Adversarial Search

George Konidaris
gdk@cs.duke.edu

DUKE
COMPUTER
SCIENCE

Spring 2015

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

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.
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:

Perform well:
• Bridge
• Other poker types

Far off: Go
Go: The New Frontier