Adversarial Search

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Games

"Chess is the Drosophila of Artificial Intelligence"
Kronrod, c. 1966

TuroChamp, 1948

Why Study Games?

Of interest:

- Many human activities (especially intellectual ones) can be modeled as games.
- Prestige.

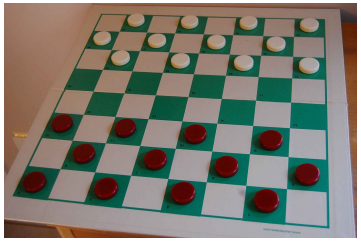
Convenient:

- Perfect information.
- Concise, precise rules.
- Well defined "score".

"Solved" Games

A game is solved if an optimal strategy is known.

Strong solved: *all positions.*
Weakly solved: *some (start) positions.*



Typical Game Setting

Games are usually:

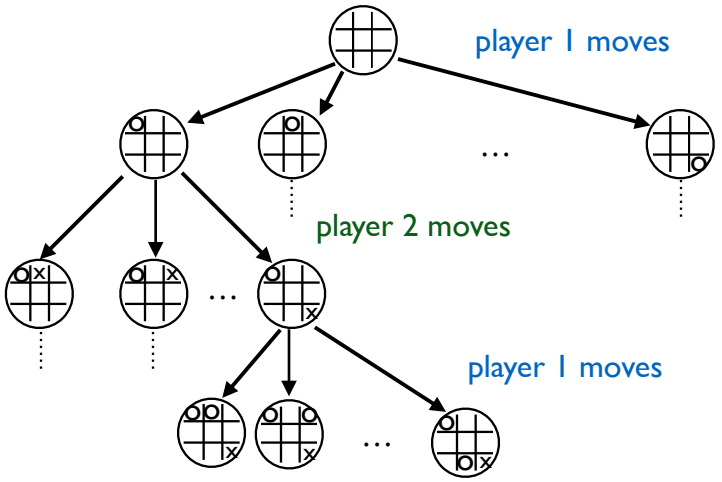
- 2 player
- Alternating
- Zero-sum
  - Gain for one loss for another.
- Perfect information

Very much like search:

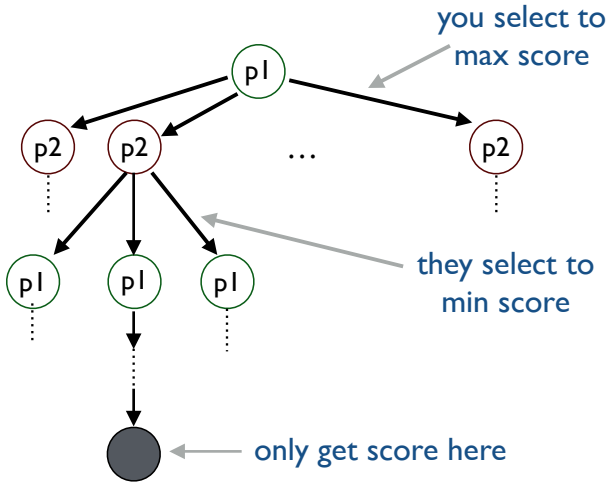
- Start state
- Successor function
- Terminal states (many)
- Objective function

but alternating control.

Game Trees



Key Differences vs. Search



Minimax Algorithm

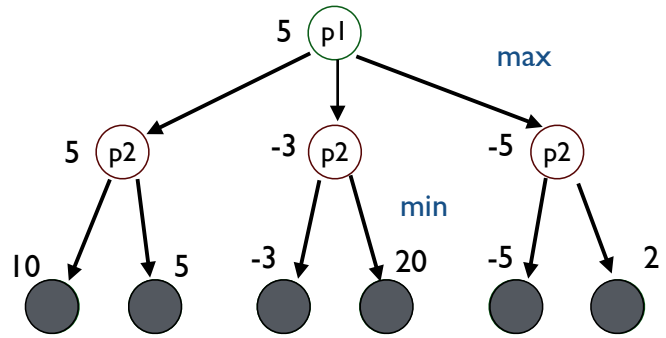
Max player: select action to maximize return.
Min player: select action to minimize return.

This is optimal for both players (if zero sum).
Assumes perfect play, worst case.

Can run as depth first:

- Time $O(b^d)$
- Space $O(bd)$

Minimax



In Practice

Depth is too deep.
- 10s to 100s of moves.

Breadth is too broad.
- Chess: 35, Go: 361.

Full search never terminates for non-trivial games.

Solution: *substitute evaluation function*.
- Like a heuristic - estimate value.
- Perhaps run to fixed depth then estimate.

Search Control

- Horizon Effects
  - What if something interesting at horizon + 1?
  - How do you know?

- When to generate more nodes?
- How to selectively expand the frontier?
- How to allocate fixed move time?

Pruning

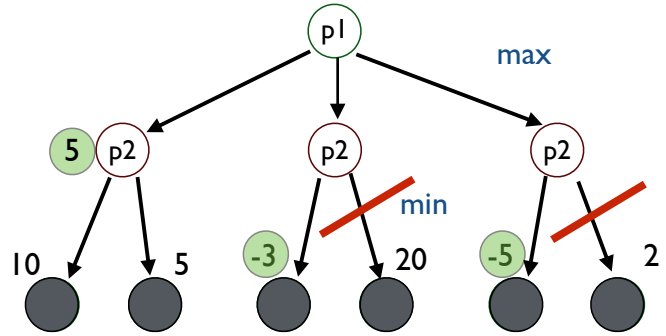
Single most useful search control method:
- Throw away whole branches.
- Use the min-max behavior.

- Cutoff search at *min* nodes where *max* can force a better outcome.

- Cutoff search at *max* nodes when *min* can force a worse outcome.

Resulting algorithm: *alpha-beta pruning*.

Alpha-Beta



Alpha-Beta

Empirically, has the effect of reducing the branching factor by a *square root* for many problems.

Effectively doubles the search horizon.

Alpha-beta makes the difference between novice and expert computer game players. *Most successful players use alpha-beta.*

Deep Blue (1997)

480 Special Purpose Chips
200 million positions/sec
Search depth 6-8 moves (up to 20)

Games Today

World champion level:
- Backgammon
- Chess
- Checkers (solved)
- Othello
- Some poker types:

"Heads-up Limit Hold'em Poker is Solved", Bowling et al., *Science*, **January 2015**.

Perform well:
- Bridge
- Other poker types

Far off: *Go*

Go: The New Frontier