

CS 156: Introduction to Artificial Intelligence

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San José State University

Adversarial Search

Multi-Agent Systems



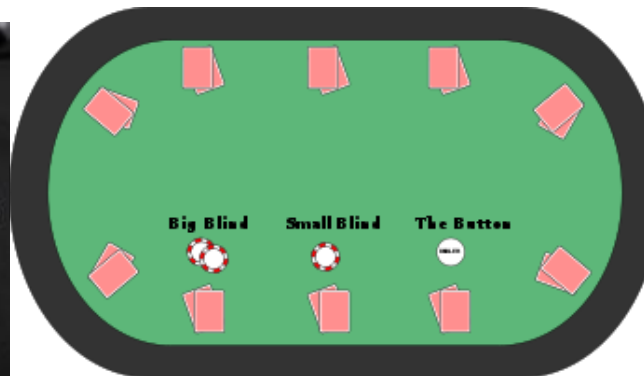
Robocup 2006



Mafia Game



Texas Hold'em



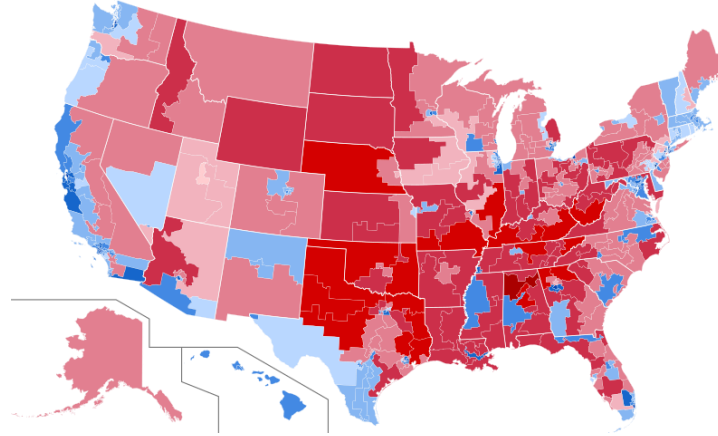
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Multi-Agent Systems

Negotiation



Societal Decision Making



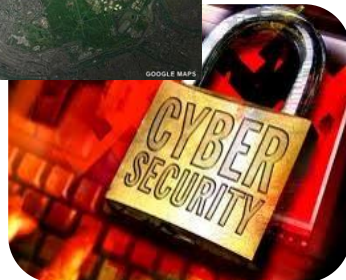
Mobility



Security



Environment Sustainability



Economy

Premium

Fares are slightly higher due to increased demand



\$4.99
00:03



\$11.02
23:58

REQUEST UBERX



Tic-Tac-Toe



- Two players, *X* and *O*, take turns marking the spaces in a 3×3 grid
- The player who succeeds in placing three of their marks in a horizontal, vertical, or diagonal row wins the game

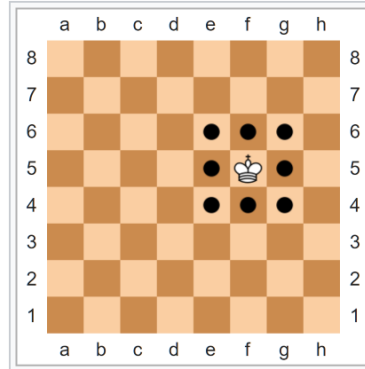
<https://en.wikipedia.org/wiki/Tic-tac-toe>

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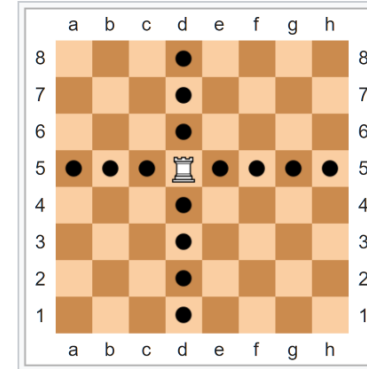
Chess



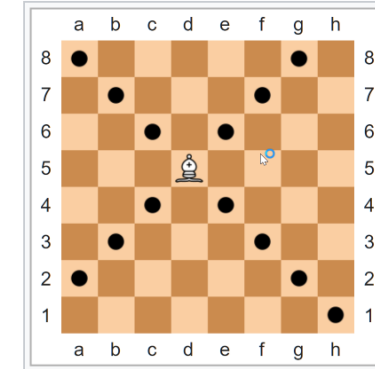
Moves of the **king**



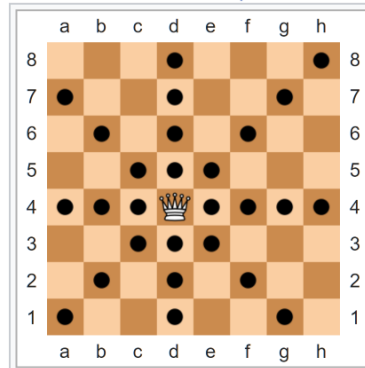
Moves of a **rook**



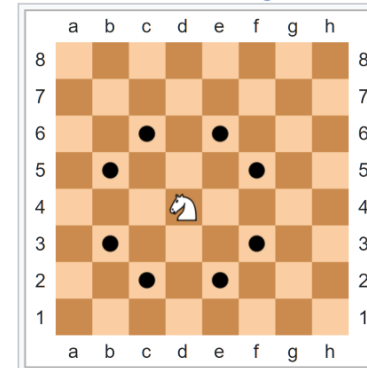
Moves of a **bishop**



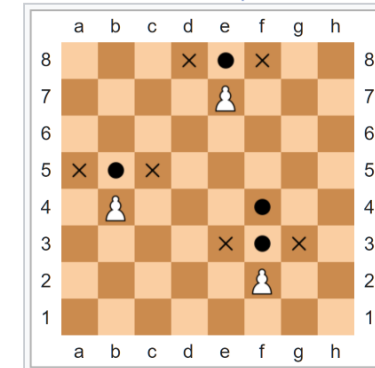
Moves of the **queen**



Moves of a **knight**



Moves of a **pawn**

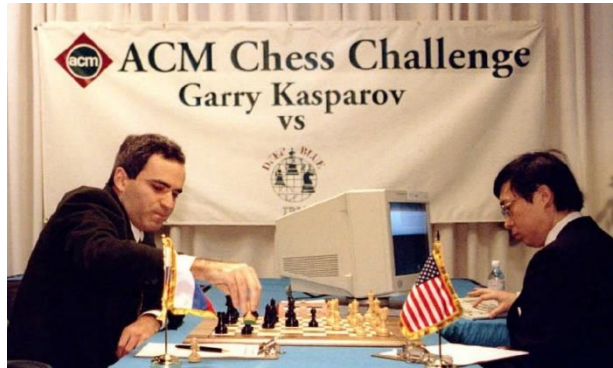


<https://en.wikipedia.org/wiki/Chess>

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Chess

Garry Kasparov vs Deep Blue (1996)



Result: Win-loss-draw-draw-draw-loss
(In even-numbered games, Deep Blue played white)



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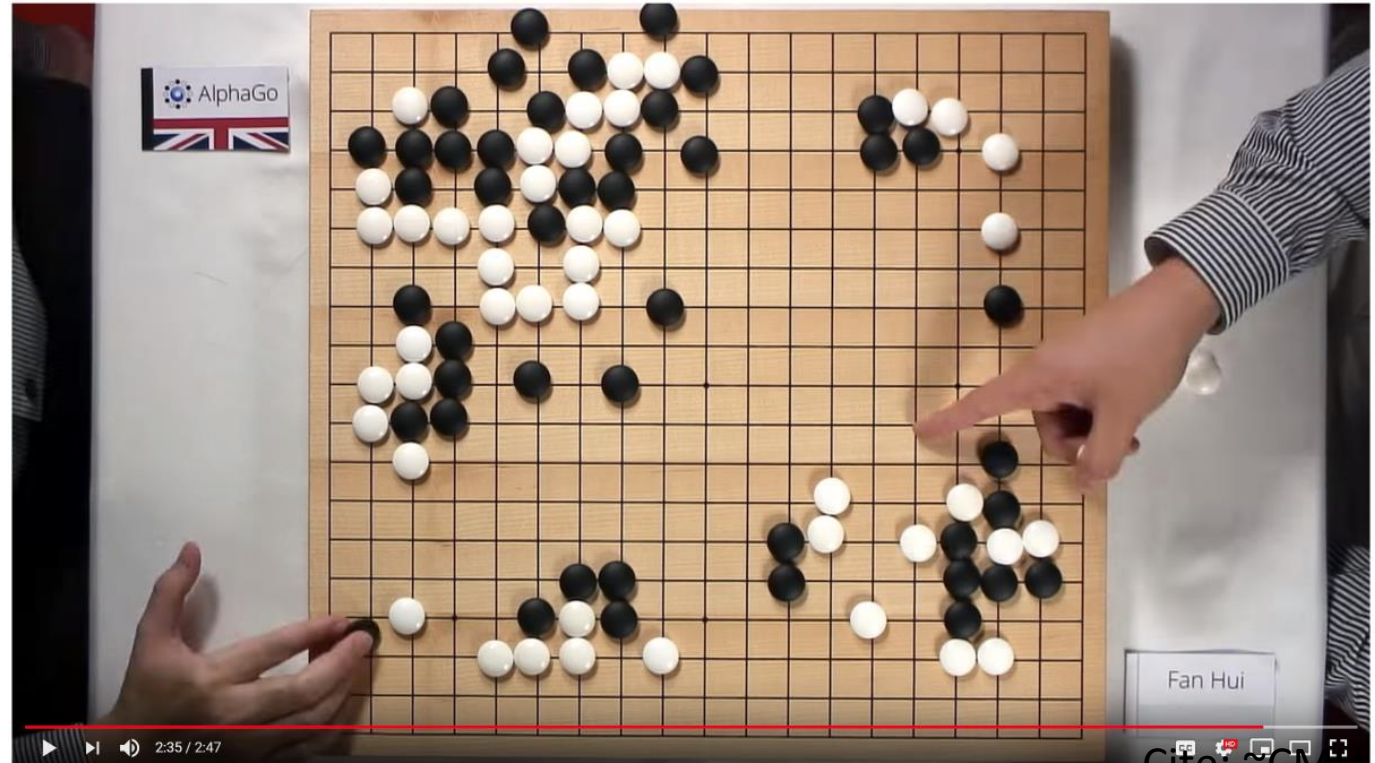
Chess



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Reading: Go

- DeepMind promotion video before the game with Lee Sedol
- **Backgammon:** Neural-net learning program **TDGammon one of world's top 3 players**



<https://www.youtube.com/watch?v=SUBqykXVx0A>

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Reading: Go

Good places to learn more:

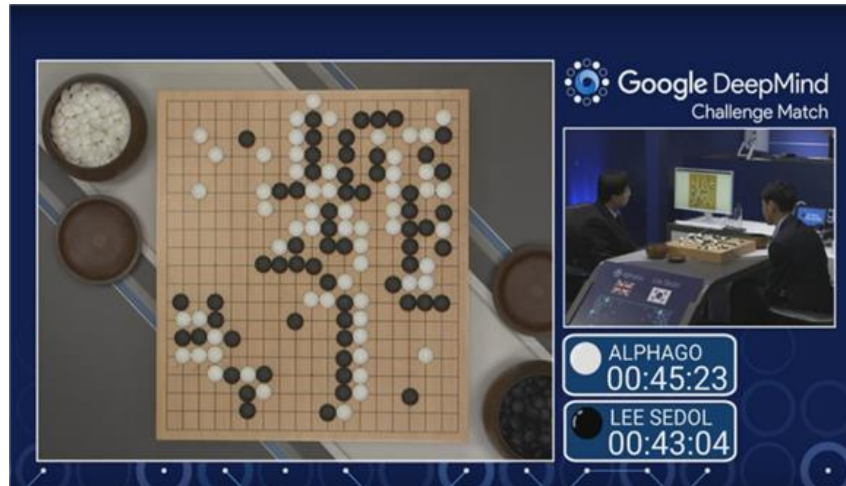
<http://www.cs.ualberta.ca/~games/>

<http://www.cs.unimass.nl/icga>

AlphaGo: <https://www.nature.com/articles/nature16961.pdf>

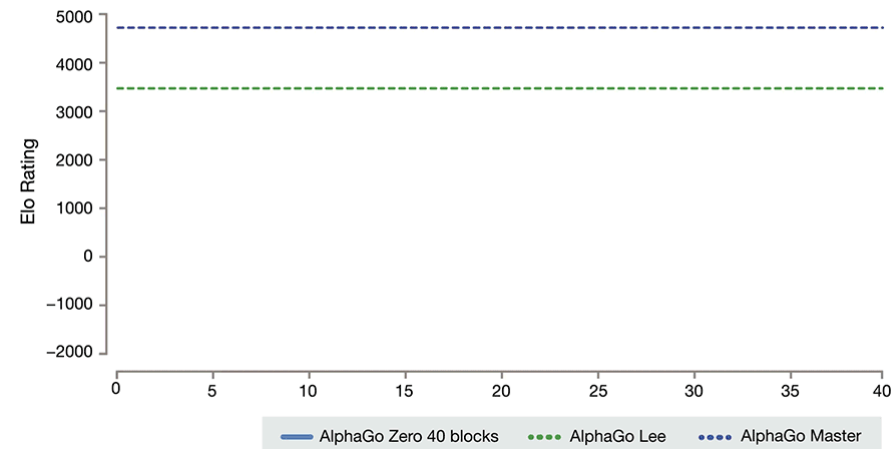
AlphaZero: www.nature.com/articles/nature24270.pdf

AlphaGo vs Lee Sedol (3/2016)



Result: win-win-win-loss-win

AlphaZero vs AlphaGo (2017)



<https://deepmind.com/blog/alphago-zero-learning-scratch/>

Result: 100-0

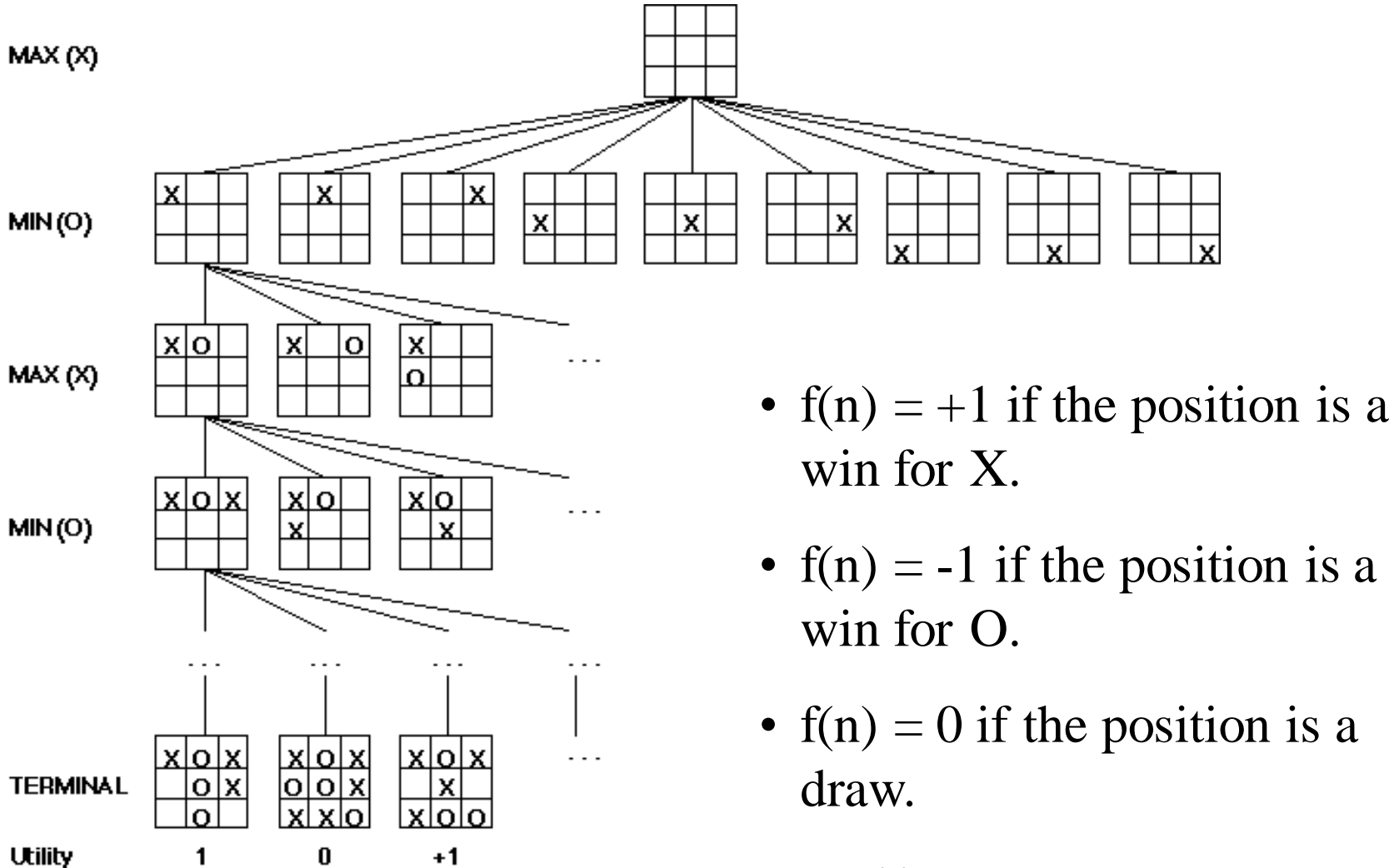
Typical case

- 2-person game
- Players alternate moves
- **Zero-sum**: one player's loss is the other's gain
- **Perfect information**: both players have access to complete information about the state of the game. No information is hidden from either player.
- No chance (e.g., using dice) involved
- Examples: Tic-Tac-Toe, Checkers, Chess, Go, Nim, Othello
- Not: Bridge, Solitaire, ...

Game representation

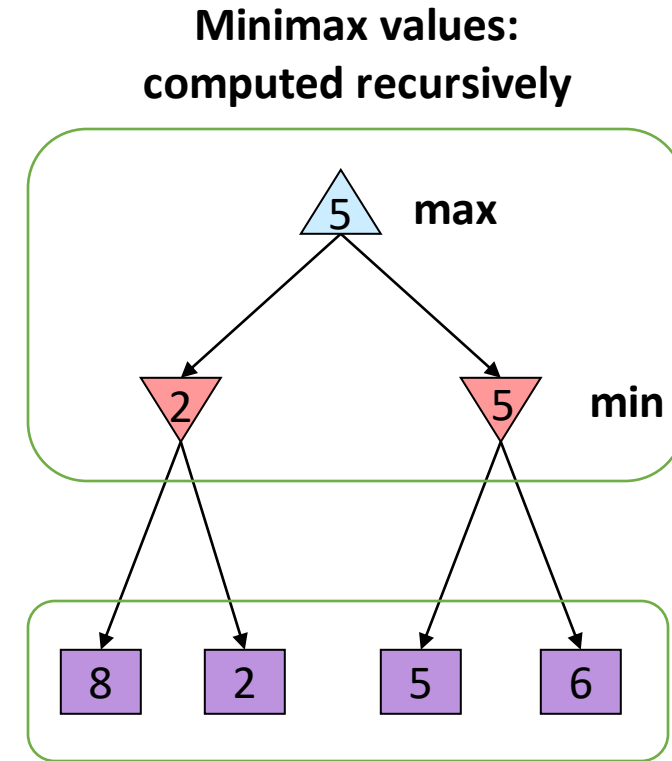
- Initial state
 - Current board position (description of current game state)
- Operators
 - Legal moves a player can make
- Terminal nodes
 - Leaf nodes in the tree
 - Indicate the game is over
- Utility function
 - Payoff function
 - Value of the outcome of a game
 - Example: tic tac toe, utility is -1, 0, or 1

Partial Game Tree for Tic-Tac-Toe

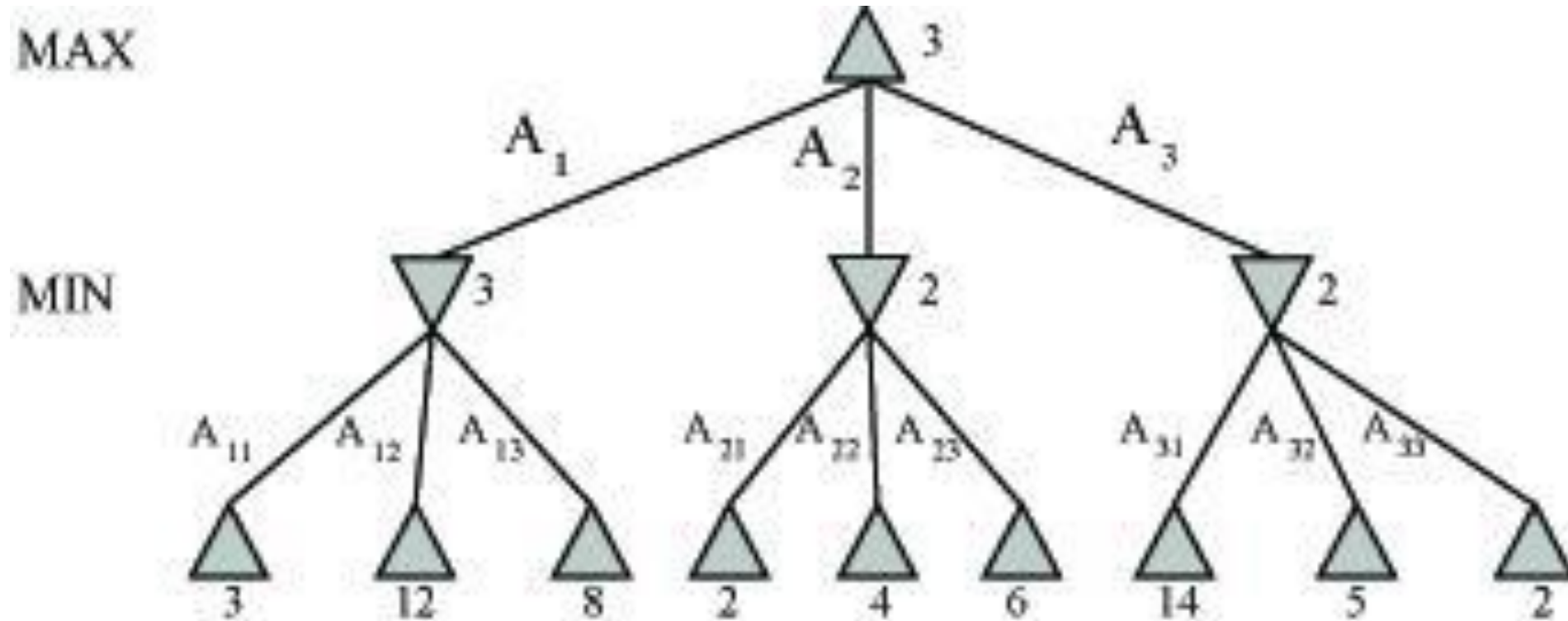


Adversarial Search (Minimax)

- Minimax search:
 - A state-space search tree
 - Players alternate turns
 - Compute each node's **minimax value**: the best achievable utility against a rational (optimal) adversary

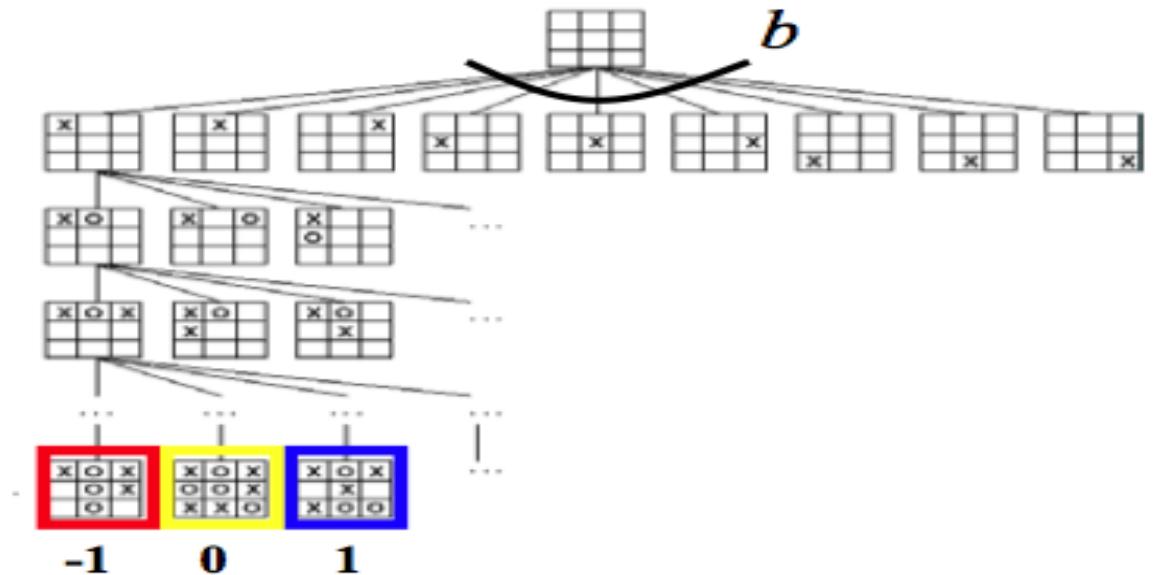


Minimax Example

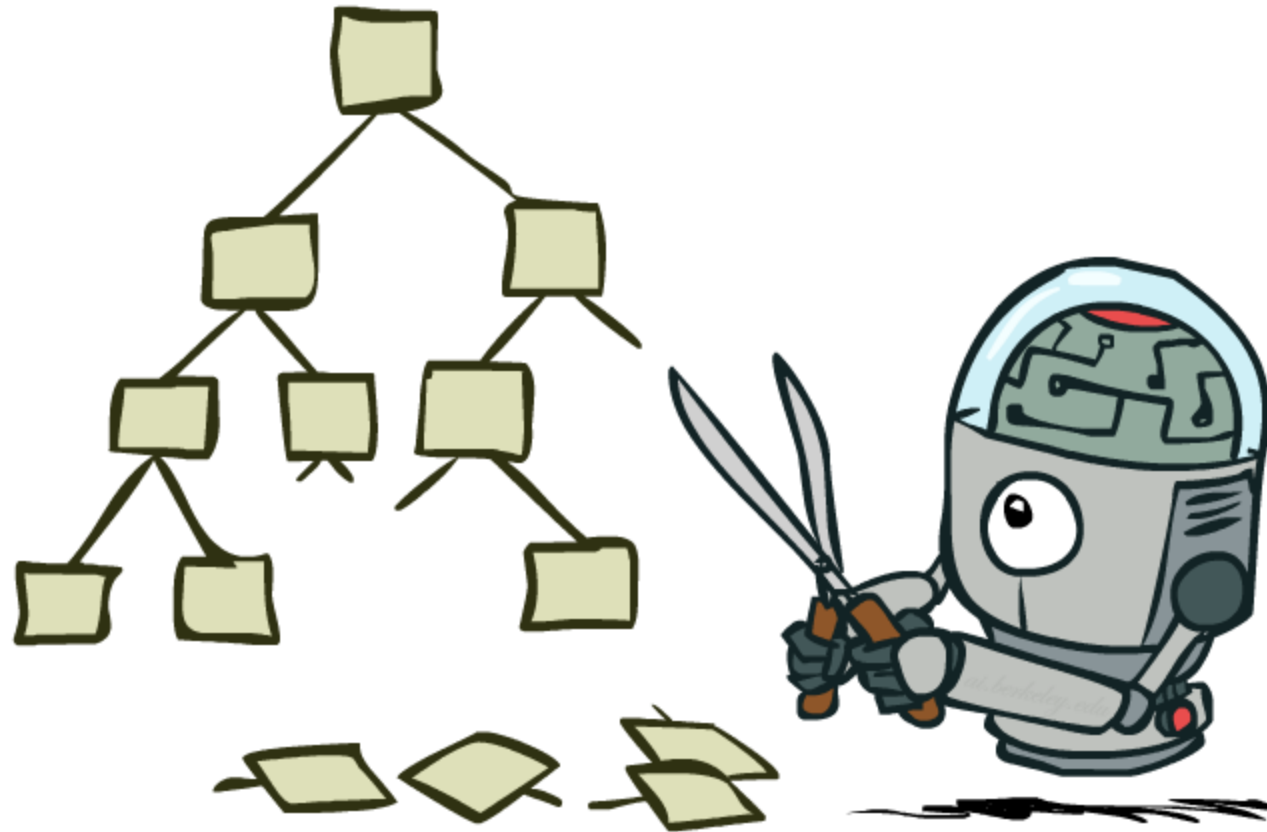


Minimax Efficiency

- How efficient is minimax?
 - Just like (exhaustive) DFS
 - Time: $O(b^m)$
 - Space: $O(bm)$
- Example: For chess, $b \approx 35$, $m \approx 100$
 - Exact solution is completely infeasible
 - But, do we need to explore the whole tree?

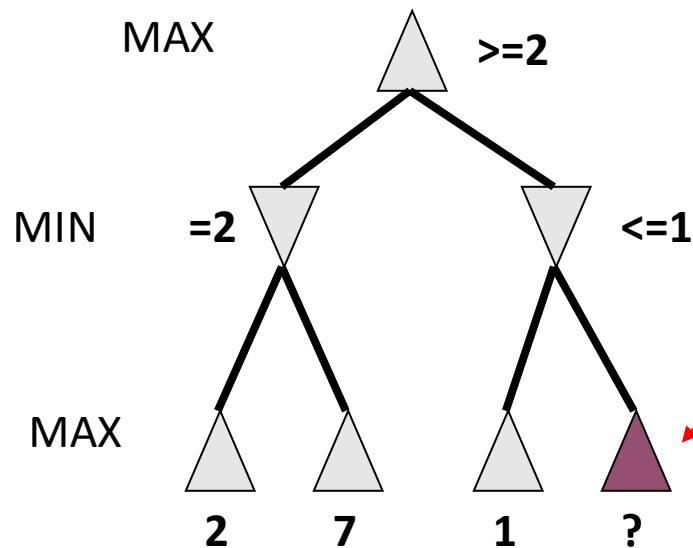


Game Tree Pruning



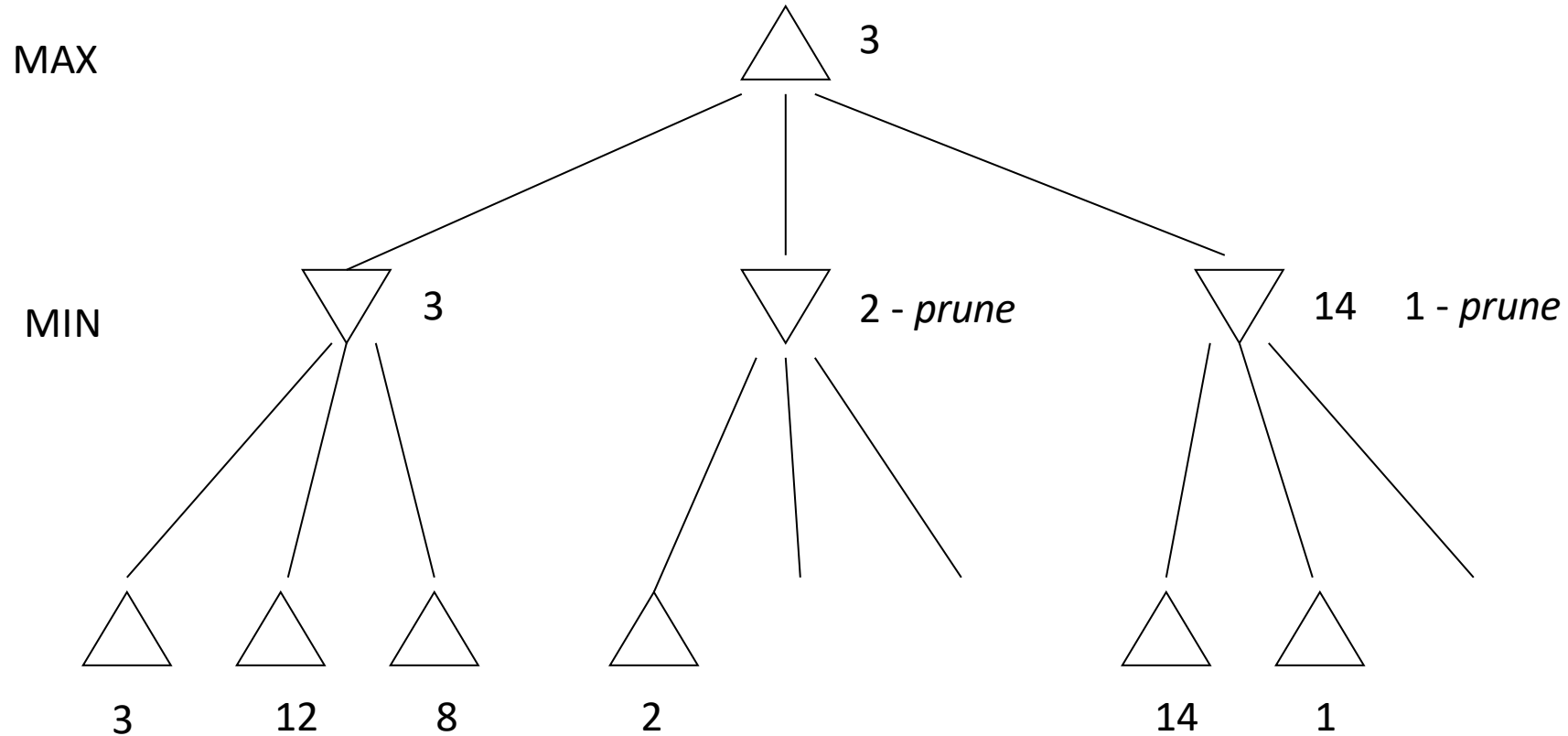
Alpha-beta pruning

- We can improve on the performance of the minimax algorithm through **alpha-beta pruning**
- Basic idea: *“If you have an idea that is surely bad, don't take the time to see how truly awful it is.”* -- Pat Winston

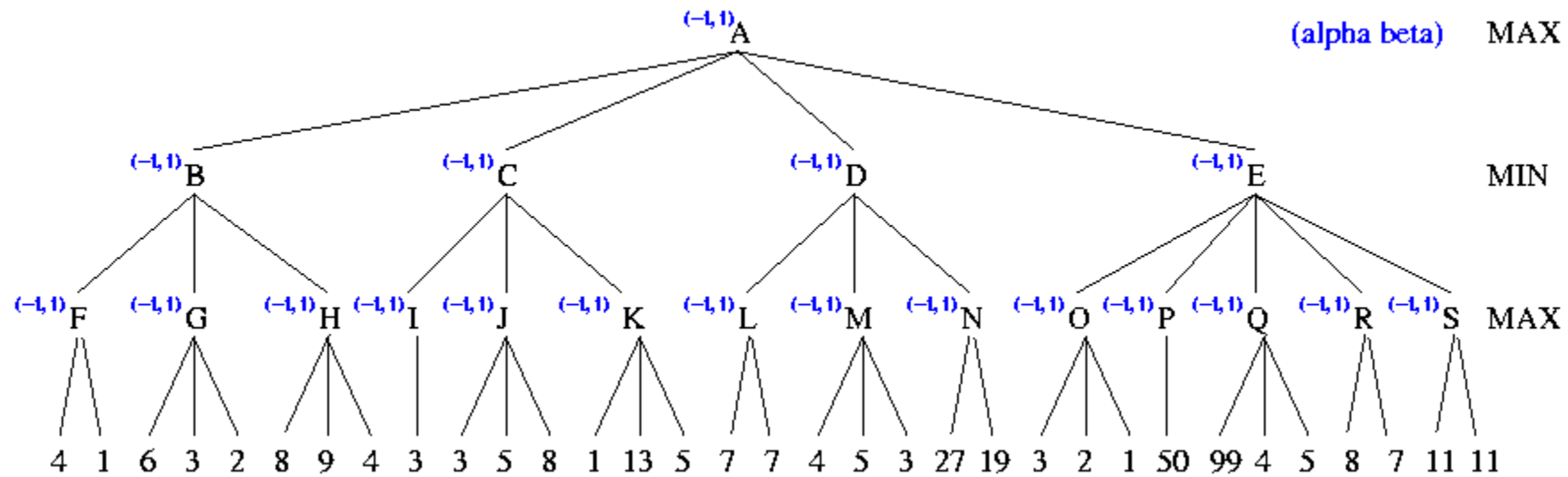


- We don't need to compute the value at this node.
- No matter what it is, it can't affect the value of the root node.

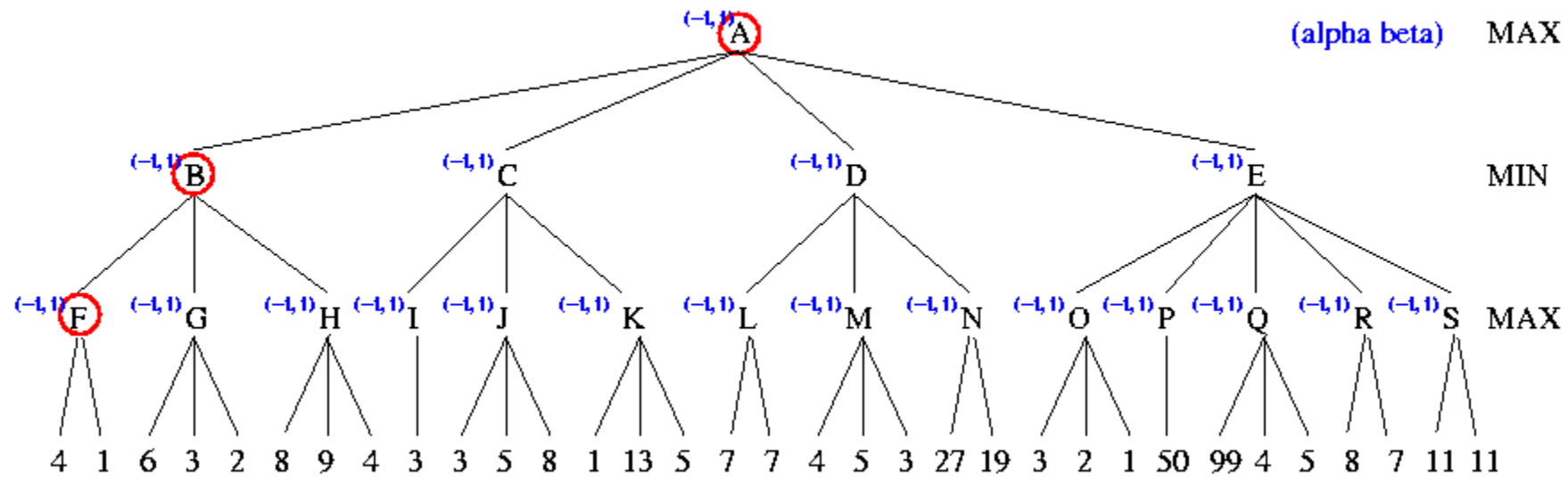
Alpha-beta example



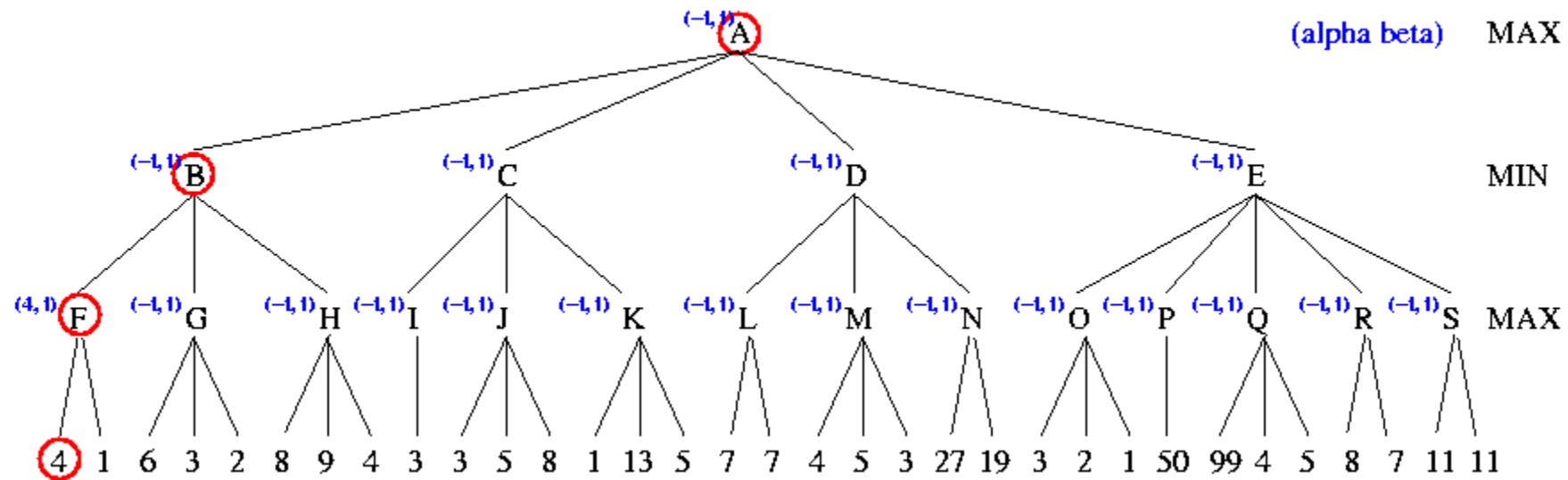
Example



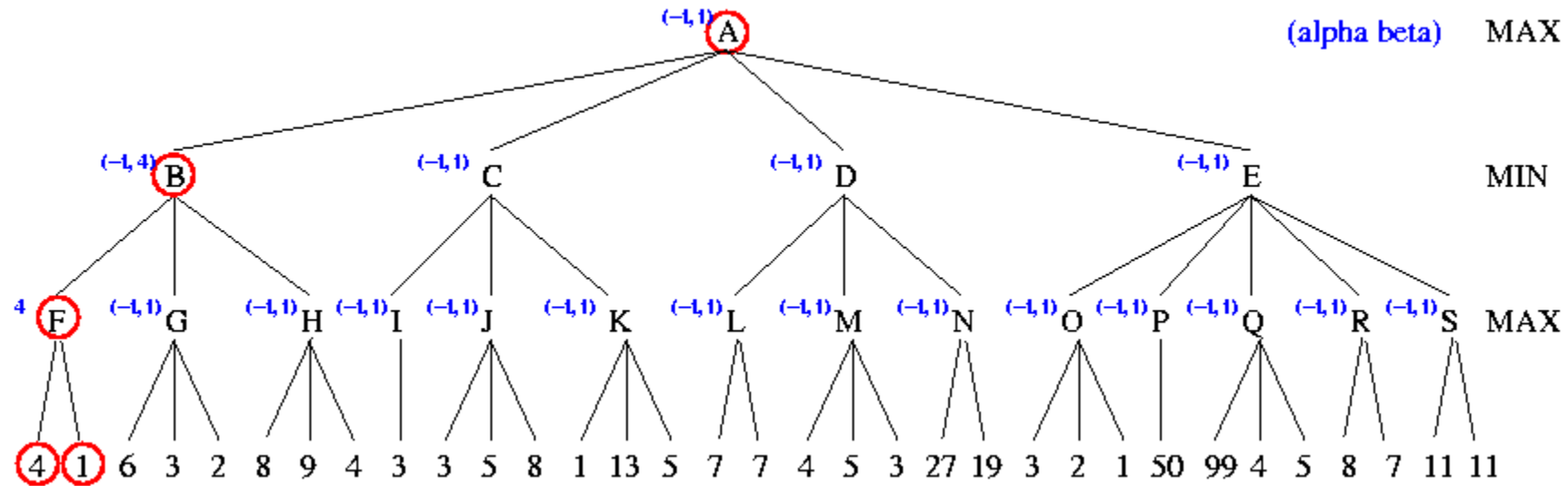
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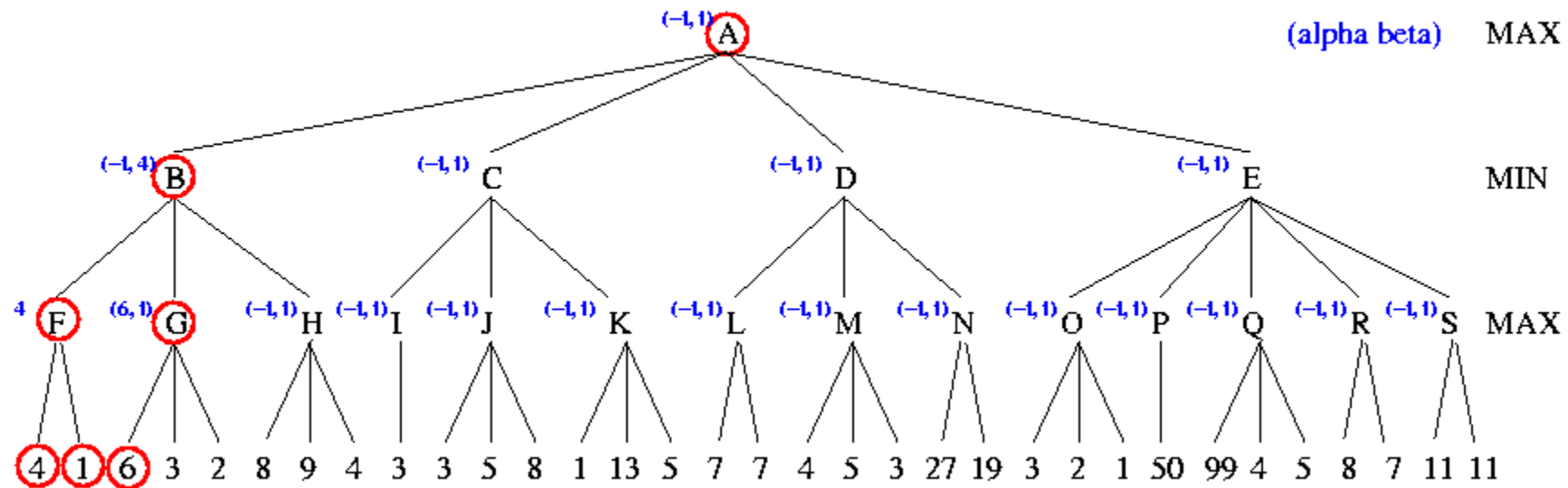
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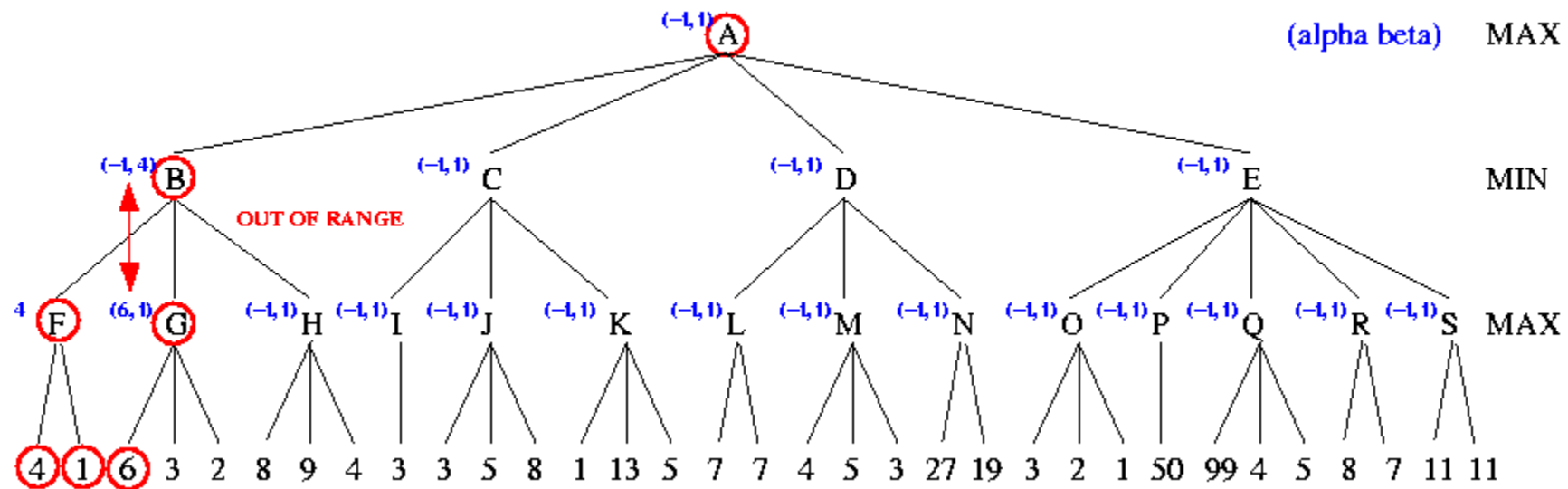
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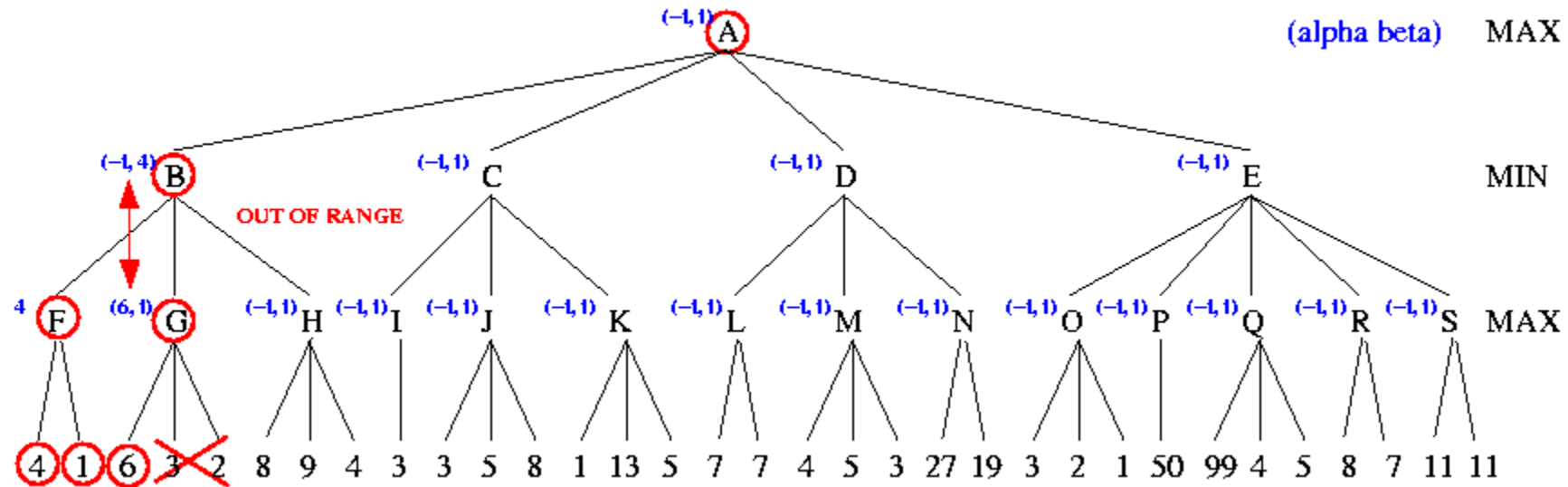
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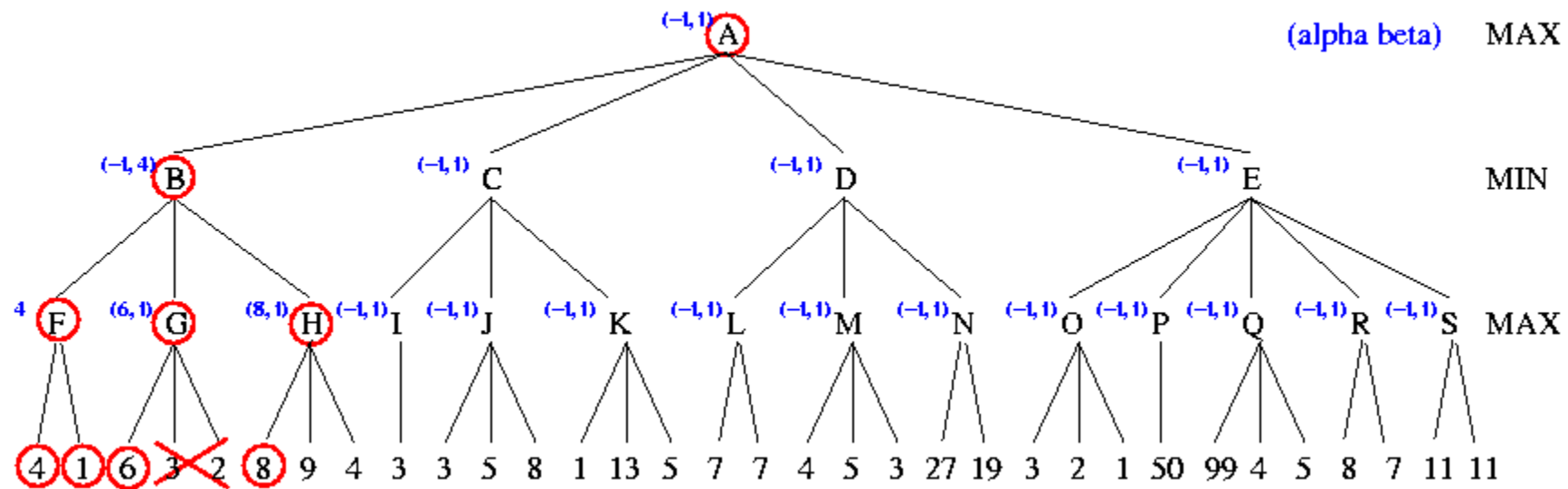
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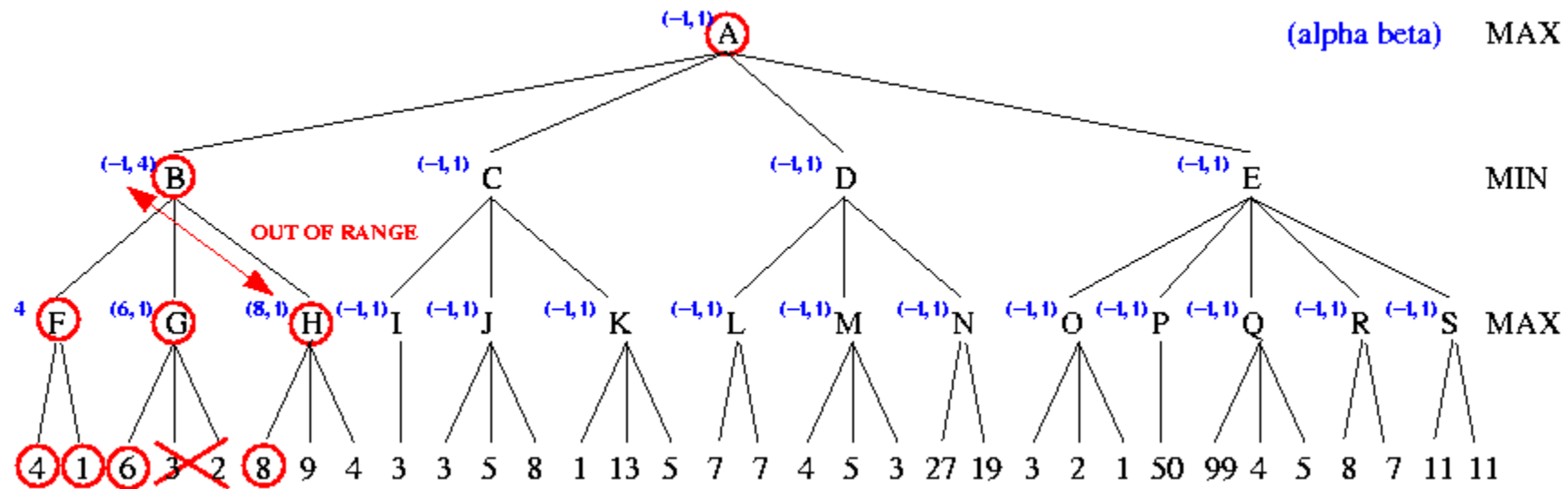
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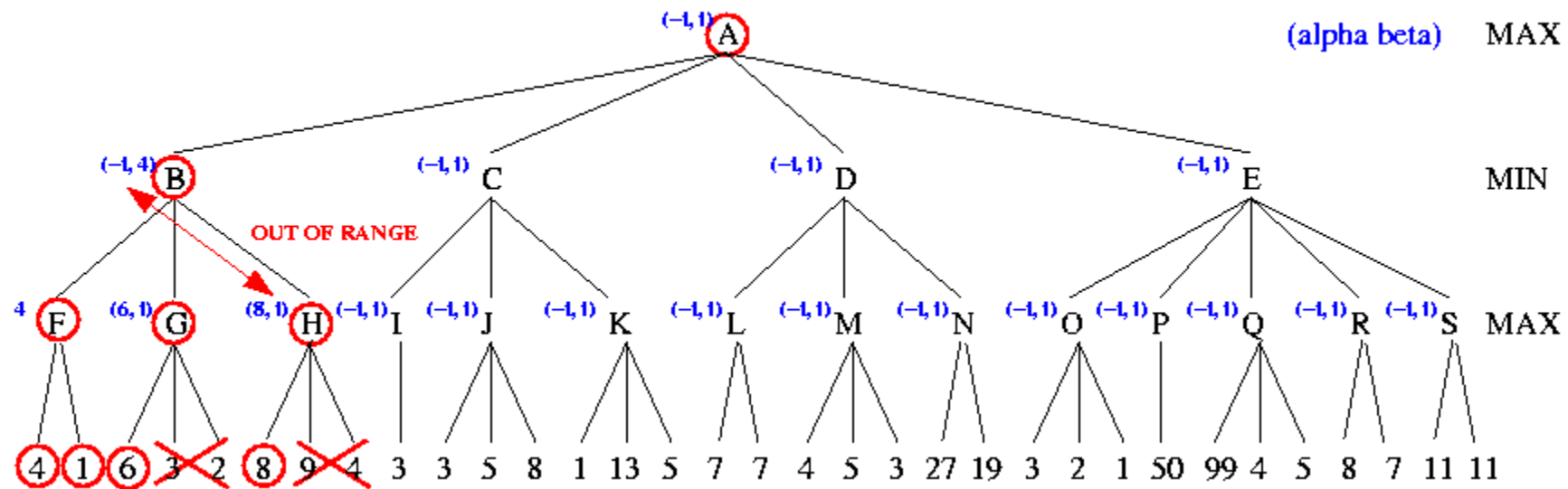
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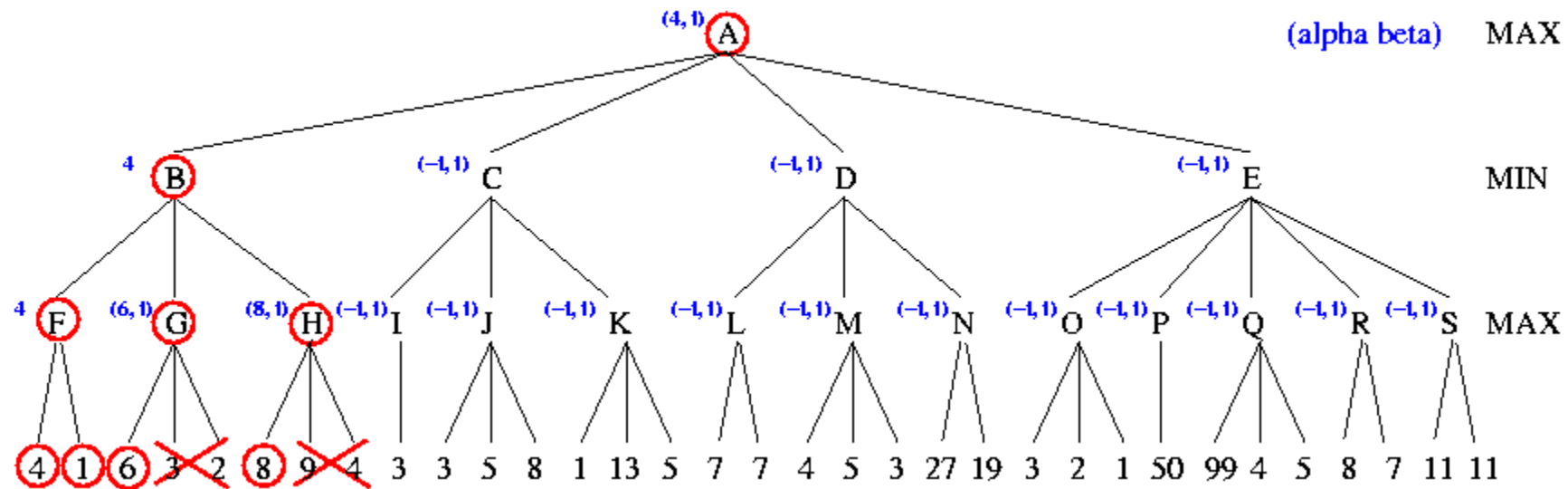
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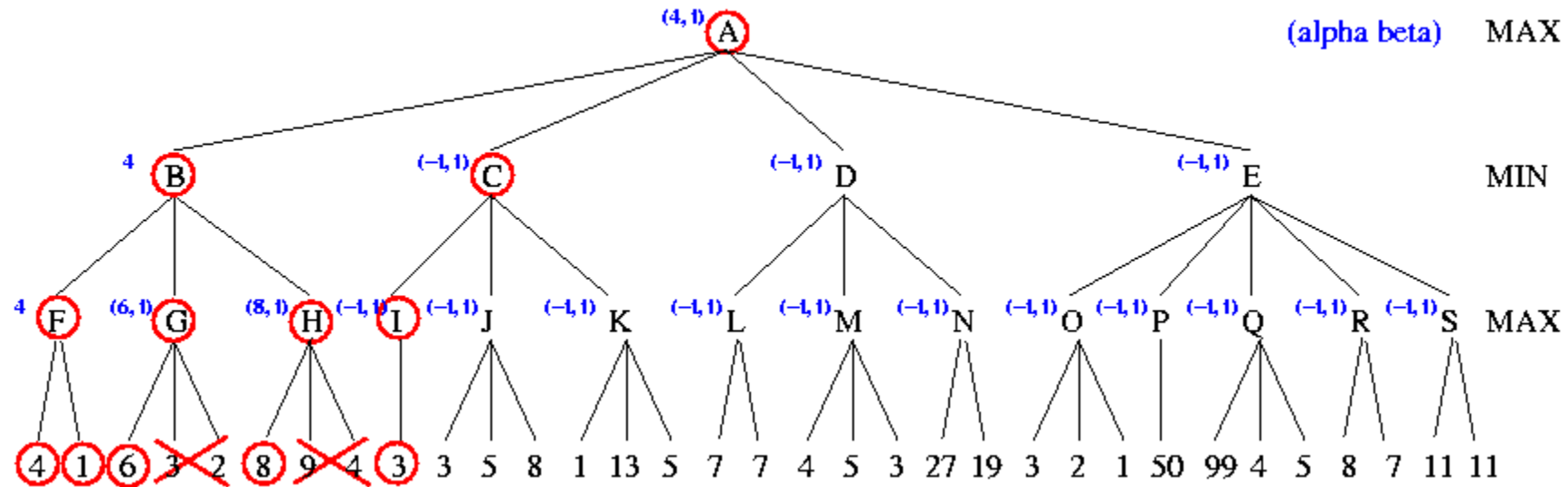
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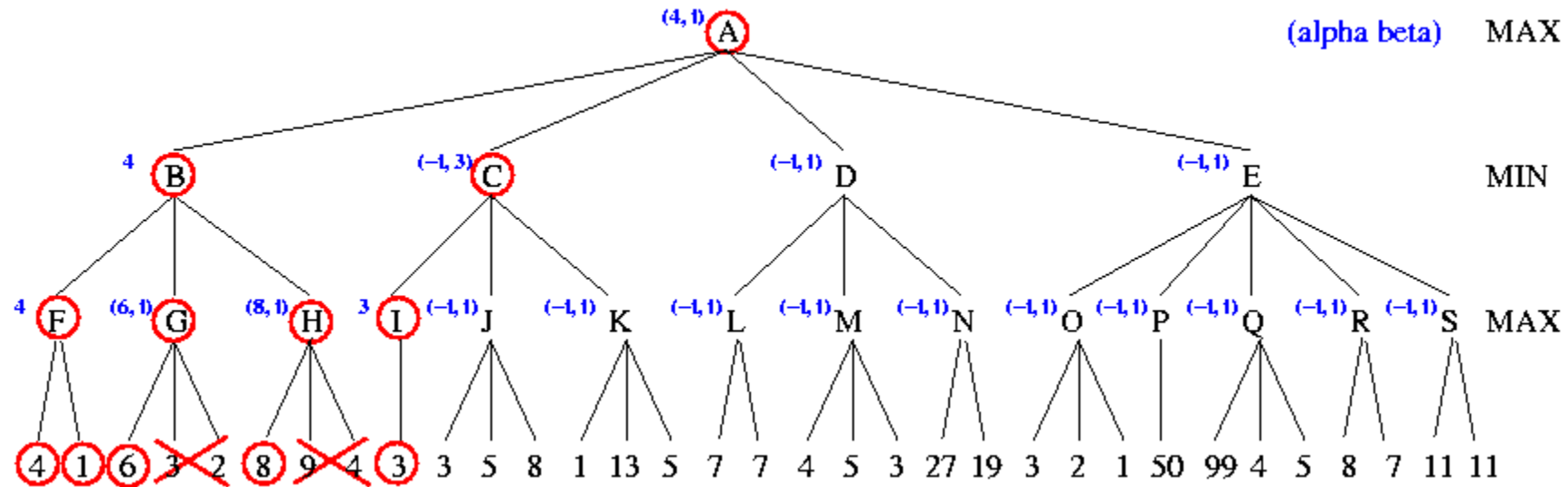
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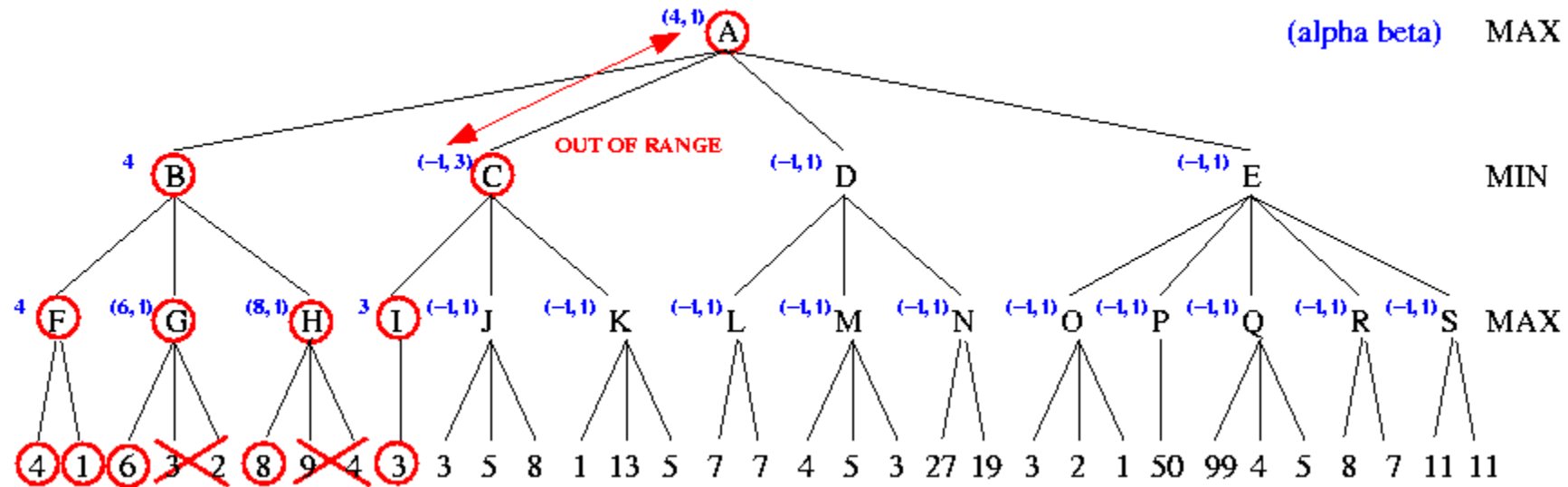
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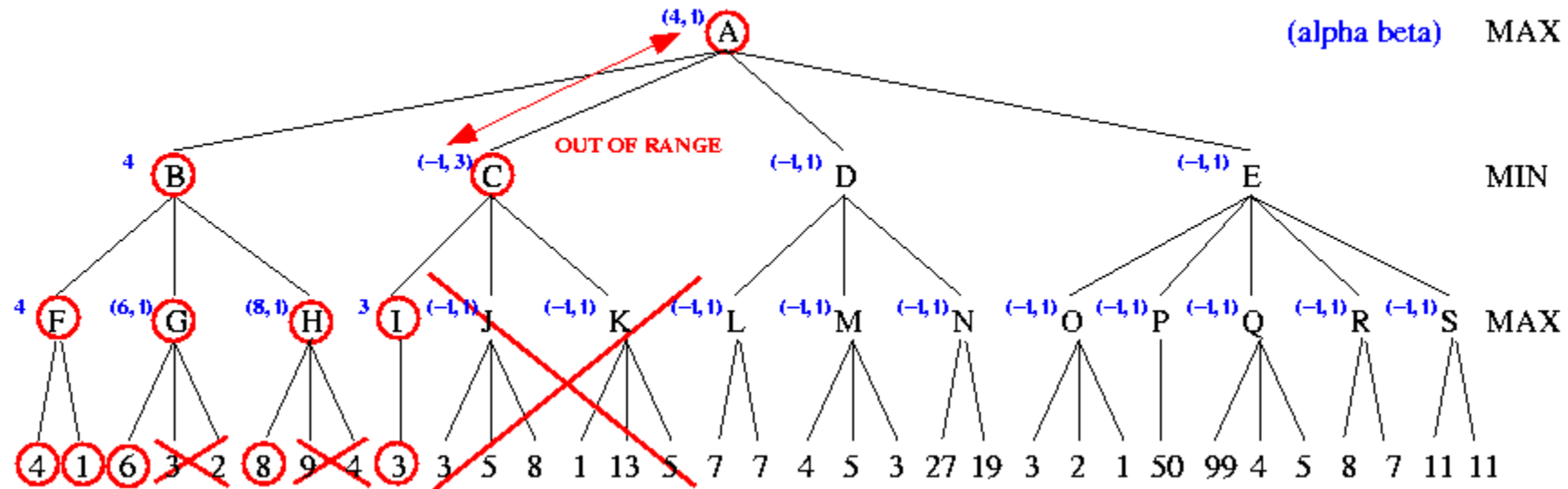
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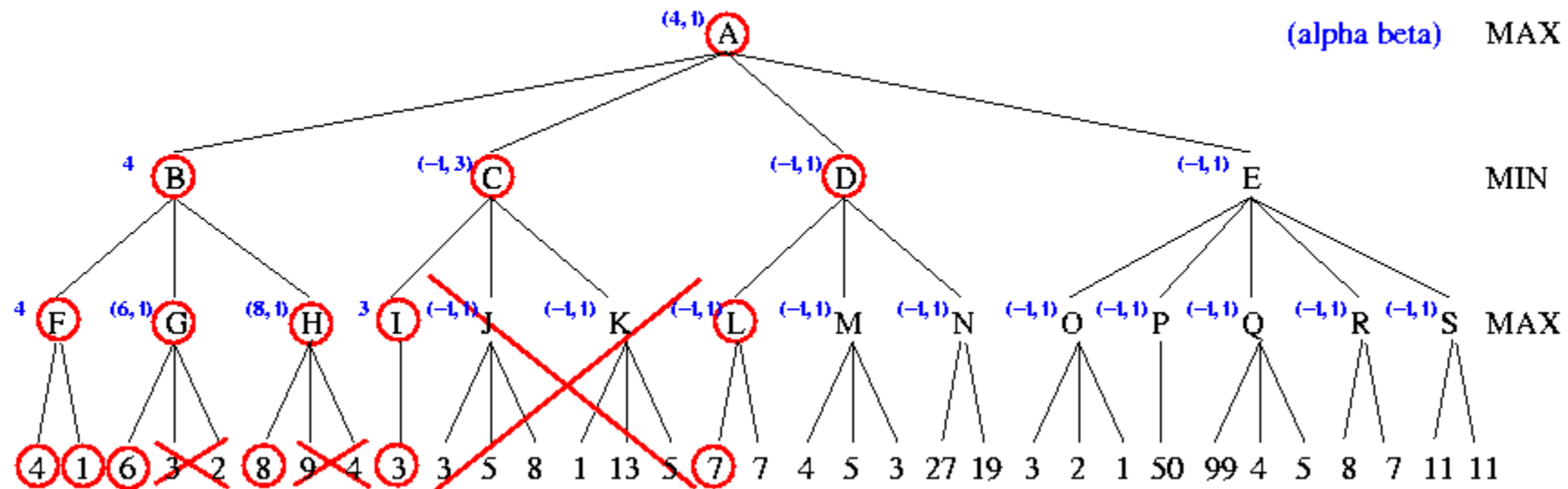
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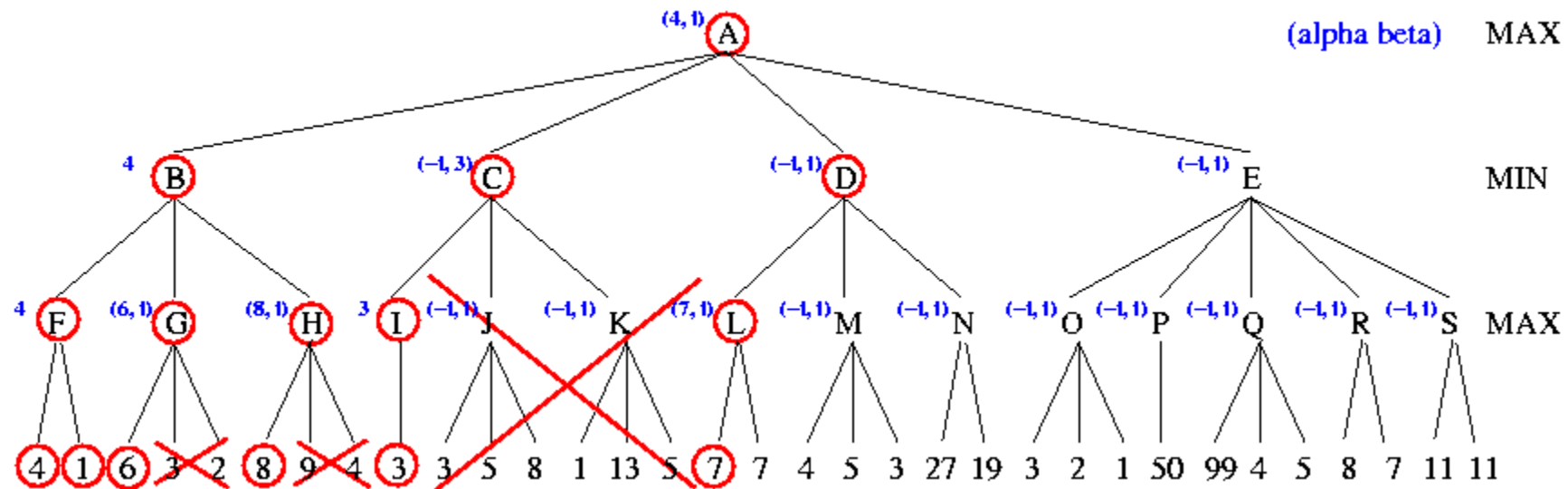
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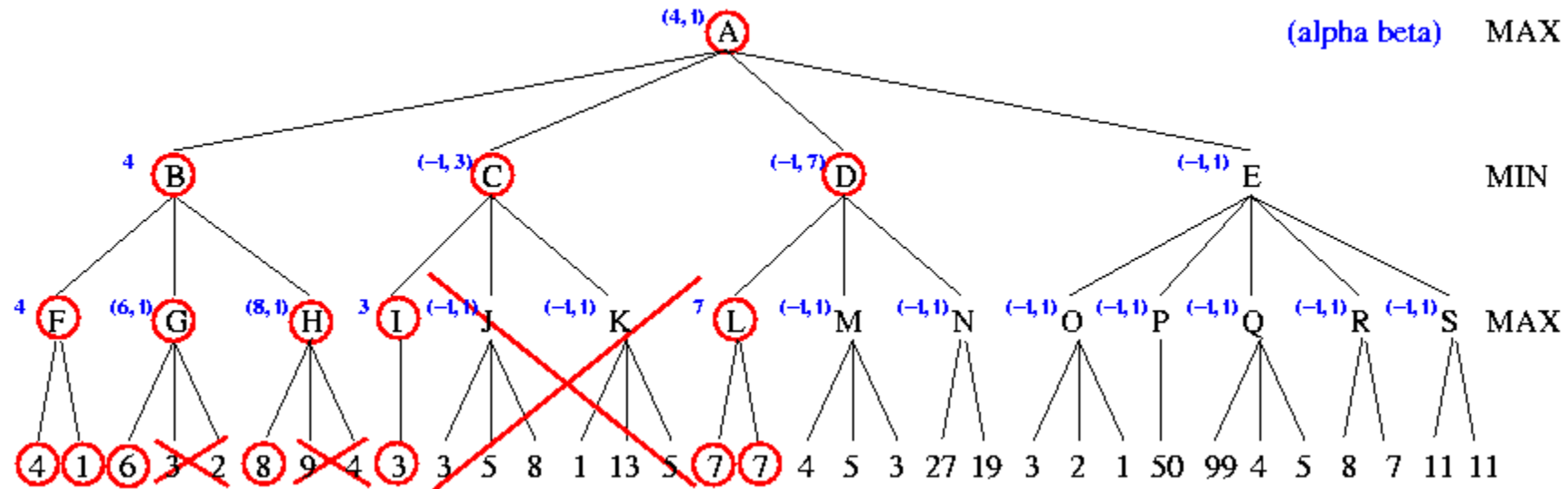
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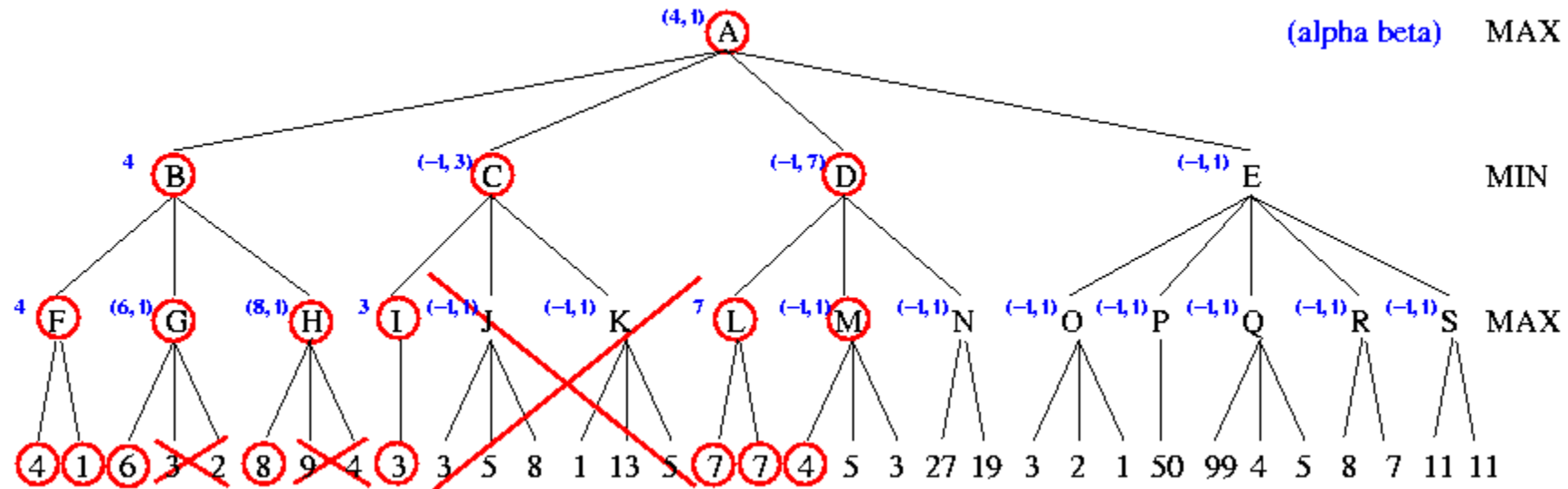
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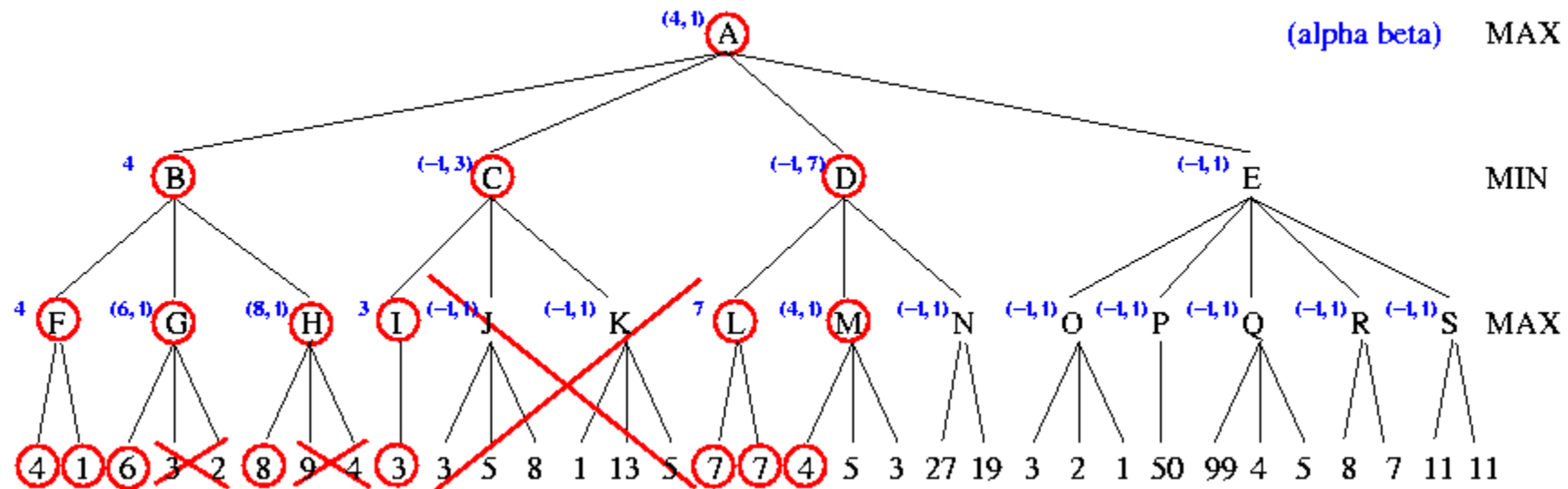
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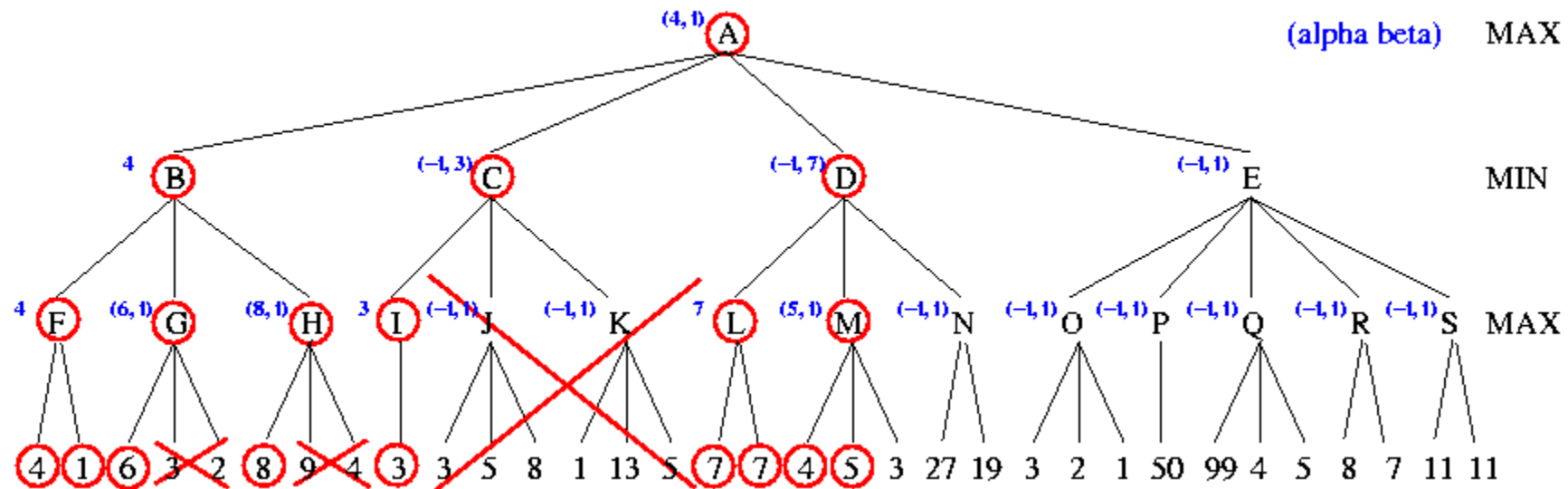
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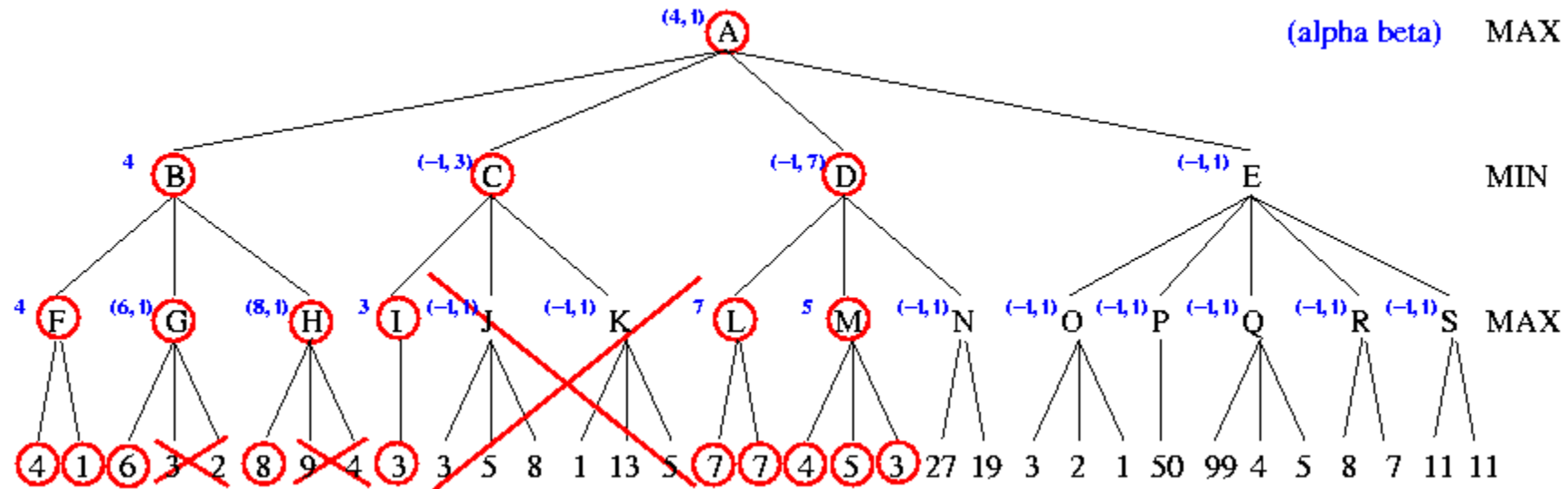
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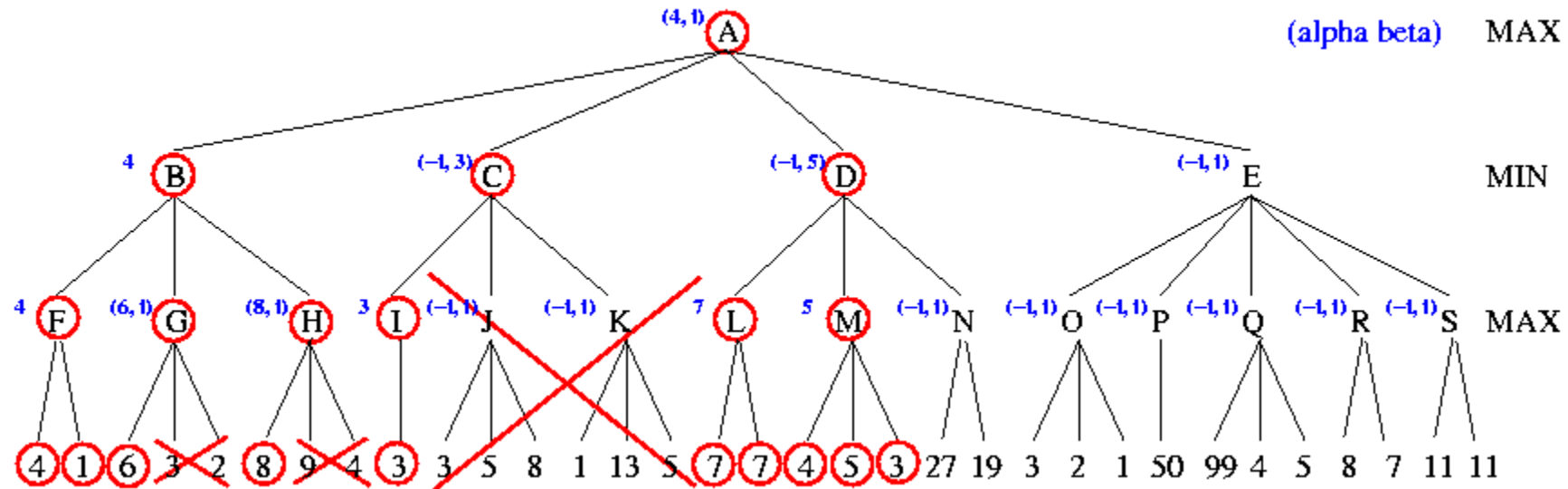
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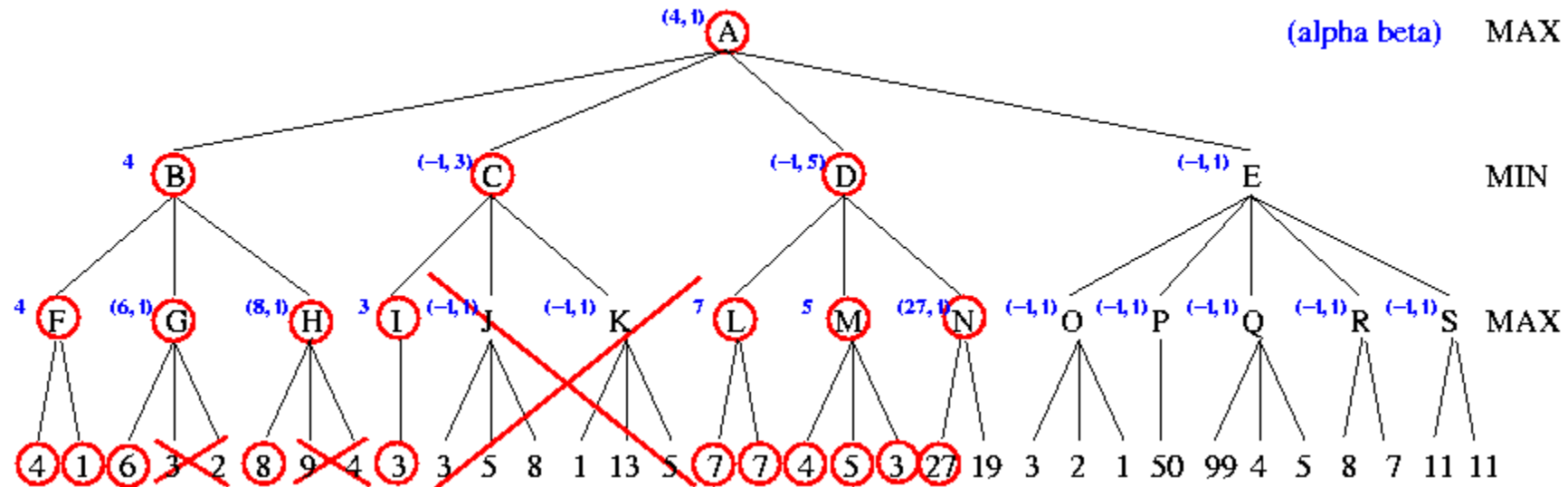
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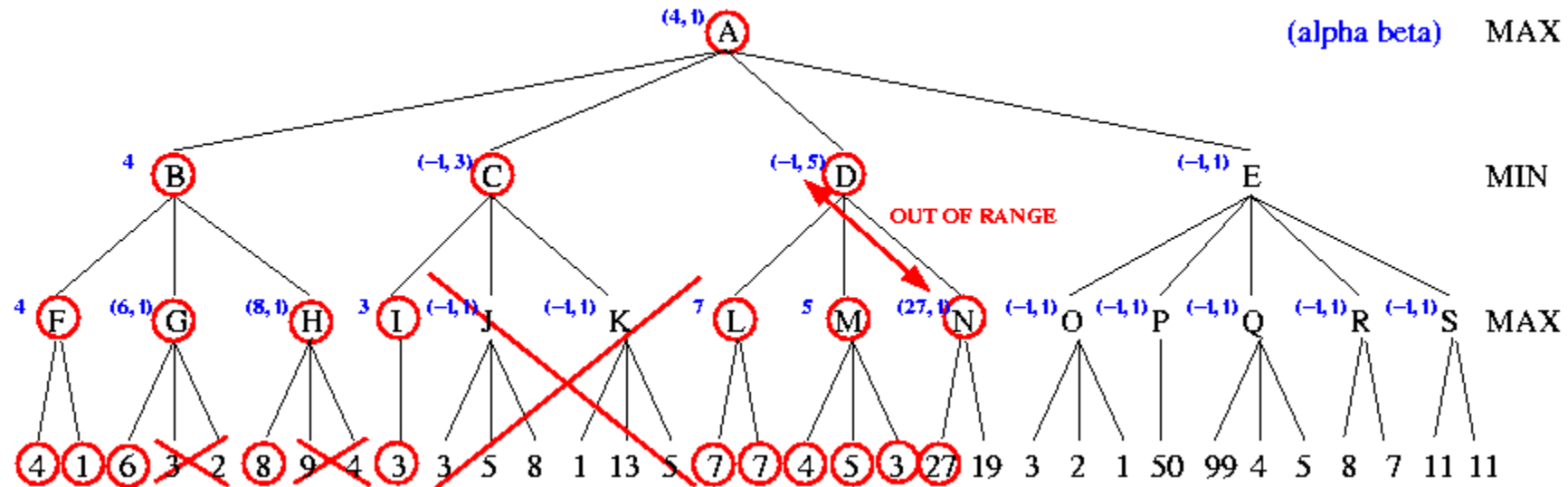
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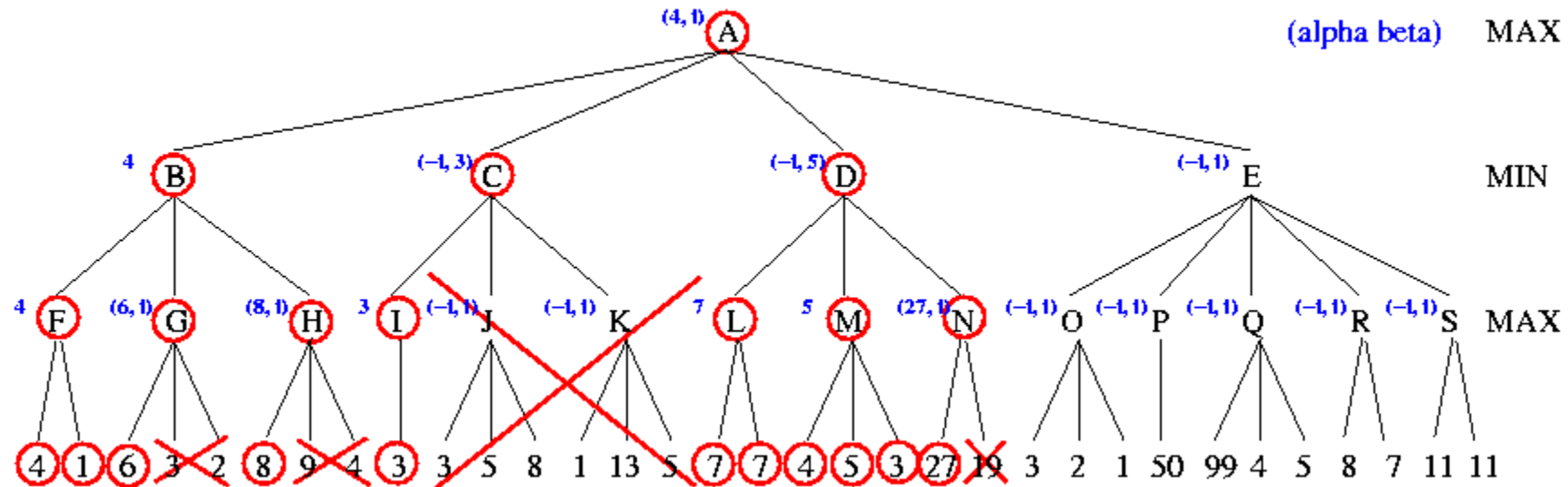
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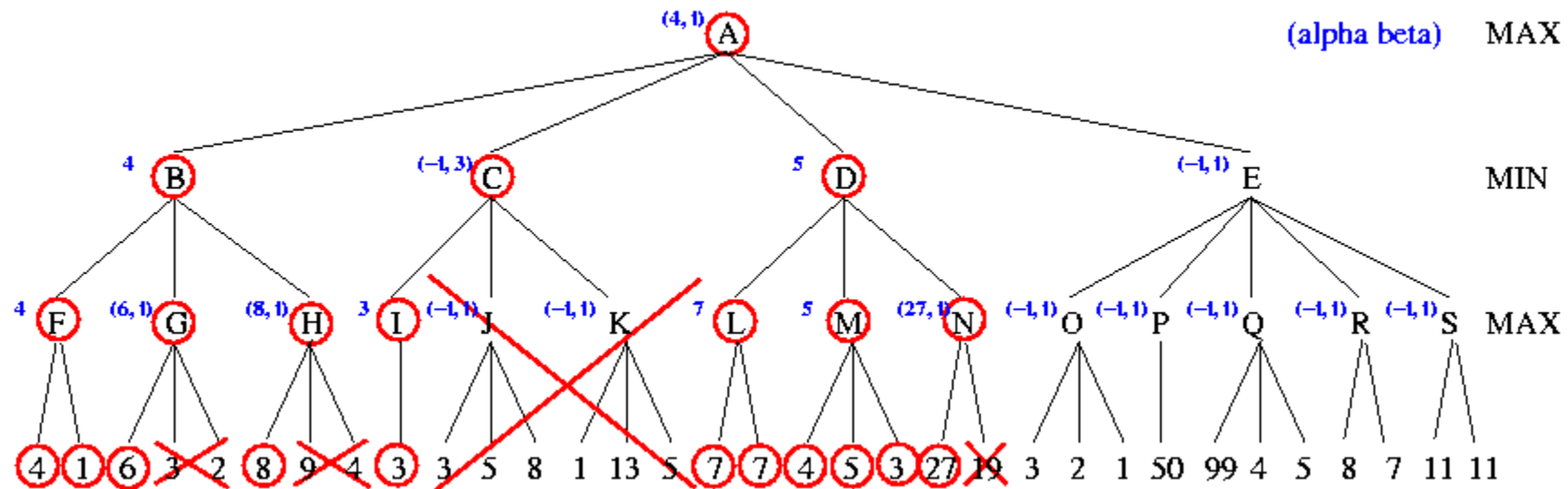
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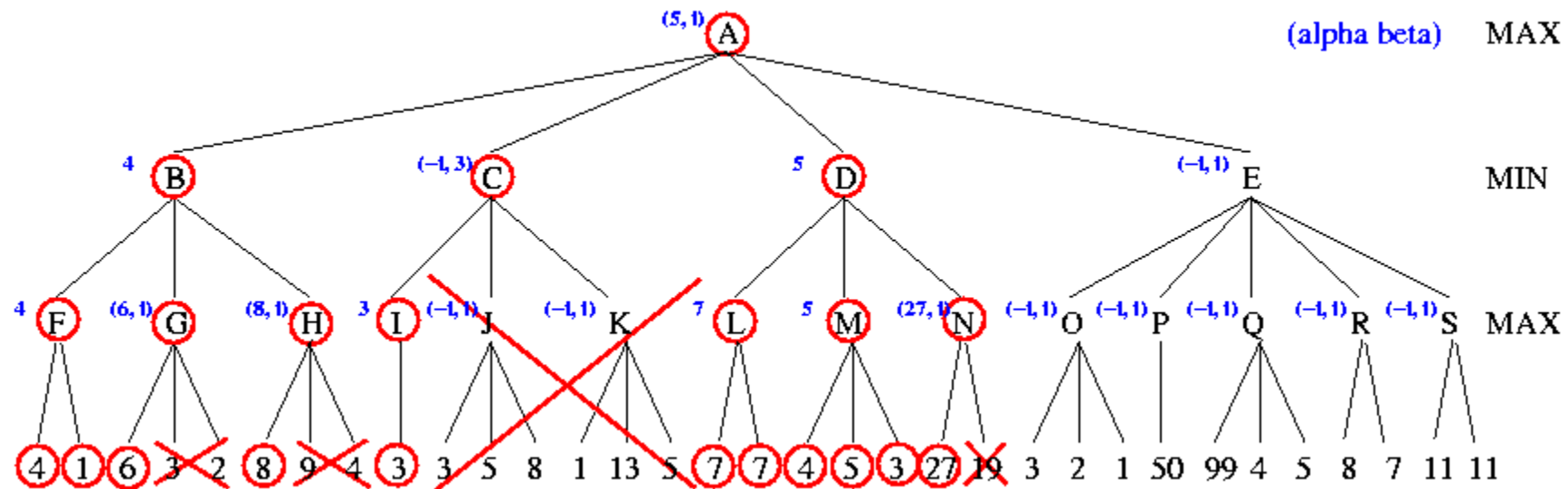
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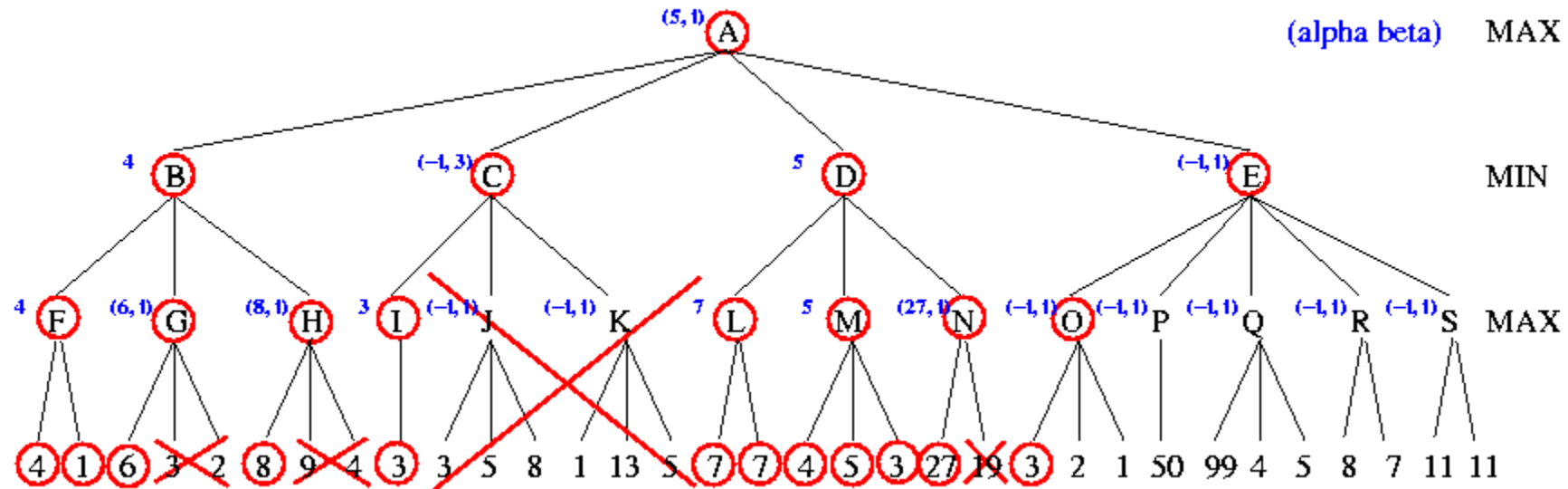
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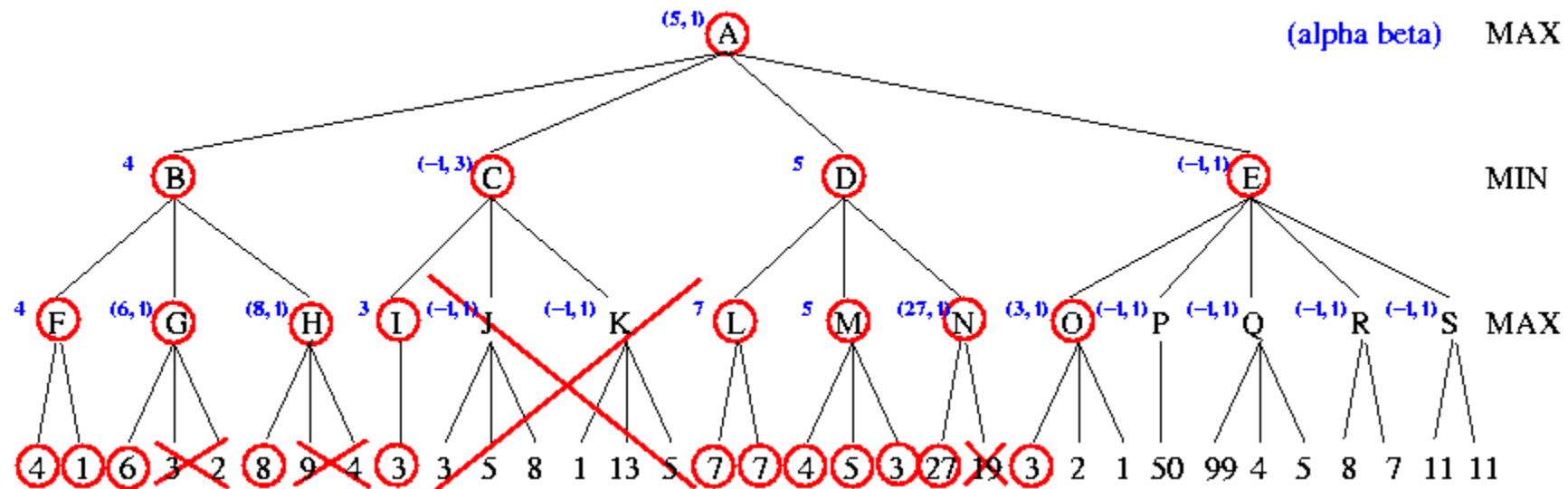
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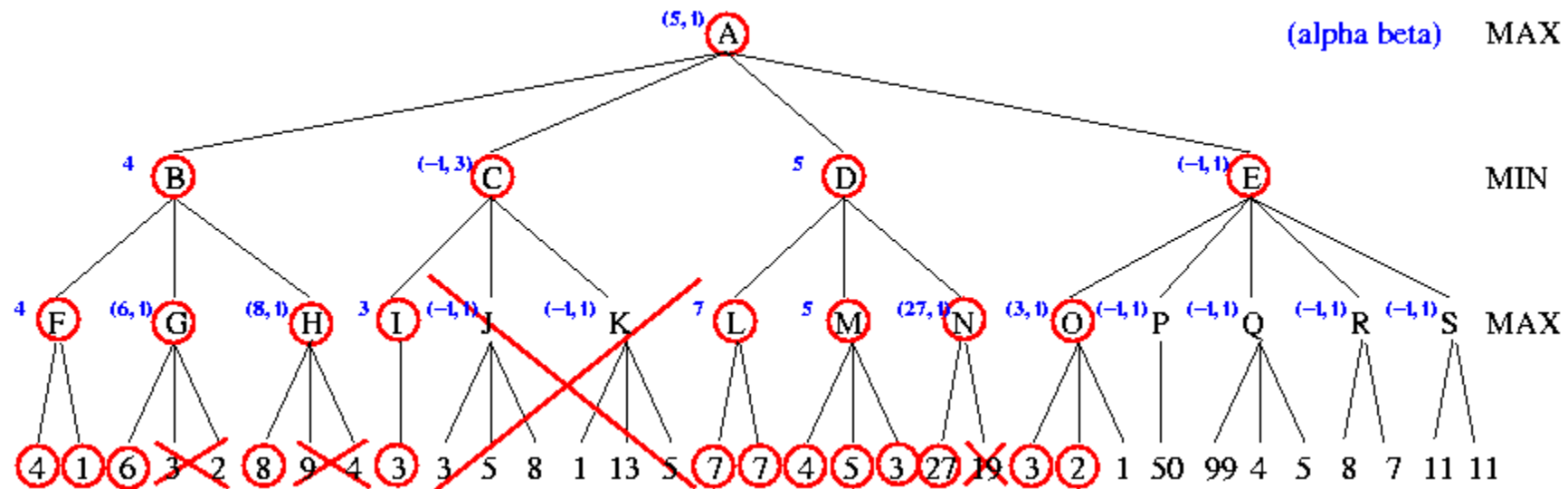
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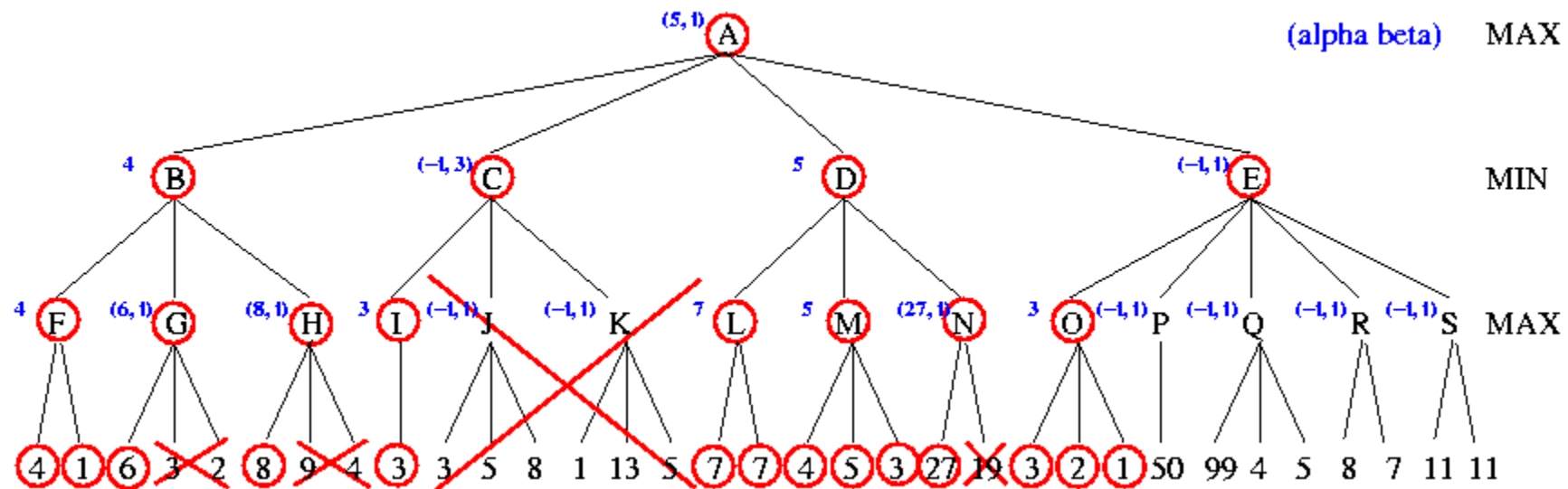
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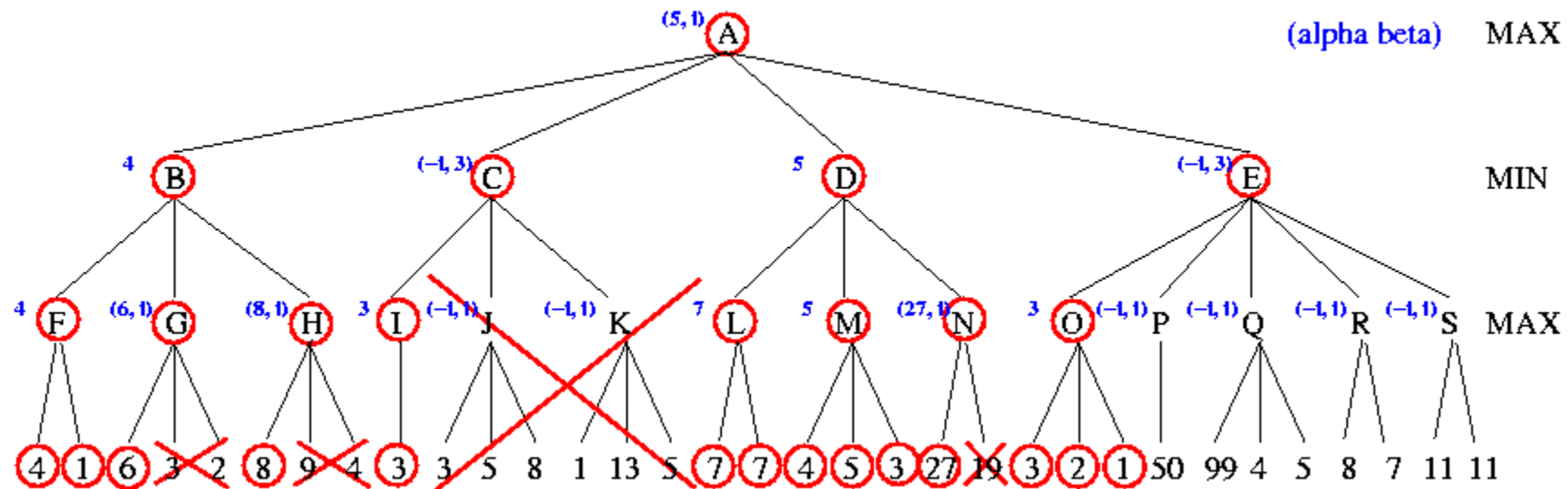
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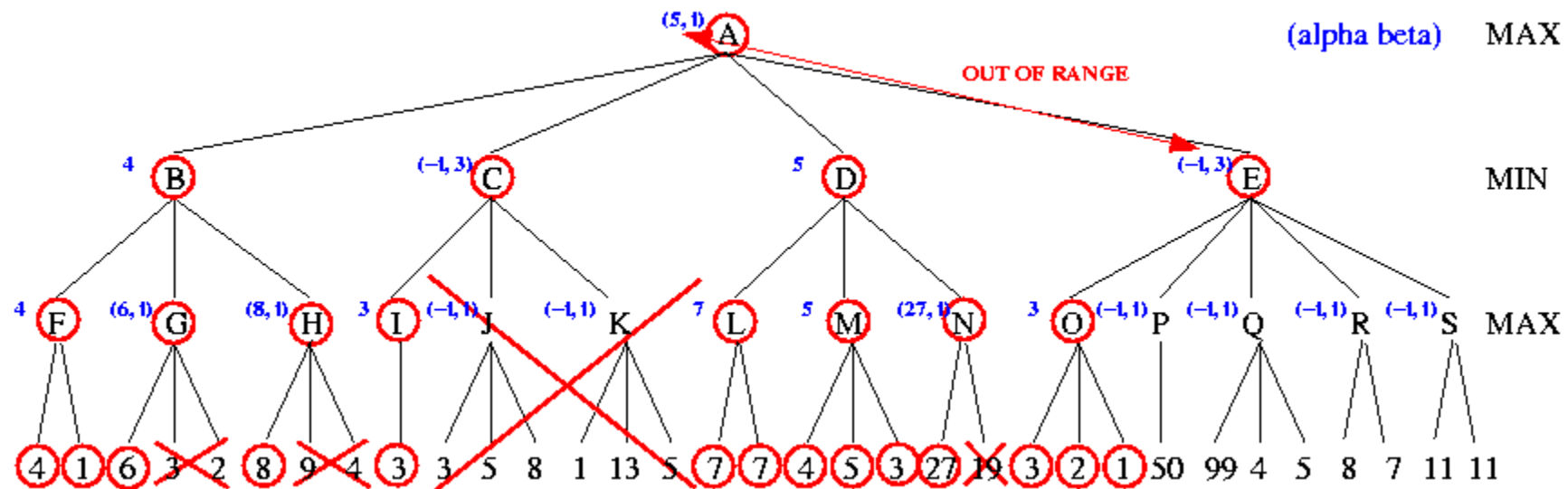
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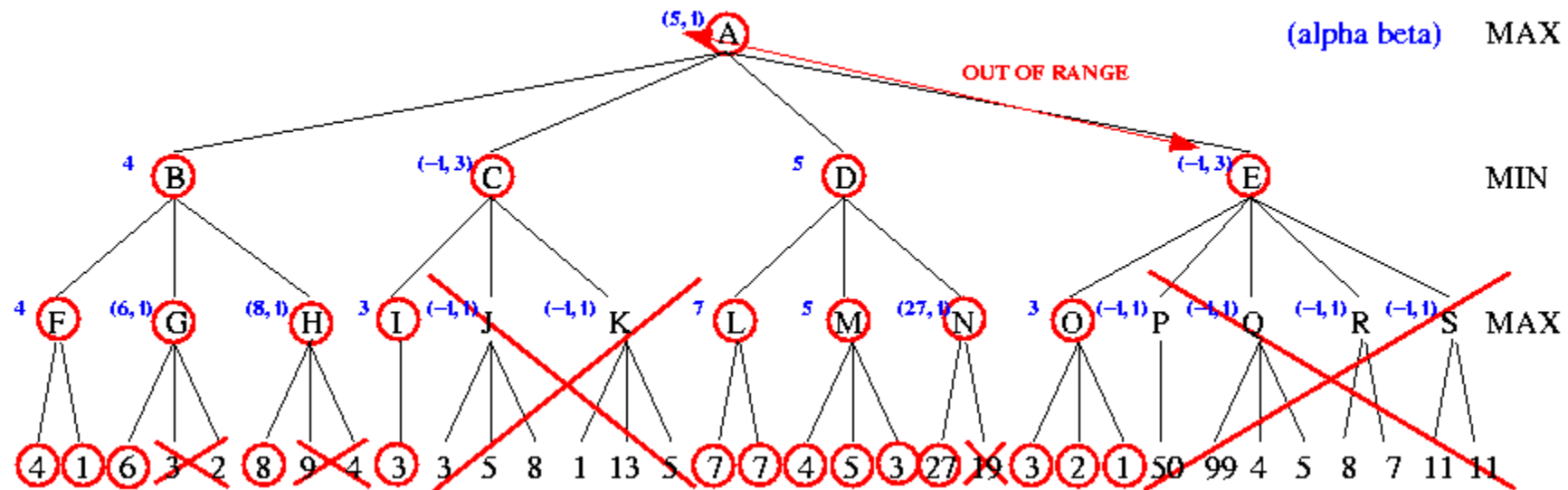
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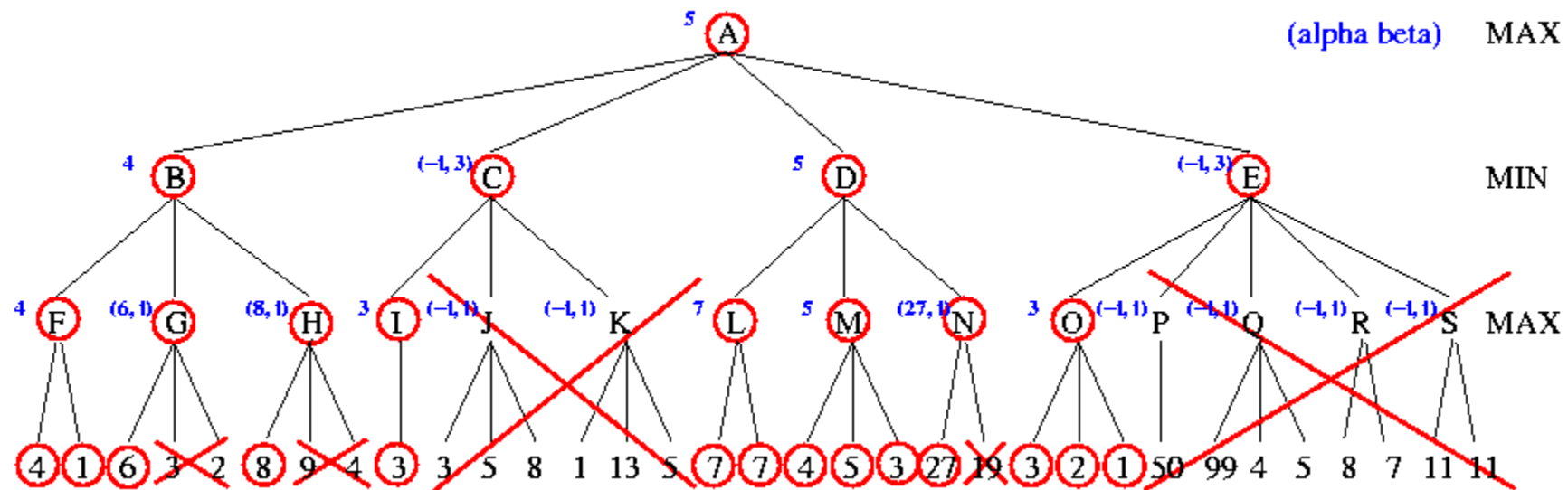
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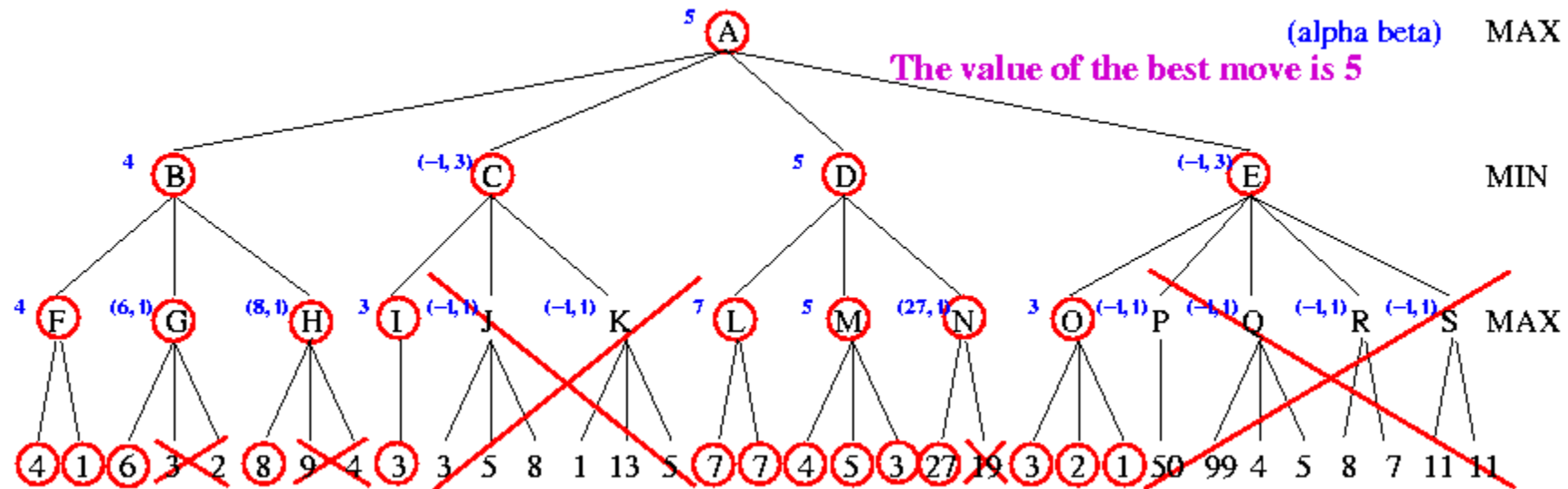
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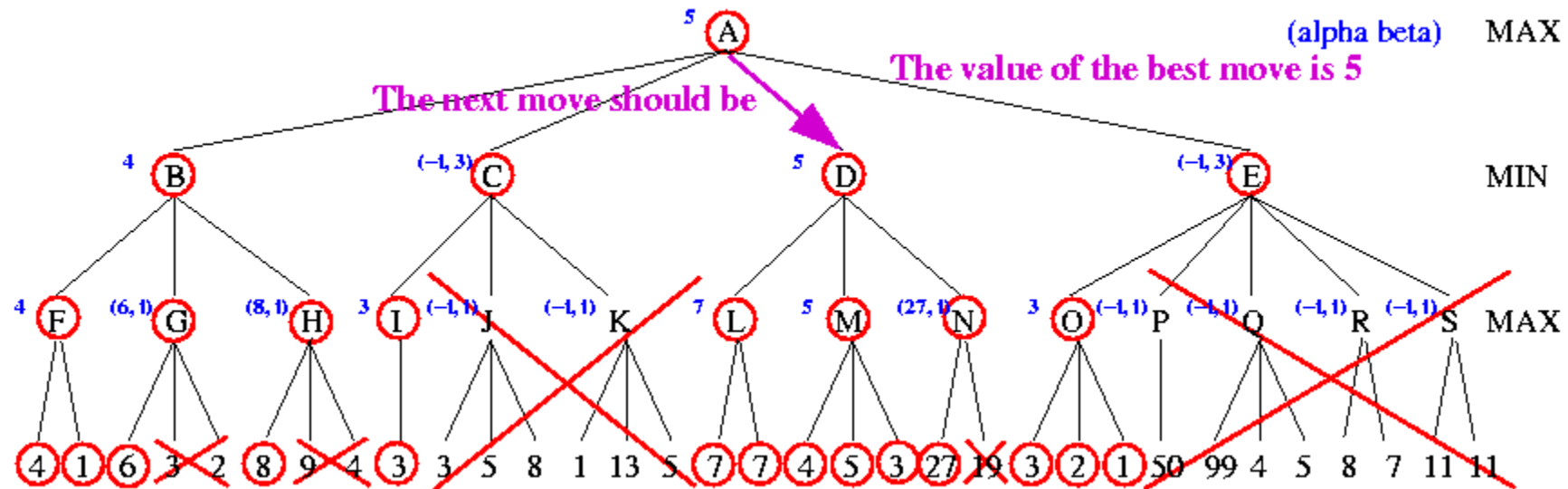
Example



Example



Example



Participation Exercise:

