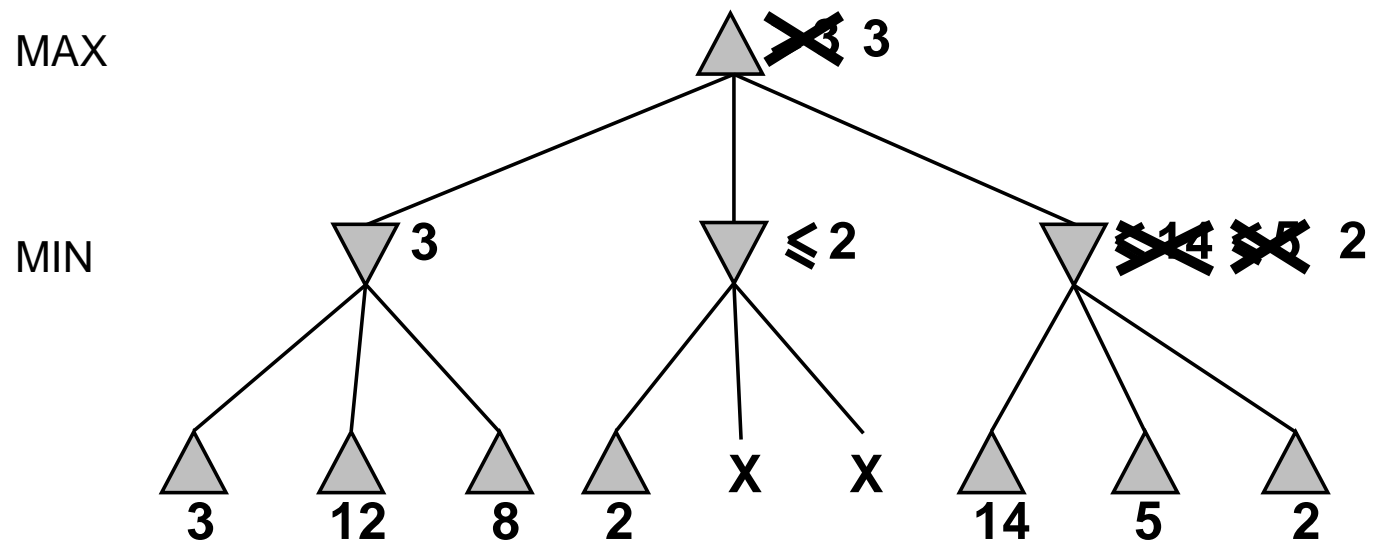
α - β pruning example



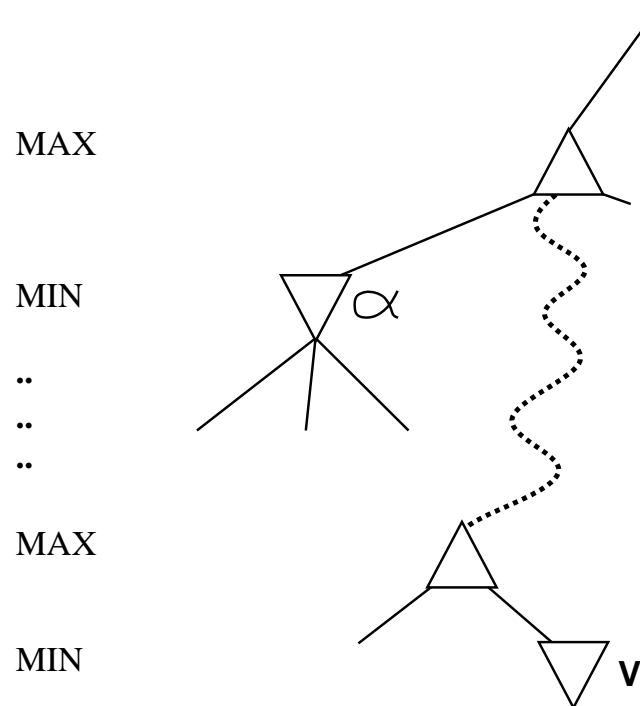
α - β pruning example



α - β pruning example



Why is it called α - β ?



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

The α - β algorithm

function ALPHA-BETA-DECISION($state$) **returns** an action
 return the a in ACTIONS($state$) maximizing MIN-VALUE(RESULT(a , $state$))

function MAX-VALUE($state, \alpha, \beta$) **returns** *a utility value*
 inputs: $state$, current state in game
 α , the value of the best alternative for MAX along the path to $state$
 β , the value of the best alternative for MIN along the path to $state$
 if TERMINAL-TEST($state$) **then return** UTILITY($state$)
 $v \leftarrow -\infty$
 for a, s in SUCCESSORS($state$) **do**
 $v \leftarrow \text{MAX}(v, \text{MIN-VALUE}(s, \alpha, \beta))$
 if $v \geq \beta$ **then return** v
 $\alpha \leftarrow \text{MAX}(\alpha, v)$
 return v

function MIN-VALUE($state, \alpha, \beta$) **returns** *a utility value*
 same as MAX-VALUE but with roles of α, β reversed

Properties of $\alpha-\beta$

Pruning **does not** affect final result

Good move ordering improves effectiveness of pruning

With “perfect ordering,” time complexity = $O(b^{m/2})$
 \Rightarrow **doubles** solvable depth

A simple example of the value of reasoning about which computations are relevant (a form of **metareasoning**)

Unfortunately, 35^{50} is still impossible!

Resource limits

Standard approach:

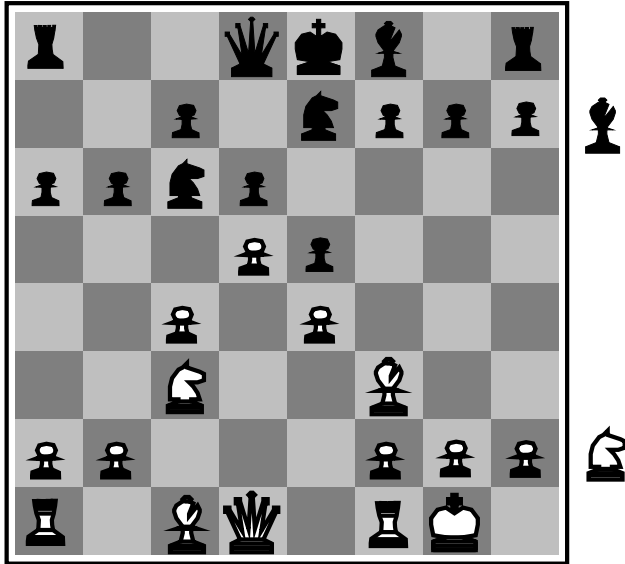
- Use CUTOFF-TEST instead of TERMINAL-TEST
e.g., depth limit (perhaps add quiescence search)
- Use EVAL instead of UTILITY
i.e., evaluation function that estimates desirability of position

Suppose we have 100 seconds, explore 10^4 nodes/second

$\Rightarrow 10^6$ nodes per move $\approx 35^{8/2}$

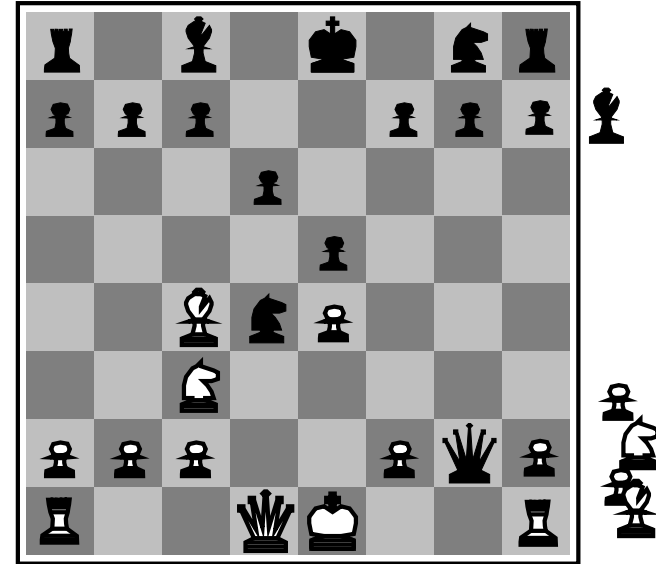
$\Rightarrow \alpha\text{-}\beta$ reaches depth 8 \Rightarrow pretty good chess program

Evaluation functions



Black to move

White slightly better



White to move

Black winning

For chess, typically **linear** weighted sum of **features**

$$Eval(s) = w_1 f_1(s) + w_2 f_2(s) + \dots + w_n f_n(s)$$

e.g., $w_1 = 9$ with

$f_1(s) = (\text{number of white queens}) - (\text{number of black queens}), \text{ etc.}$

Summary

Games are fun to work on! (and dangerous)

They illustrate several important points about AI

- ◇ perfection is unattainable \Rightarrow must approximate
- ◇ good idea to think about what to think about
- ◇ uncertainty constrains the assignment of values to states
- ◇ optimal decisions depend on information state, not real state

Games are to AI as grand prix racing is to automobile design