Heuristic Search in the Age of Deep Learning

Martin Müller
Contents

一. Why Heuristic Search?
二. Past Successes
三. Modern Successes
四. Future
Why Heuristic Search?

Make complex decisions:
- Look ahead
- Evaluate different options
- Simulate future scenarios
Examples

• Prediction
• Planning
• Games
Why Games?

• Simple clear rules
• Try many new ideas
• Use results in real world
• Games are good business!
Past Successes

一. Search: minimax, alphabeta
二. Knowledge: handcoded rules
三. Perfect endgame databases
四. Case studies: chess, checkers
五. TD-Gammon: a glimpse of the future
Chess

- 20 years ago, IBM’s Deep Blue beat Kasparov
- Deep search, parallel computing
- Evaluation with hand-designed features
- Some automated tuning
Checkers

- Solved ten years ago, Jonathan Schaeffer
- Exact, proven result
- Massive search, endgame databases
- Hand-built evaluation
Backgammon - TD-Gammon

- Gerry Tesauro, IBM
- 25 years ago
- Early success of
  - Neural networks
  - Reinforcement learning
Modern Successes

一. Search: Monte Carlo Tree Search
二. Knowledge: large scale machine learning, deep networks
三. Massively parallel, use GPU/TPU
四. Case studies: Go, poker
Go (Weiqi)

- AlphaGo
- Search, Knowledge, Simulations
- Supervised and reinforcement learning
- Combination much stronger than each alone
Poker

- Bowling et al 2017, DeepStack
- Heads-up No-Limit Texas Hold'em Poker
- Incomplete information, huge state space
- First application of heuristic search to such problems
Future Challenges

一. Search: combine exact and heuristic methods
二. Knowledge: learn models from data
三. Application: your decision-making problem
Challenge: Combine Exact and Heuristic Methods

- Deep Learning is very powerful
- Heuristic, not exact
- Many critical applications require certainty, exact methods
- Challenge: how to combine?
Challenge: Learn Models from Data

- Games:
  - Exact rules known
  - Can simulate billions of steps

- Real world: not known
Summary - Heuristic Search

• Core technology for complex decision-making
• Advances in deep learning greatly expand its power