Game Playing

Perfect Decisions

- Search as before
  - Initial state
    - board position and move indication
  - Operators
    - define legal moves
  - Terminal test
    - is the game over? (terminal state)
  - Utility (Payoff) function
    - numeric value for game's outcome
- Strategy
  - plan to get to favourable terminal state regardless of opponents moves
- Ply
  - number of half moves in a game

Minimax

- What is the best first move?
- Strategy in five steps:
  - Generate whole game tree
  - Apply utility function to each terminal state to get its value
  - Determine utility of nodes 1 level up
    - using utility of terminal states
  - Continue backing up towards root
    - 1 layer at a time
  - Choose move that leads to highest value
    - on assumption that opponent will try to minimize it --> **minimax decision**

Imperfect Decisions

- Impractical to generate complete game tree
  - alter minimax to an approximation
- Evaluation function
  - heuristic for early cut-off
  - replaces utility function
- Cuttoff test
  - replaces the terminal test

Evaluation Functions

- Estimate of expected utility
  - of a game from a given position
  - it's what people do
  - **material value**
- Funtion Quality?
  - agree with utility function on terminal states
  - must not take too long to calculate
  - accurately reflect actual chances of winning
- Weighted Linear Functions
  - assumes values are independent

  $w_1f_1 + w_2f_2 + \ldots + w_nf_n$

Cutting Off Search

- Naive approaches
  - Fixed depth: *d*
    - temporally selected
    - cuttoff succeeds for depths >= *d*
  - Iterative Deepening
    - move selected at deepest level acheived within time limits is returned
- More sophisticated approaches
  - evaluation only applied at quiescence
  - Quiescence search
    - non-quiescent states expanded till quiescence reached.
- Horizon problem
  - unavoidable damage only delayed

Alpha-Beta Pruning

- Game tree pruned
  - correct minimax decision made
- Principle
  - subtree pruned when better choice already exists higher in the tree.
  - α - value of best choice so far for player
  - β - value of best choice so far for opponent
- Effectiveness
  - depends on ordering
  - idealised tree model
  - empirical science

Alpha-Beta Algorithm

1. Determine if level = top_level or search limit reached or minimizing level or maximising level

1a. If level = top_level set alpha = infinity and beta = -infinity

1b. If search limit reached: compute utility function of current position (for appropriate player) and return result.

1c. If minimizing level:

1c1 Until all children are examined with MINIMAX or alpha > beta:

1c1.1 Set beta to smaller of given beta values and smallest value reported by MINIMAX on children

1c1.2 Use MINIMAX on next child of current position; giving it the current alpha and beta.

1c2 Return beta

1d If maximising level:

1d1 Until all children are examined with MINIMAX or alpha > beta:

1d1.1 Set alpha to largler of given alpha values and biggest value reported by MINIMAX on children

1c1.2 Use MINIMAX on next child of current position; giving it the current alpha and beta.

1d2 Return alpha

Games that include Chance

- Backgammon
  - Search includes unpredictability
  - Chance Nodes (possible dice rolls)
  - Expected value
    - No definite Minimax
    - Average value of dice rolls calculated
- Expectimax

  $expectimax(C) = \Sigma P(d_i) \max_{s \in S(C,d_i)} (utility(s))$
- Expectimin
  - analogous formula
- Expectiminimax
  - best move based on probabilistic evaluation

Games of Chance (2)

- Search cuttoff
  - Evaluation is scale dependant
    - must be positive linear transformation
- Complexity
  - Exponential in depth of goal and number of dice rolls
  - possible to use alpha-beta with upper and lower bounds

State of the Art

- Draughts
  - First world champion
    - Human champion ill, died soon after
- Chess
  - World champion beaten
    - not happy about it
- Backgammon
  - World champion beaten
    - lucky dice - usually plays as good amateur
    - more recenty computer in top three
- Othello
  - Usually beats humans
- Go
  - Still play poorly
    - $2 million for first to beat top player