Monte Carlo Search Tree and Its Applications

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Kasparov vs Deep Blue

Kasparov vs Deep Blue

Great display of artifical intelligence
Techniques employed by IBM

- Brute force deterministic approach
- human knowledge

Limitation

- scalability into larger search spaces

Monte Carlo tree search (MCTS) is an alternative method

Outline

Monte Carlo Tree Search (MCTS)

- Combines random sampling and game trees
- Probabilistic not deterministic
- Useful for problems with larger search spaces

Two MCTS Applications

Go

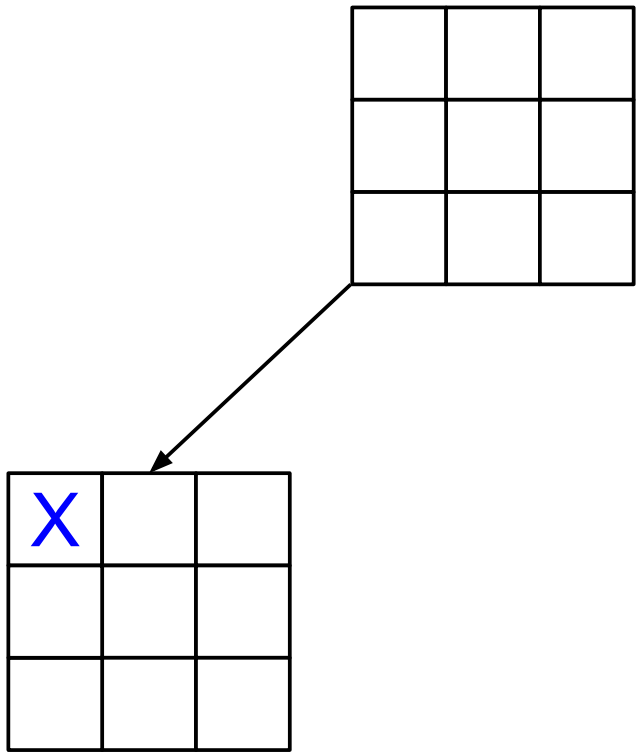
- Board game about positional advantage
- Game board for Chess: 8x8
- Possible games of Chess: 10^{120}
- Game board for Go: 19x19
- Possible games of Go: 10^{761}

Narrative generation

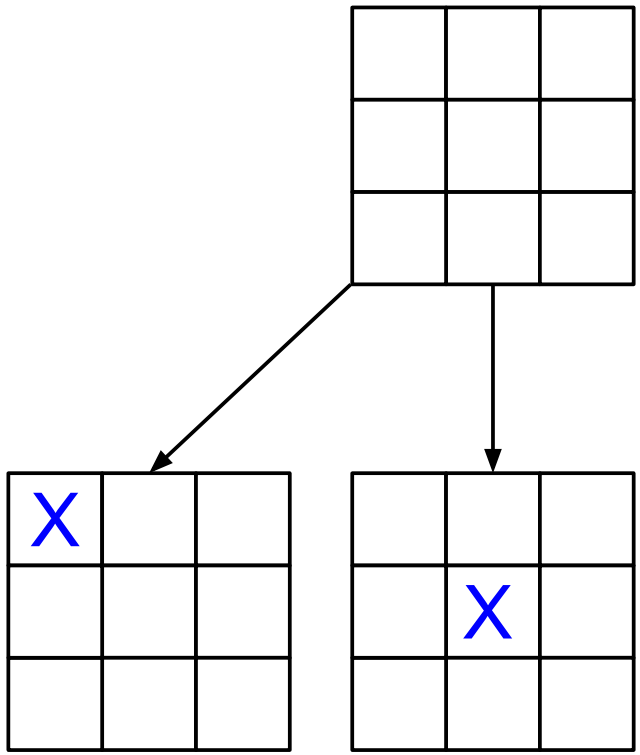
- Useful Applications
  - Video game replay value
  - educational applications
- The search space scales with the number of characters, items, locations, and actions

Outline

TicTacToe Diagram



TicTacToe Diagram



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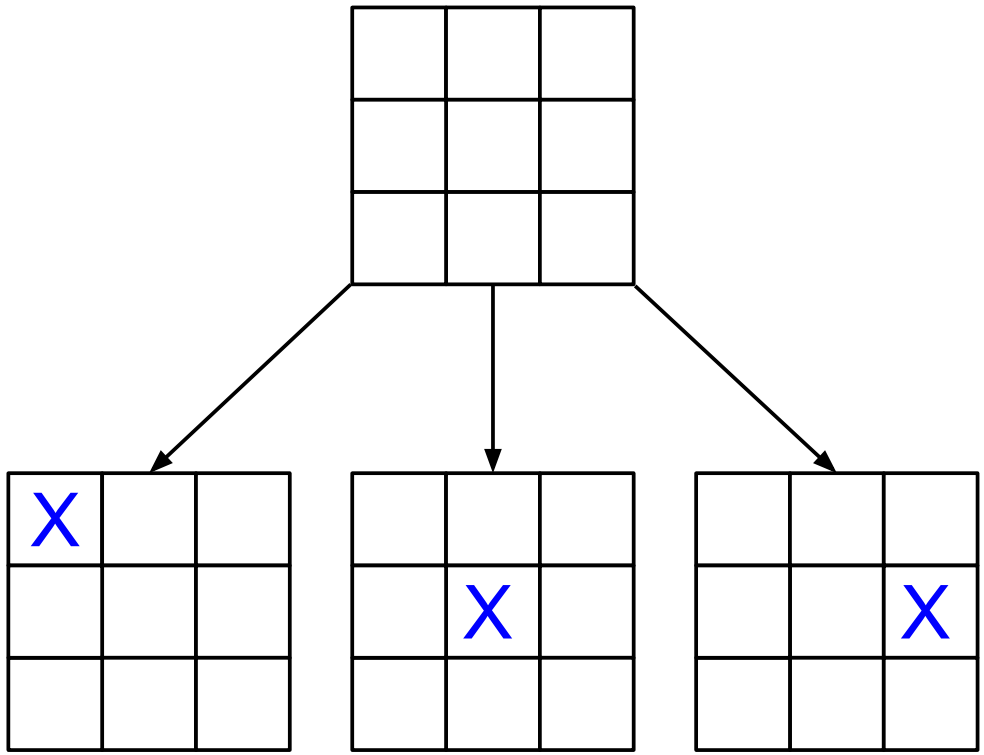
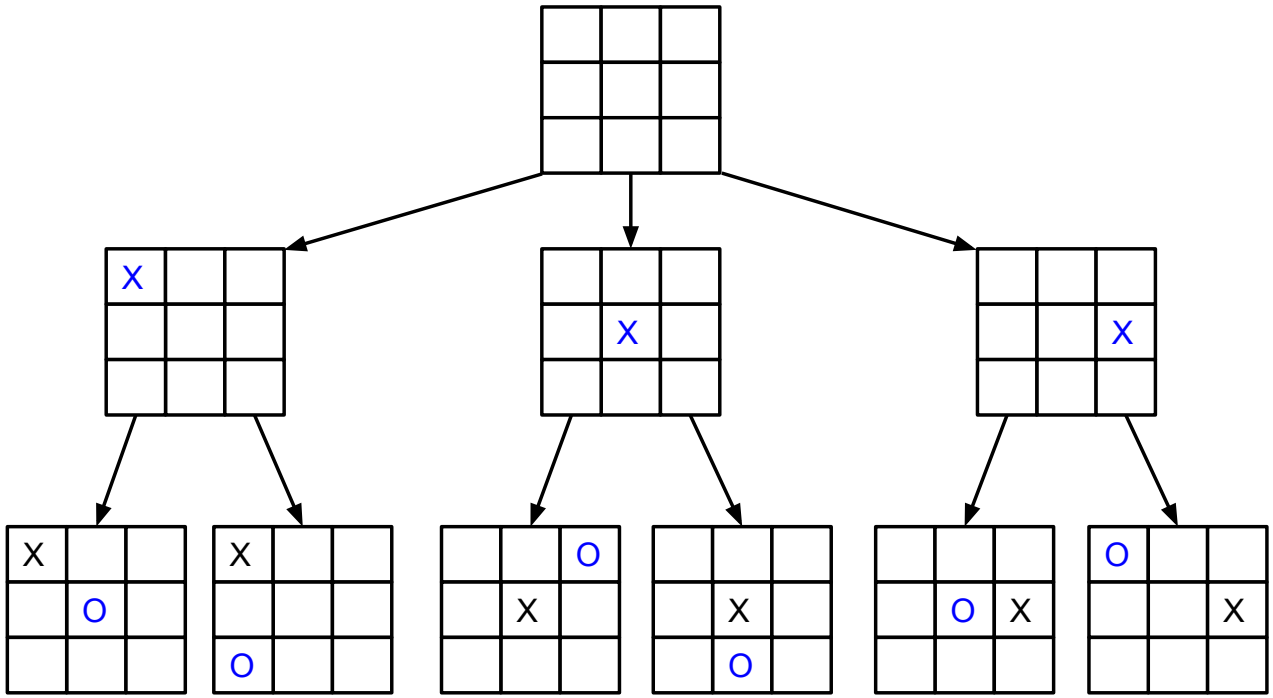


TicTacToe Diagram More Levels



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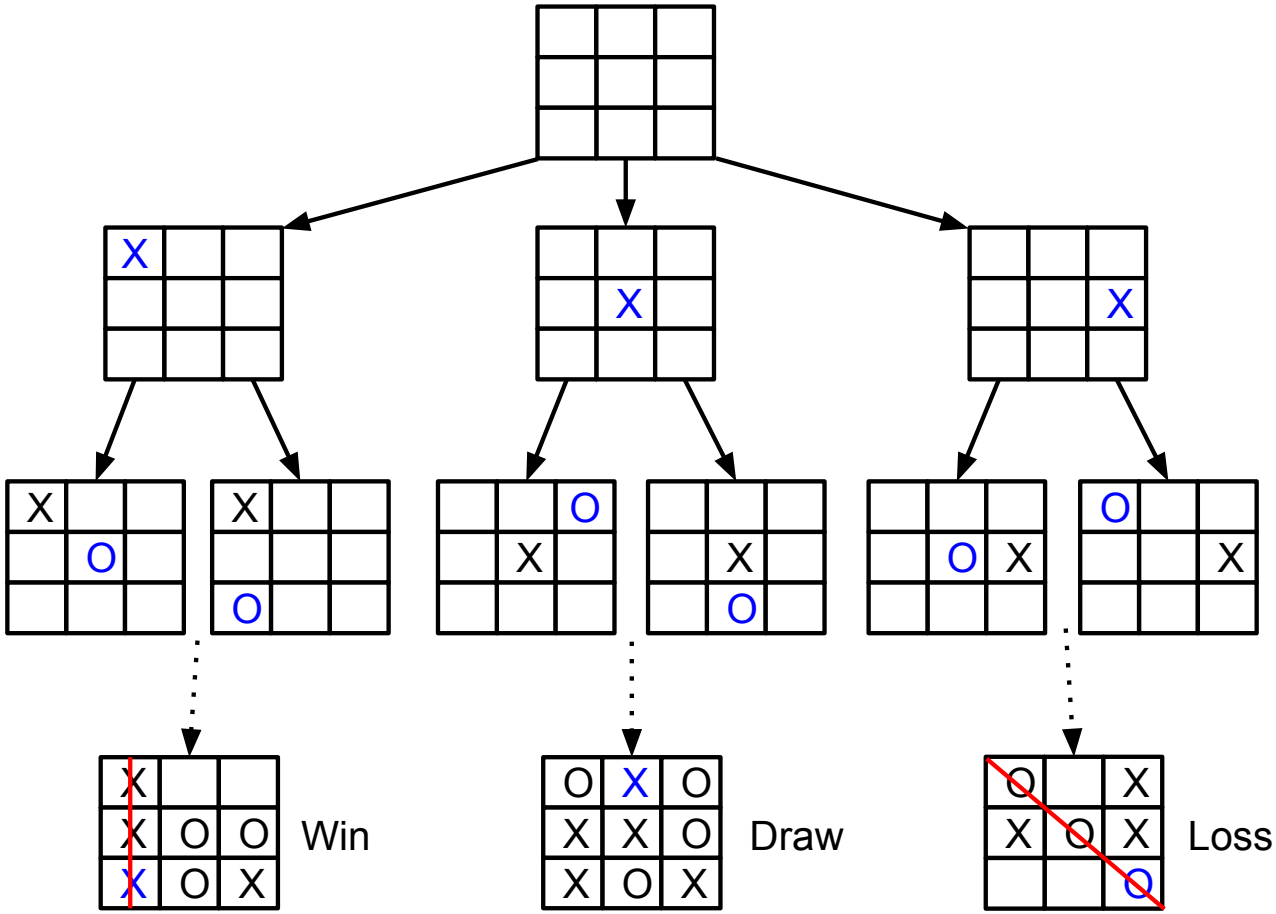

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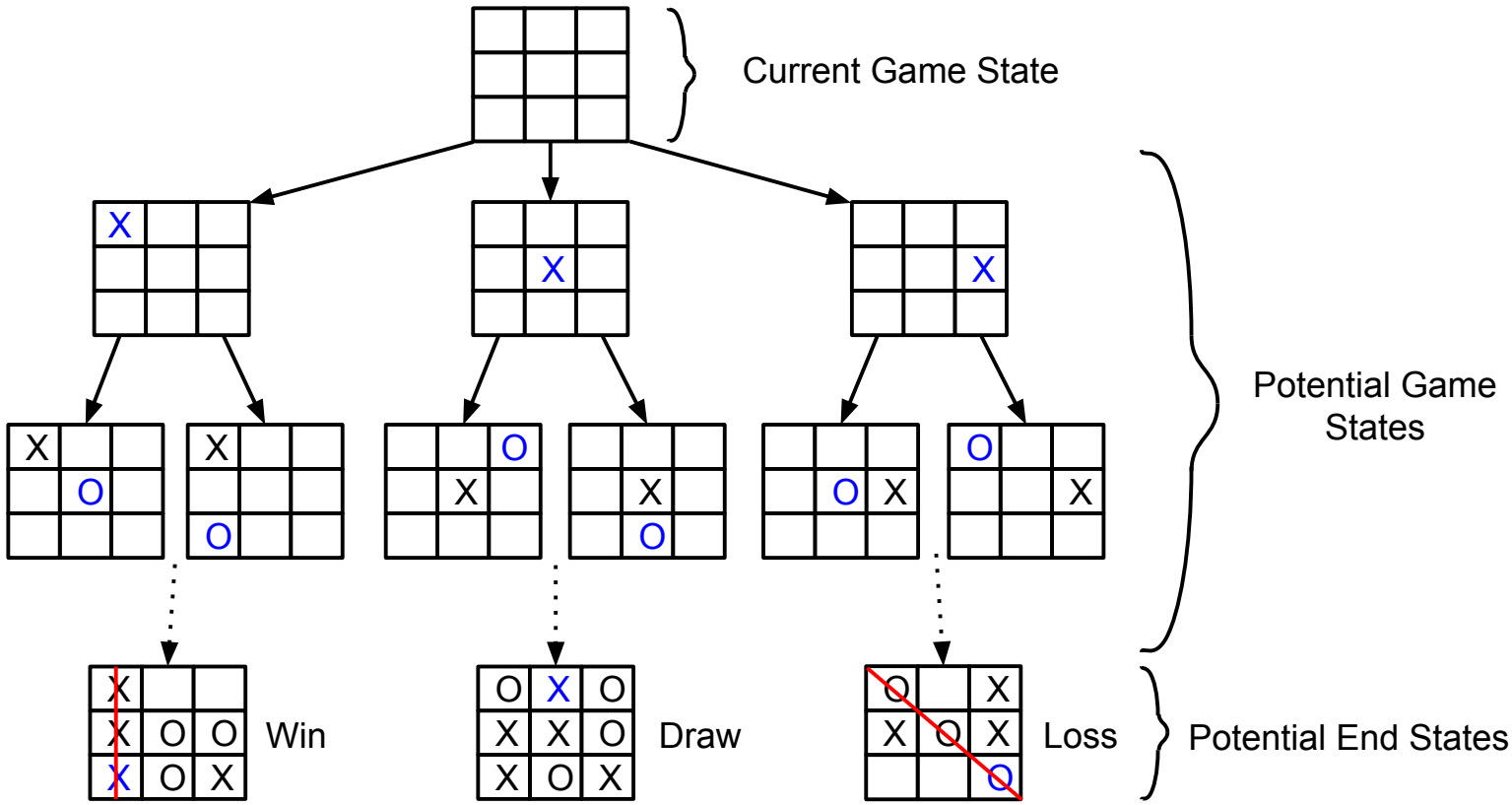
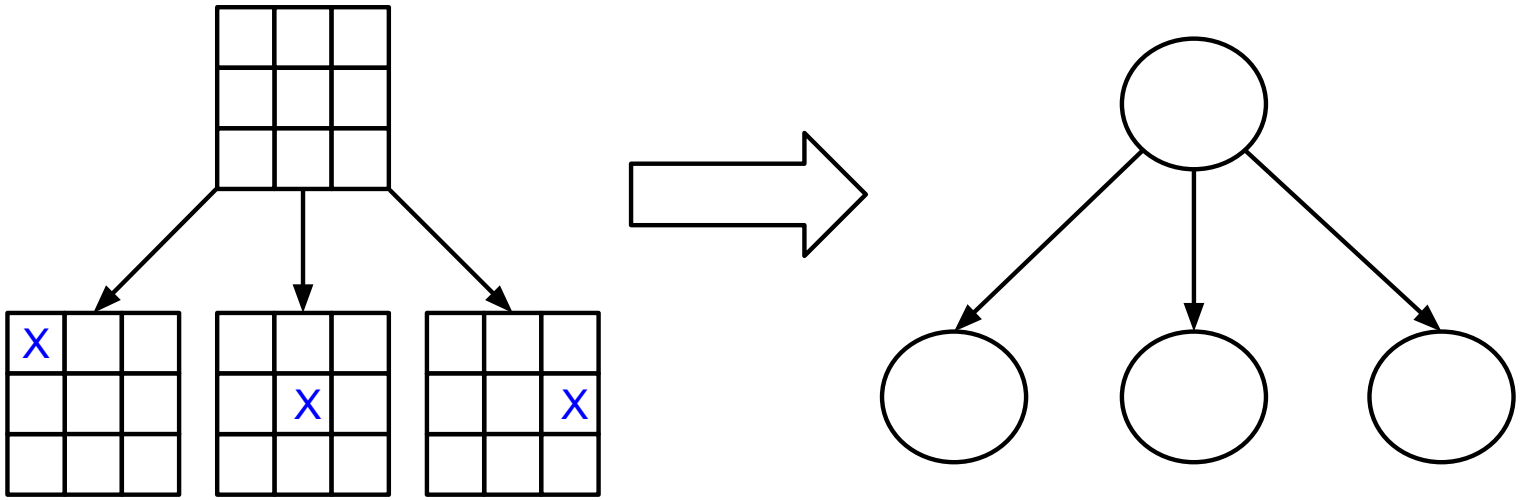
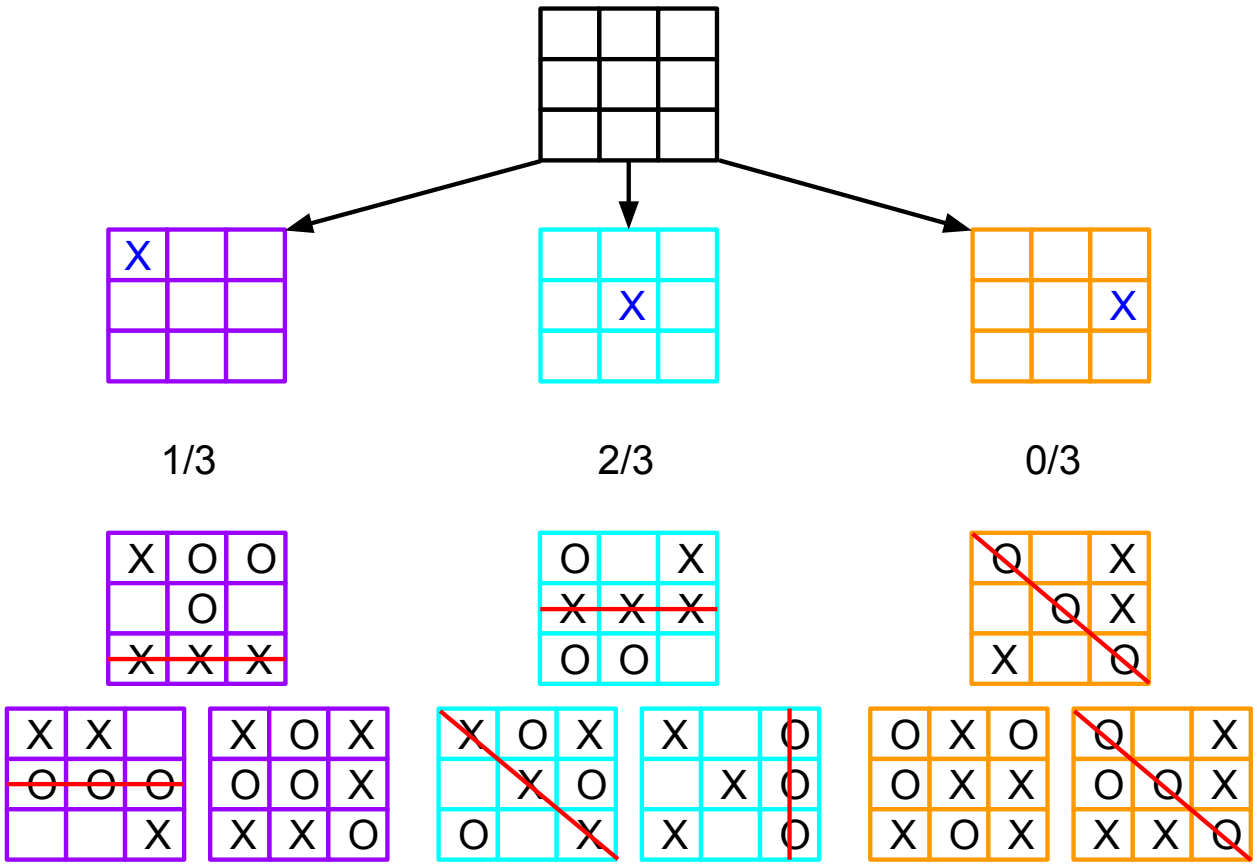


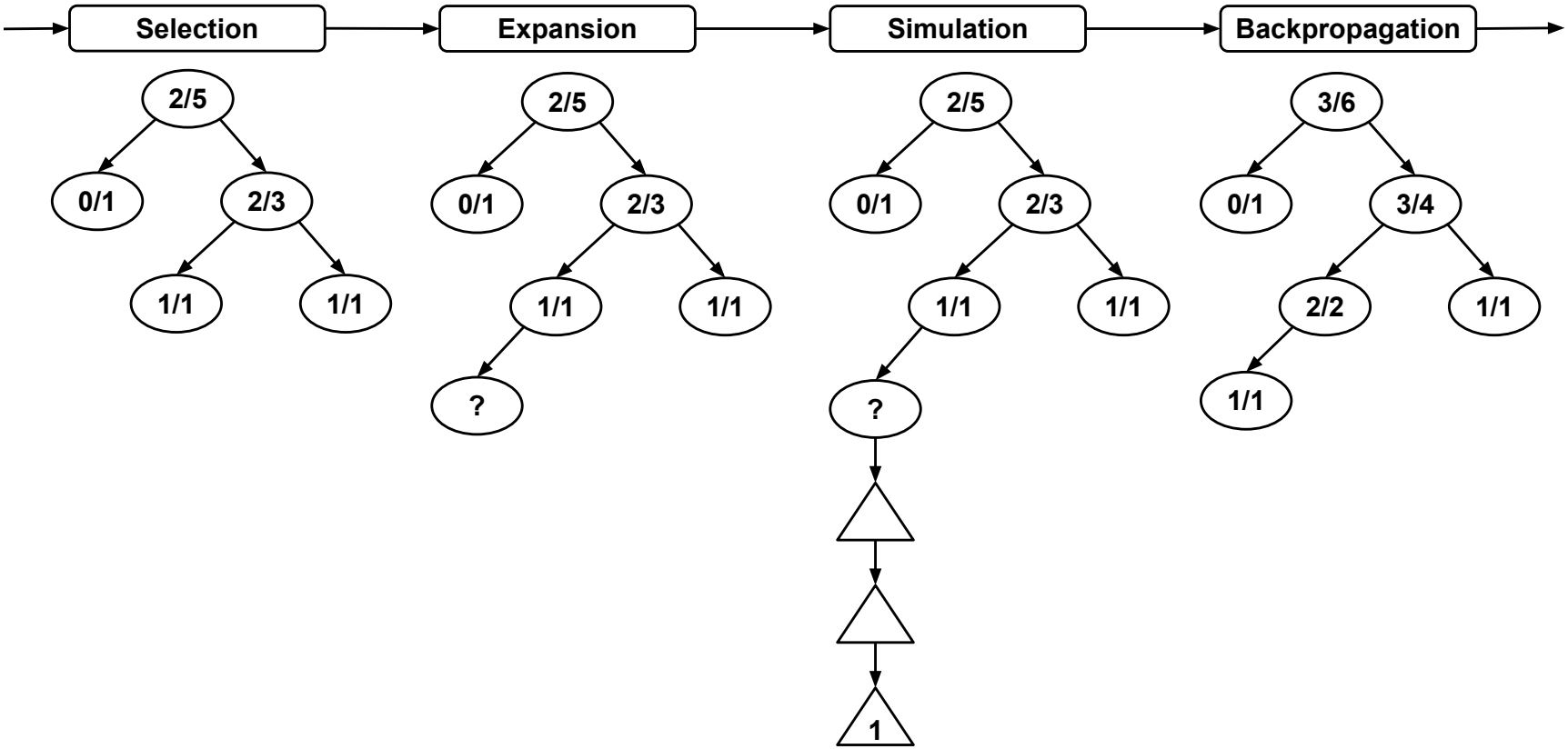
Tree Structure



Sampling



Four Steps Diagram



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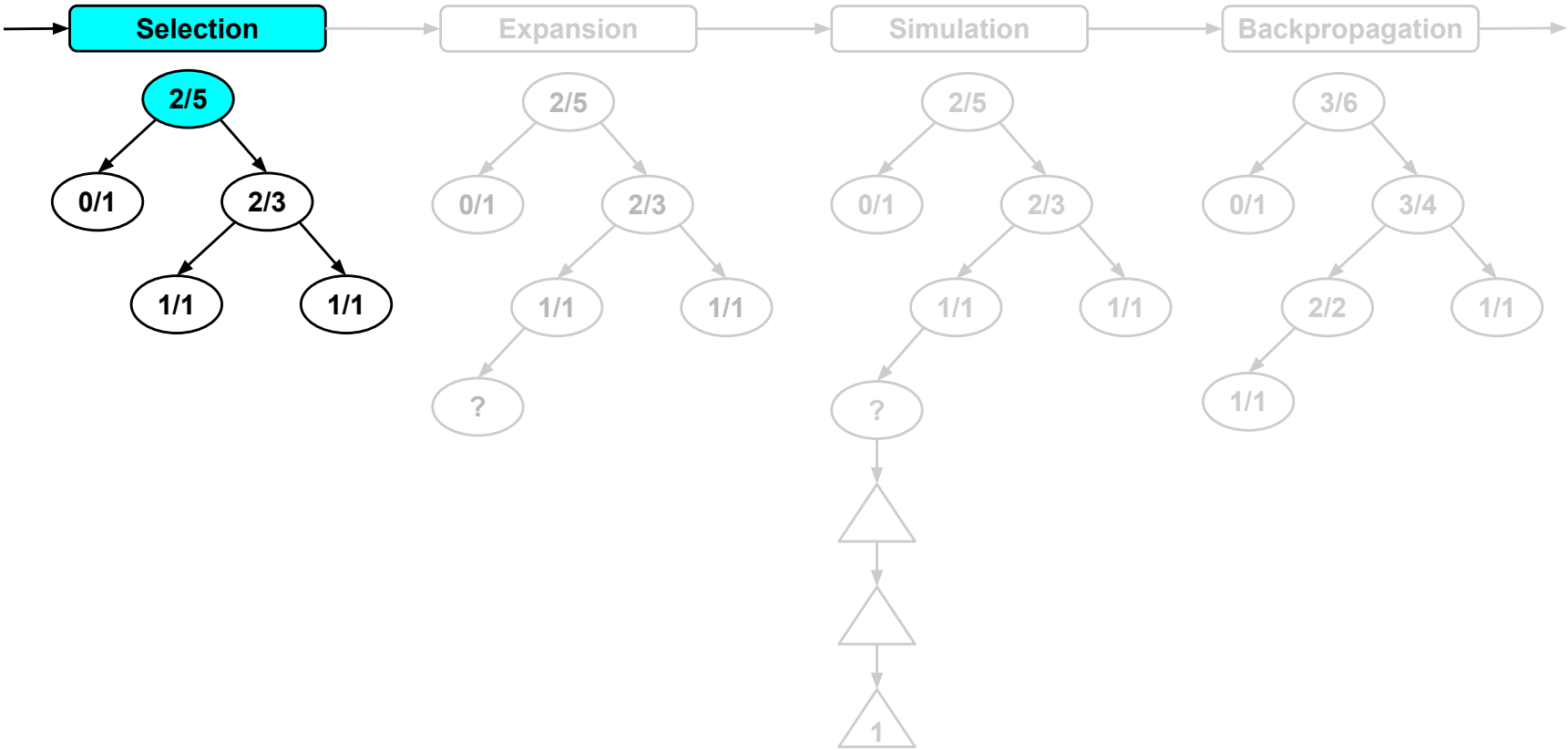

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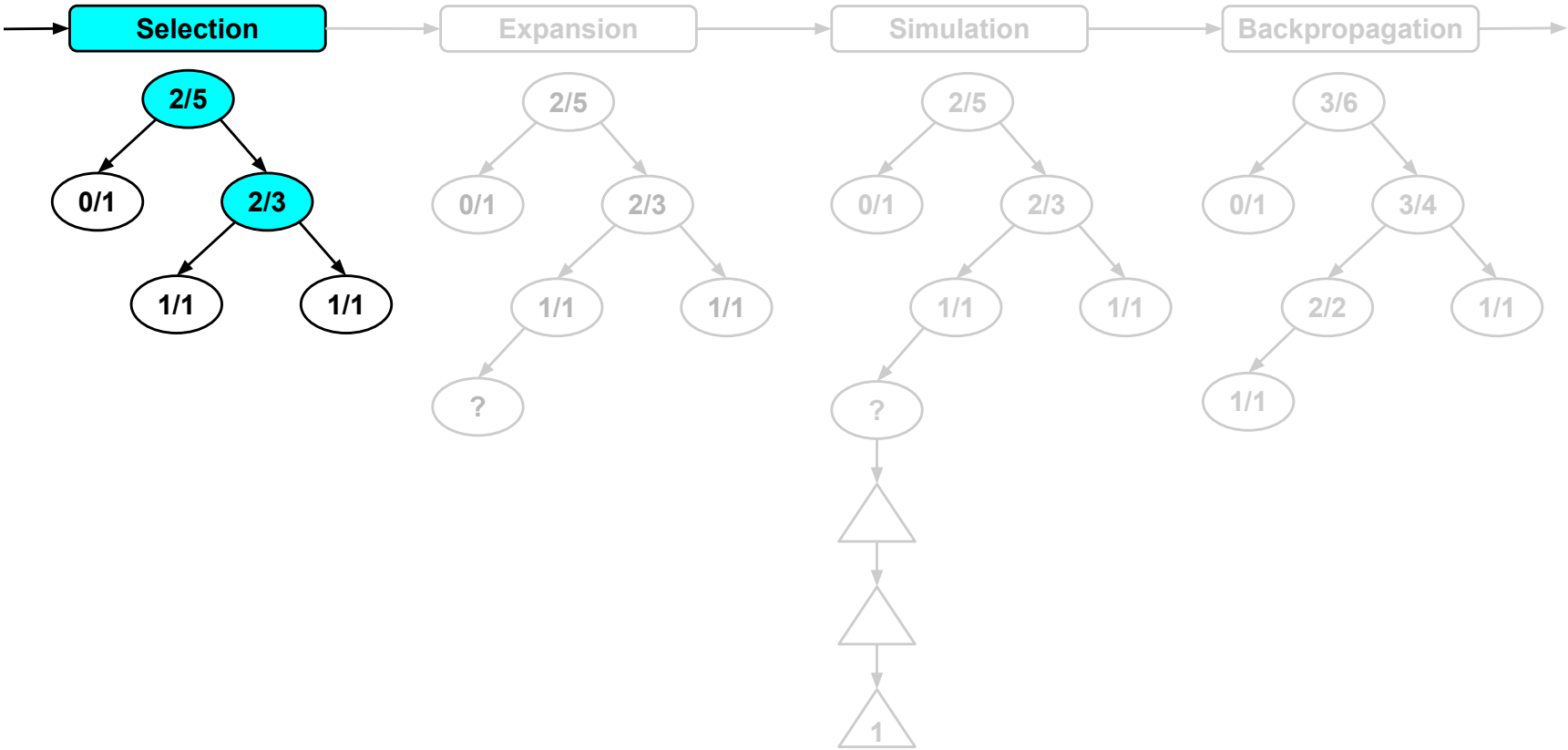

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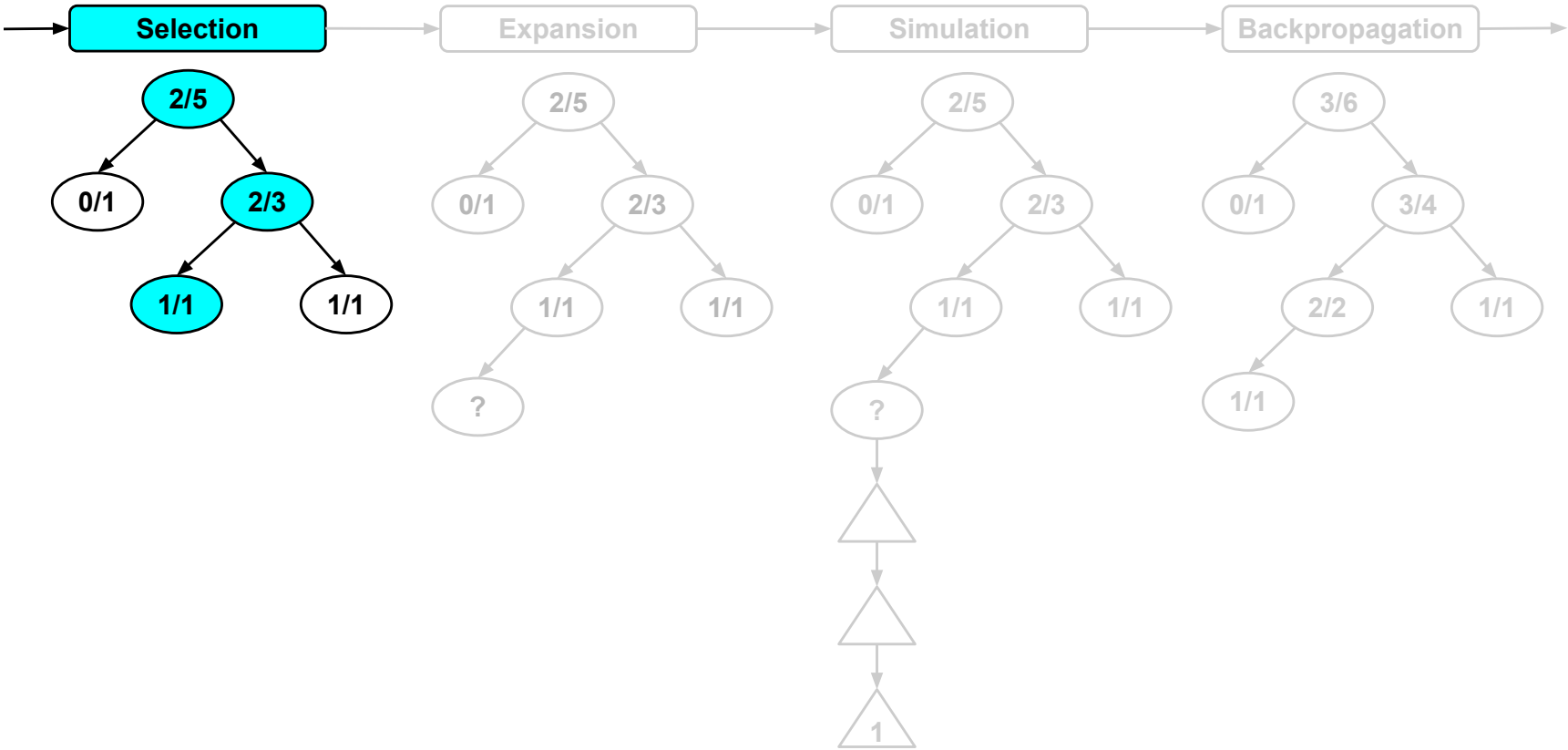

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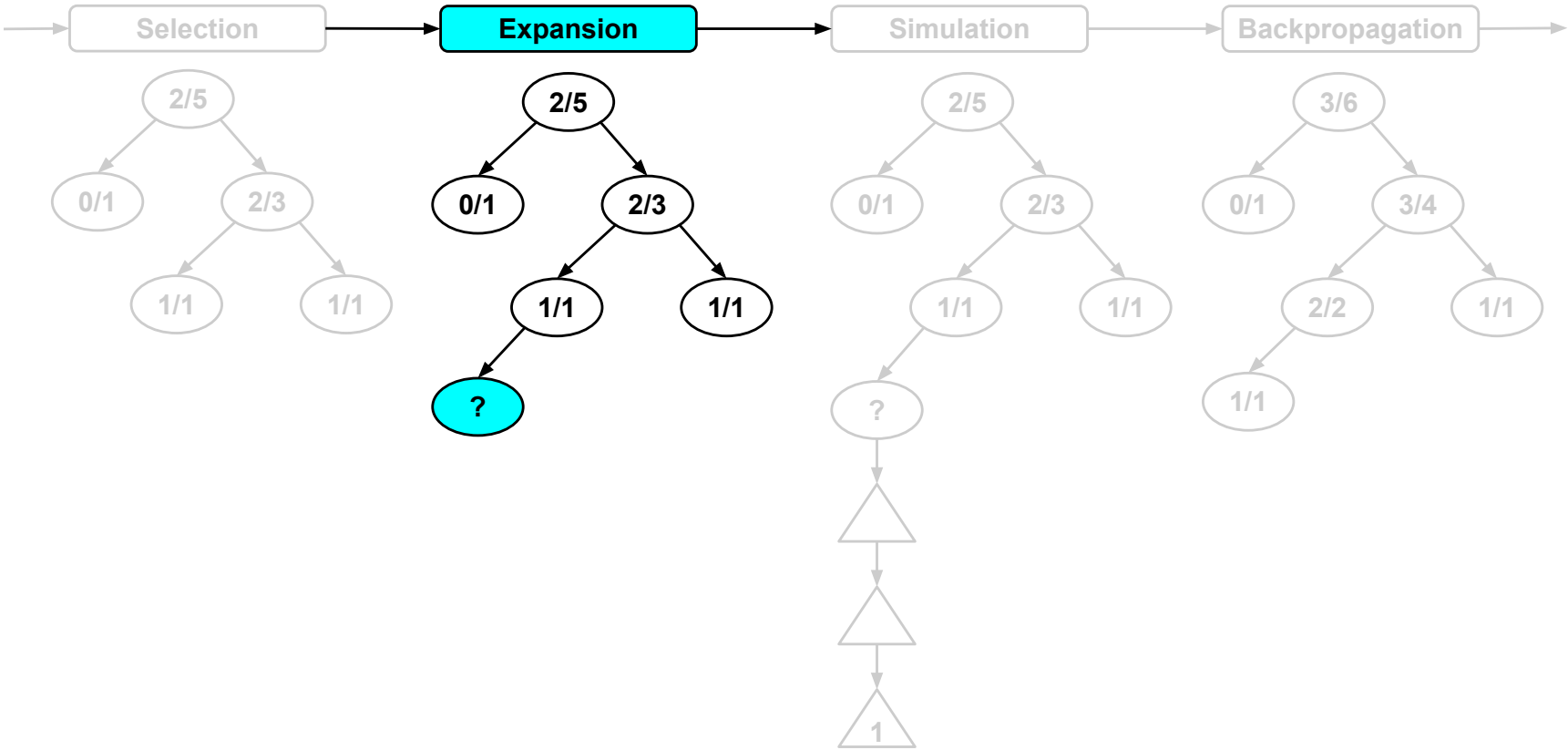

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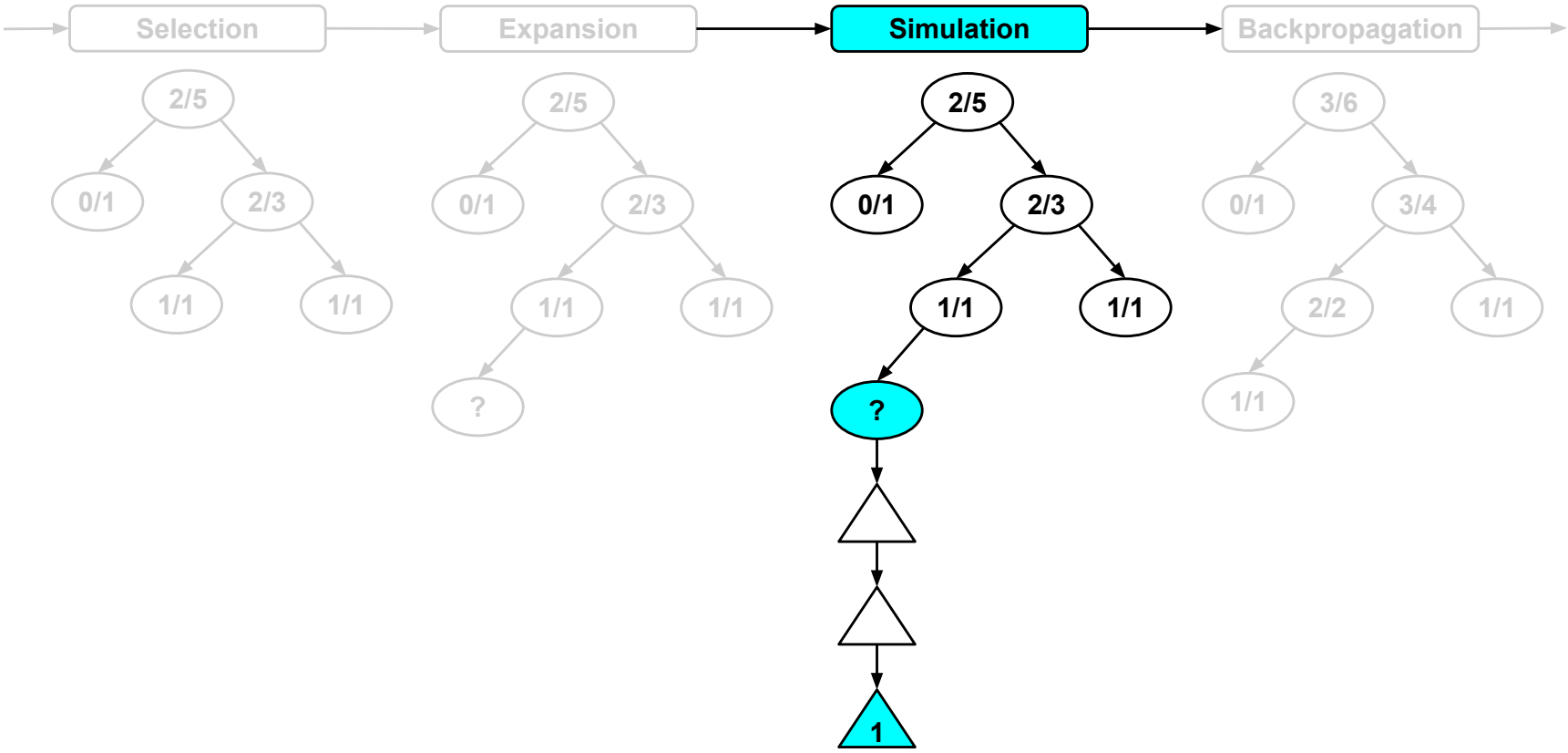

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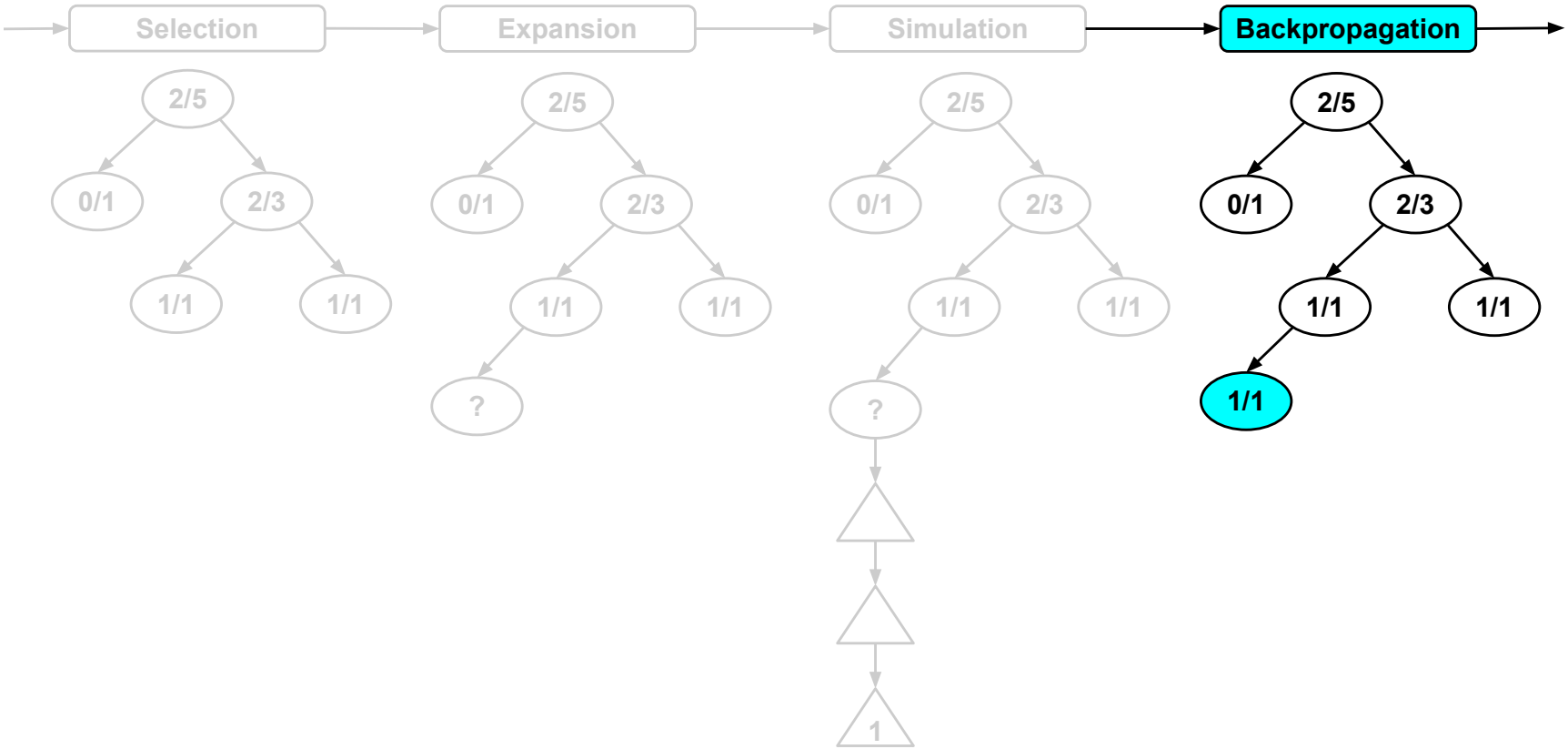

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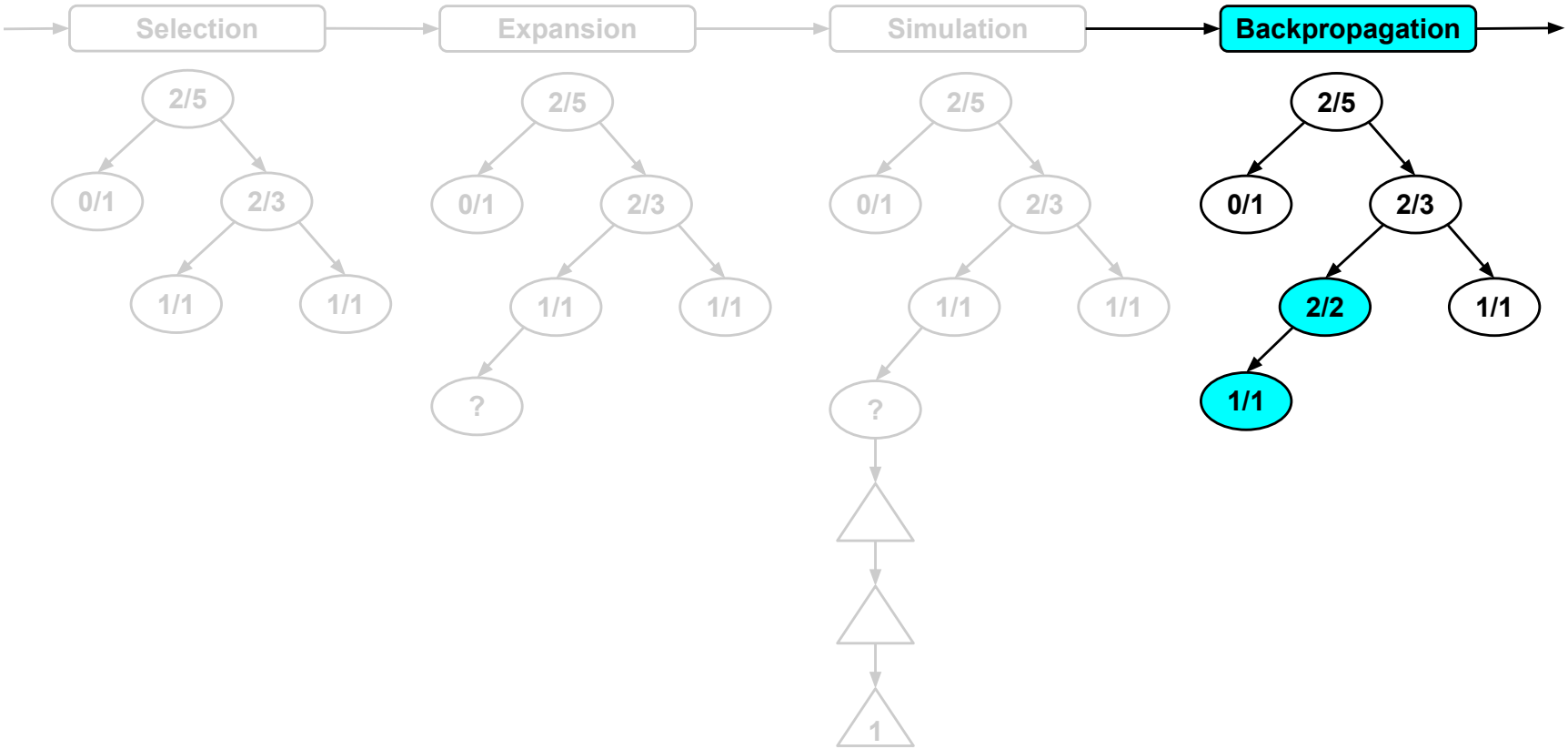

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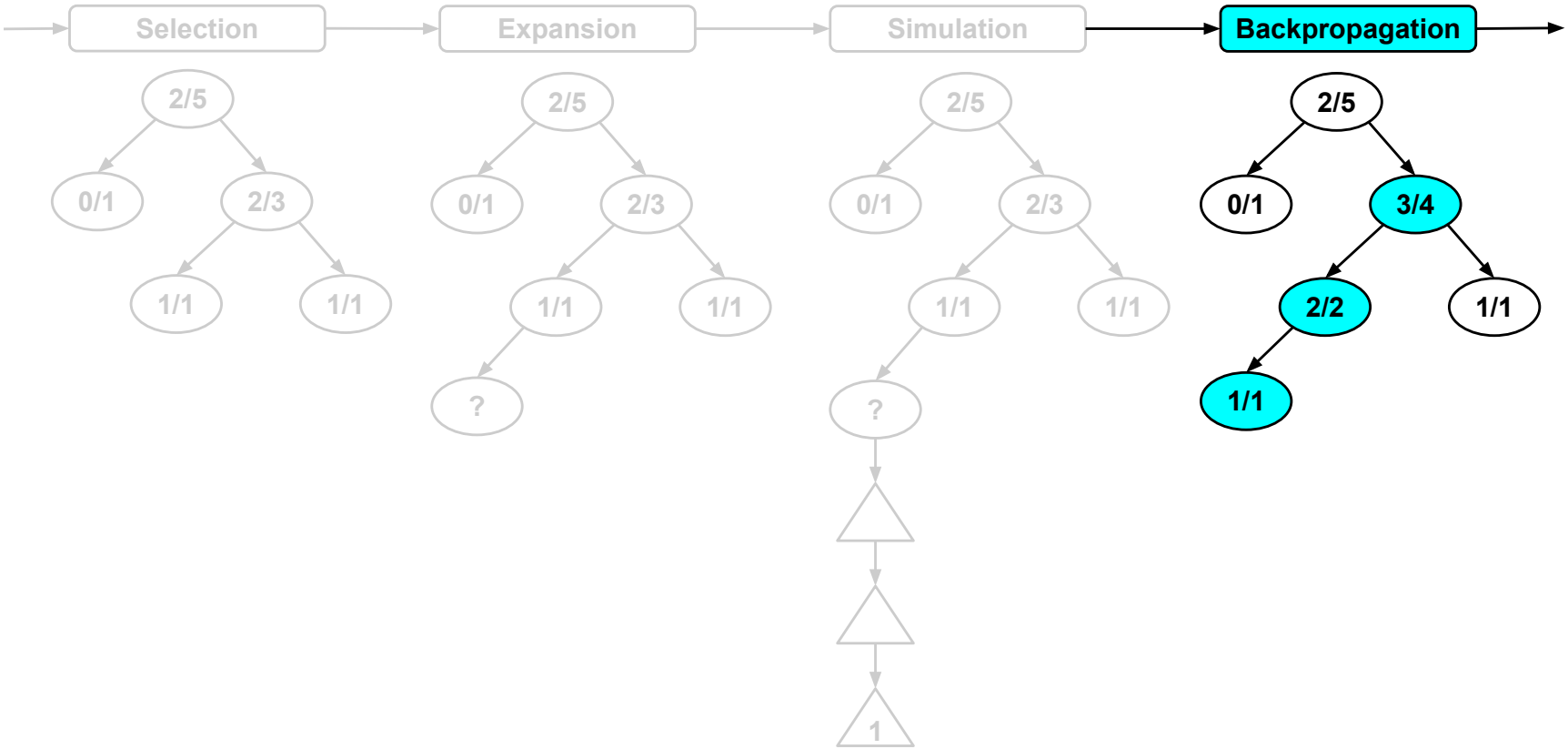

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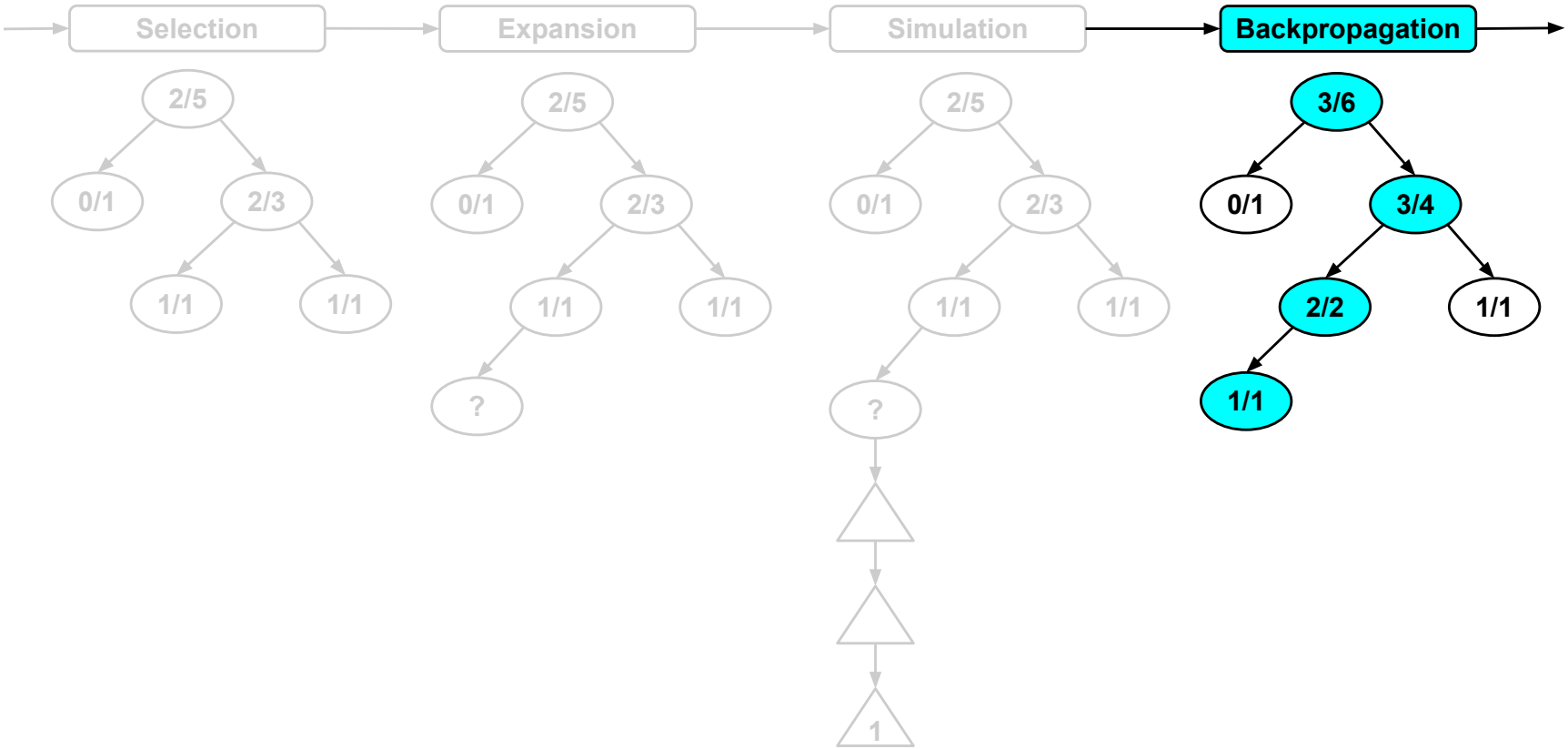

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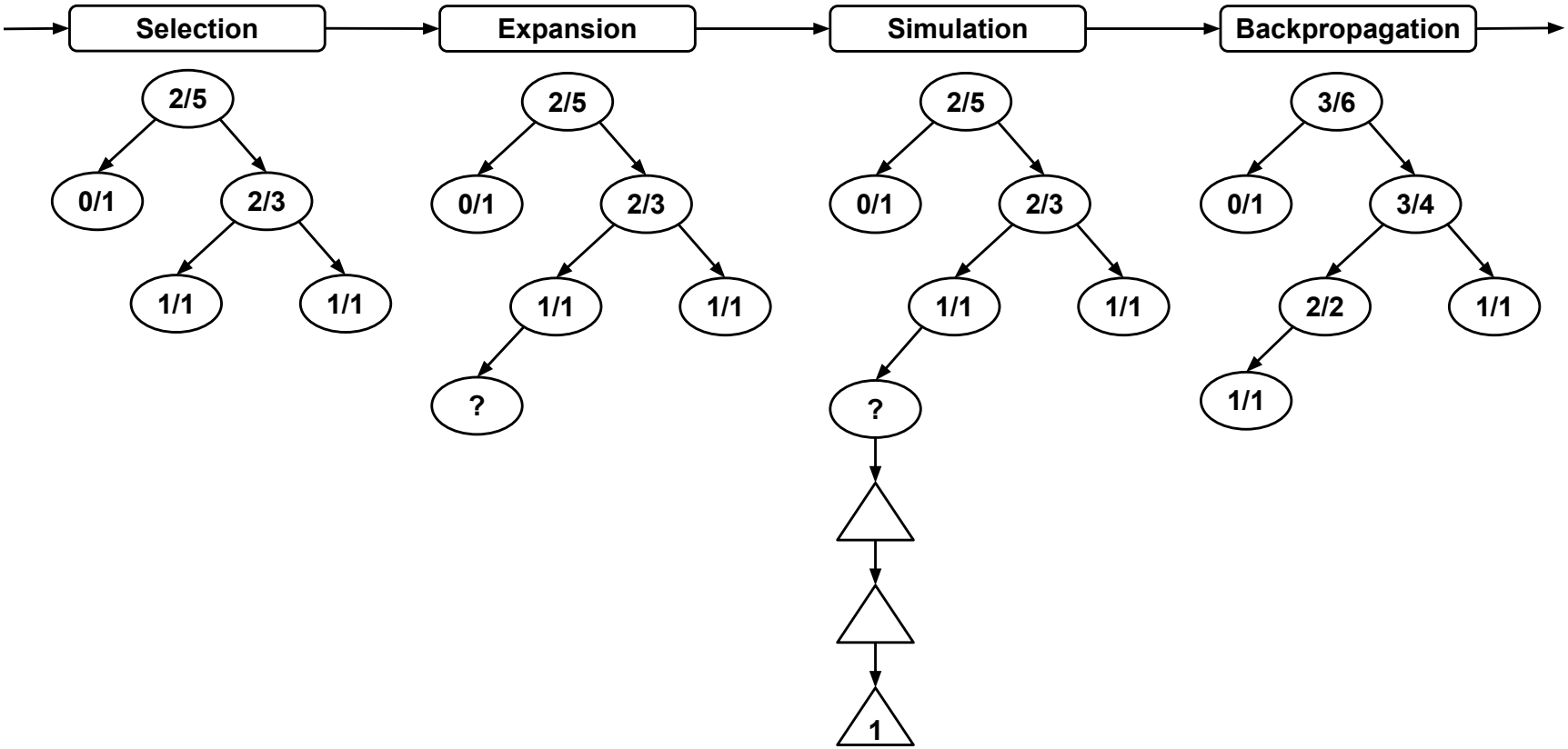

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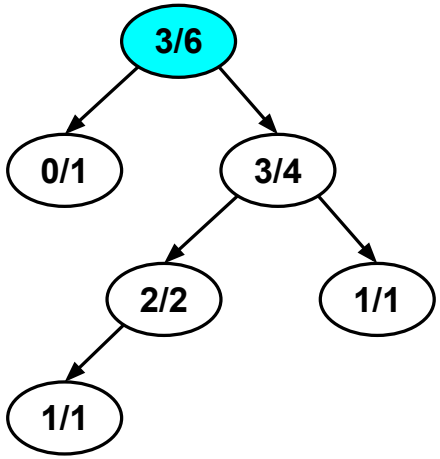

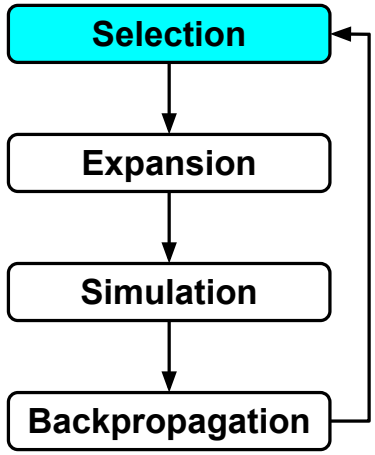

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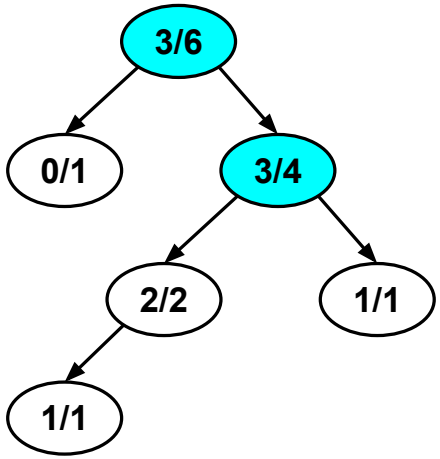

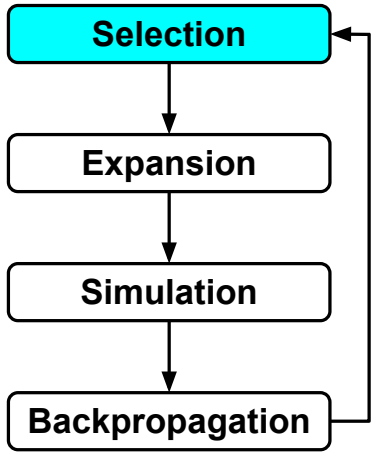

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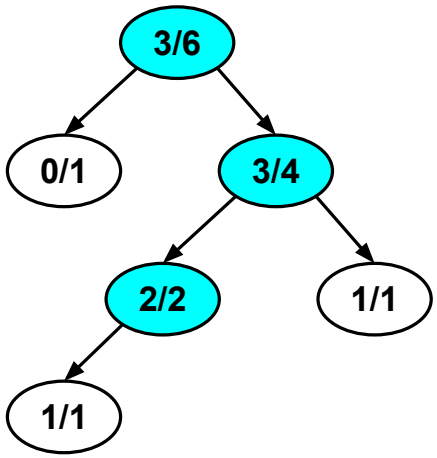

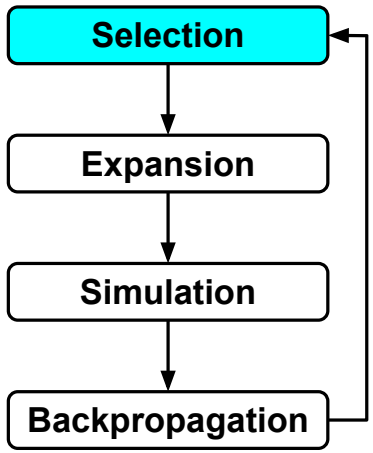

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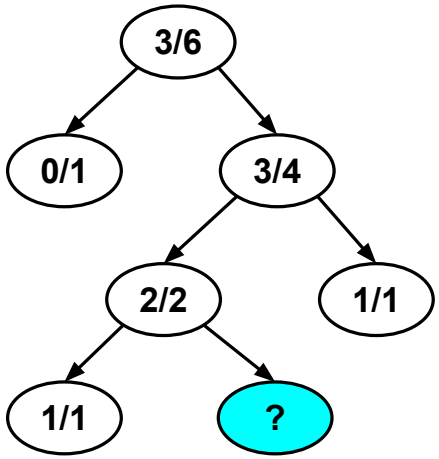

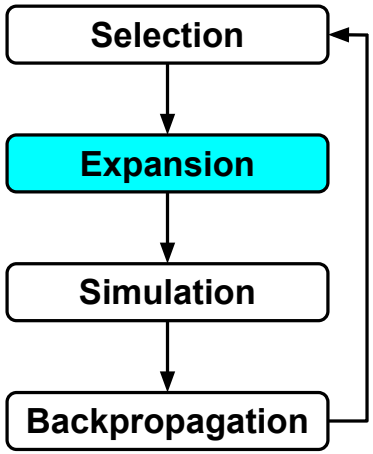

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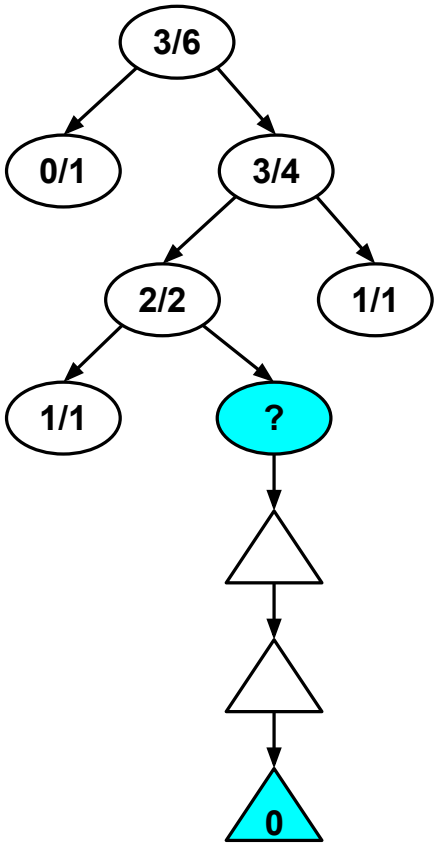

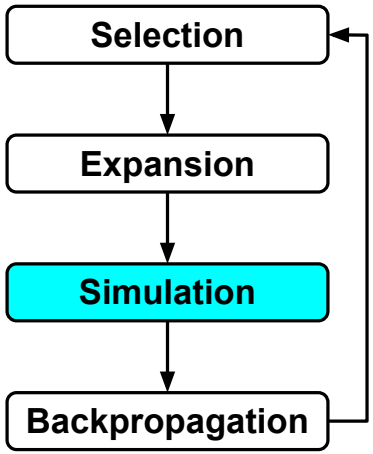

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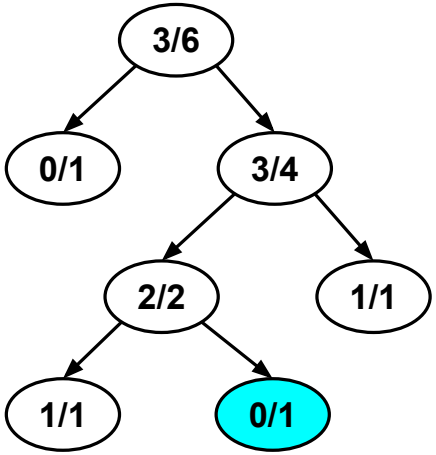

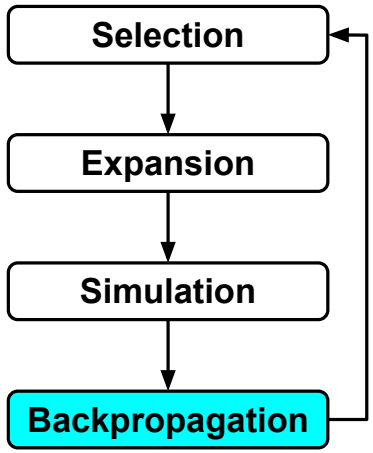

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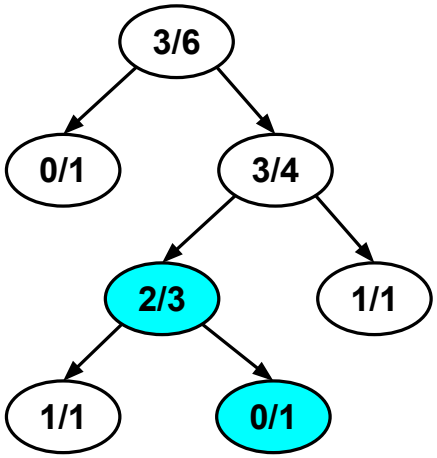

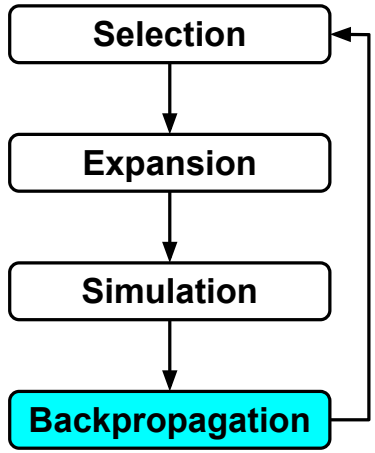

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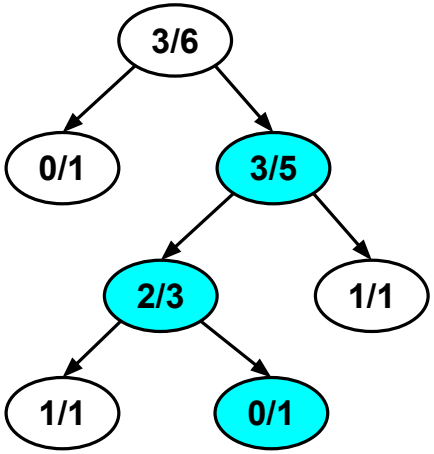

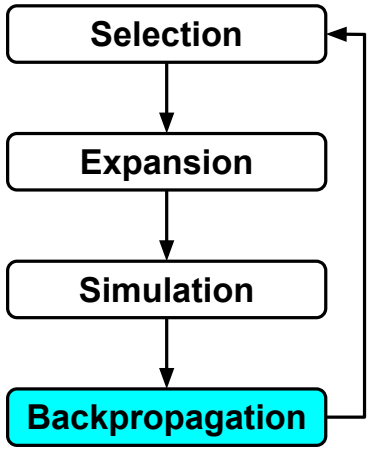

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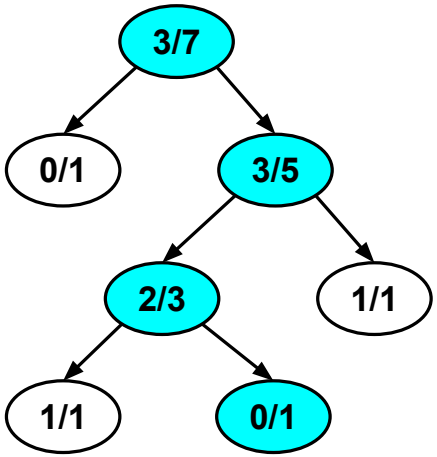

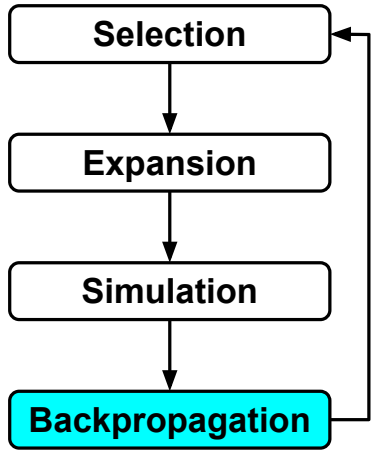

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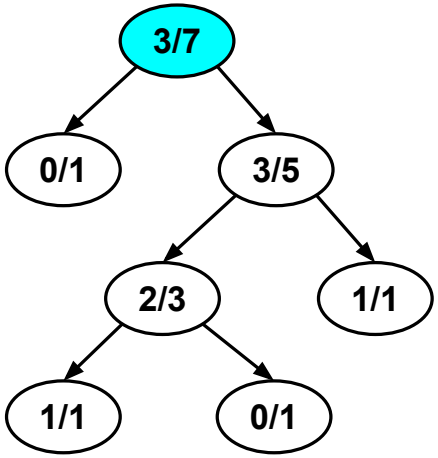

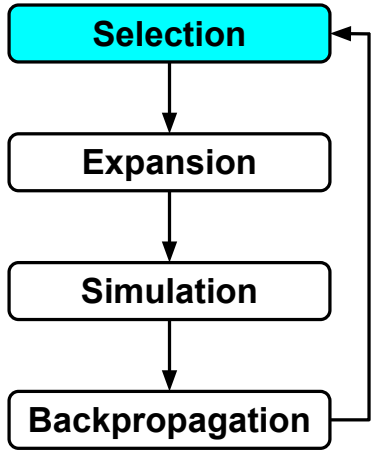

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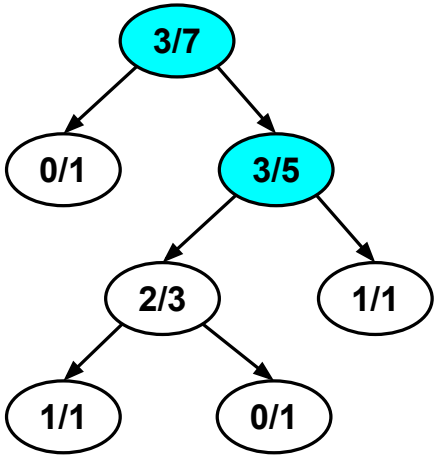

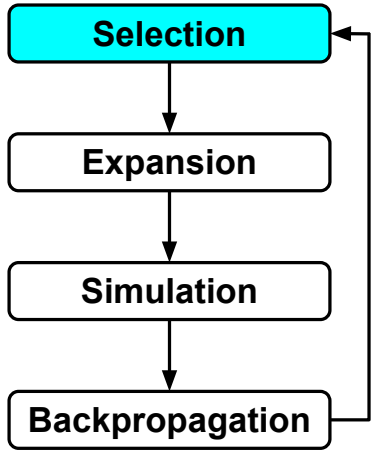

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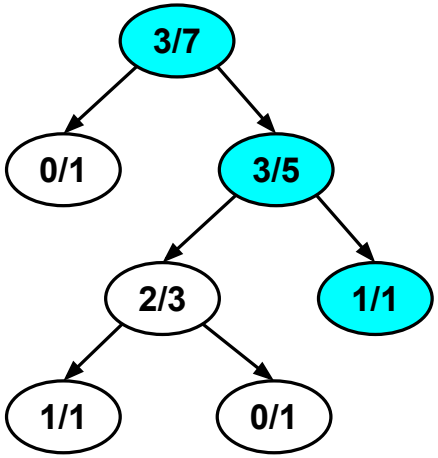

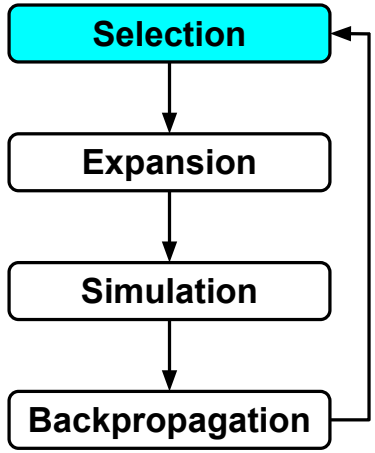

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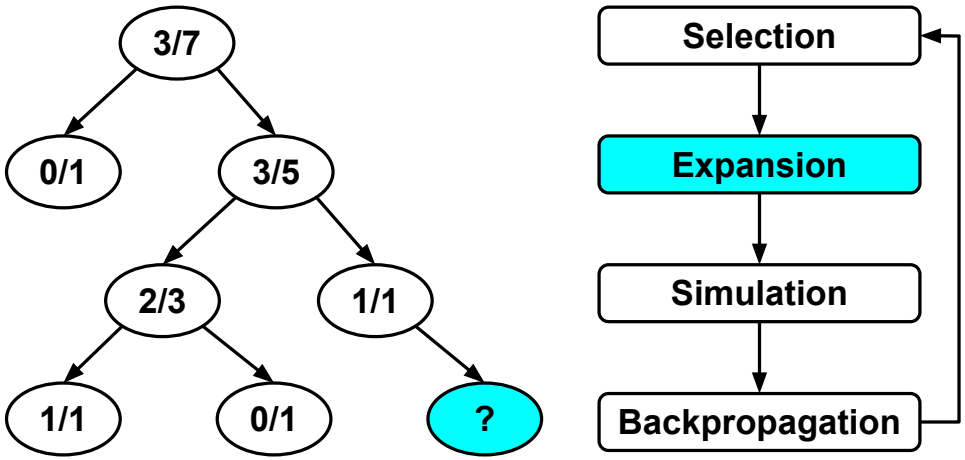

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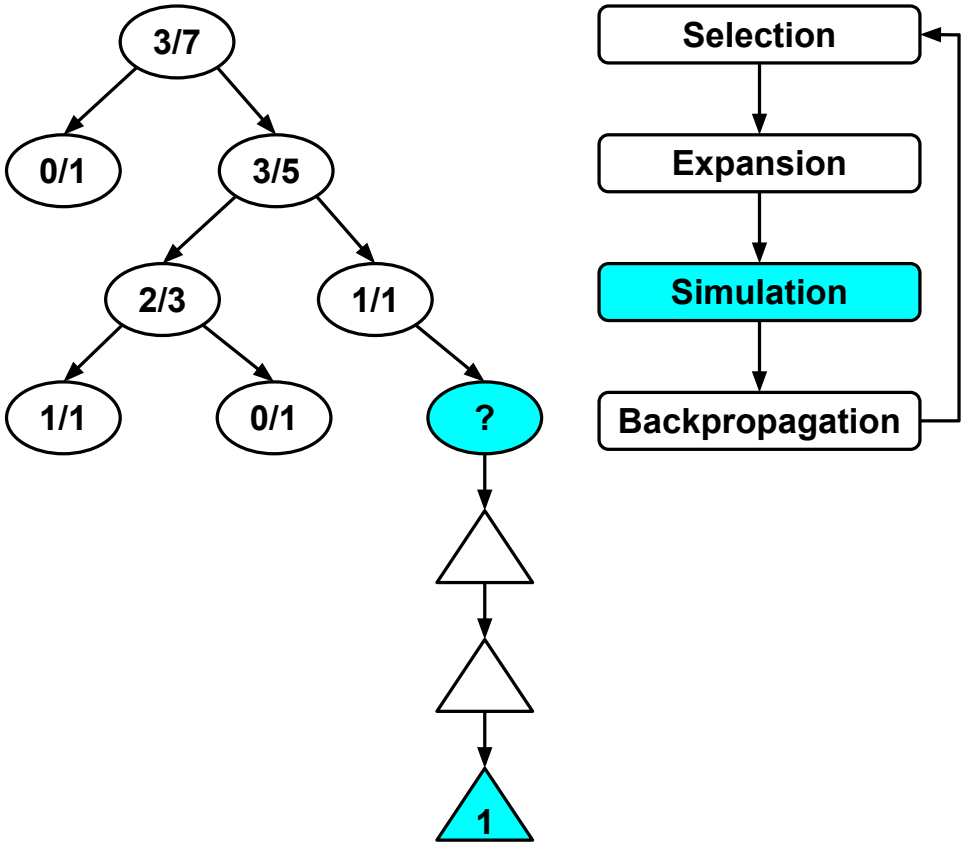

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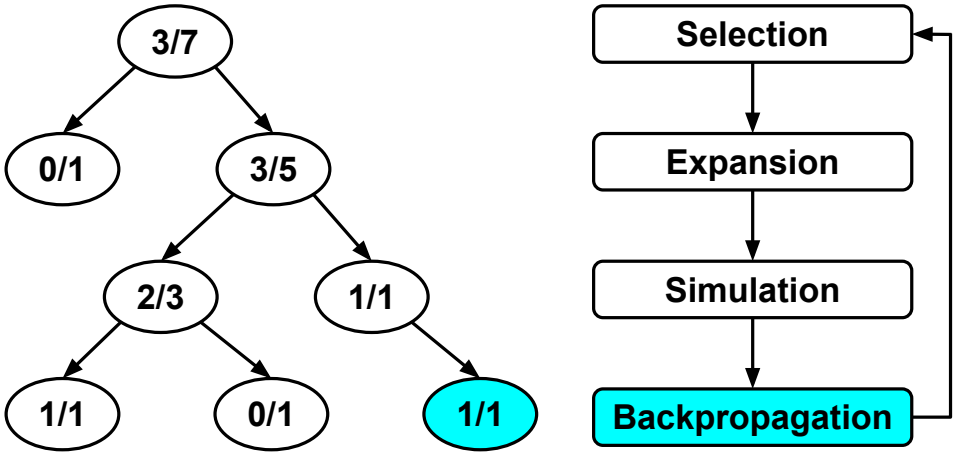

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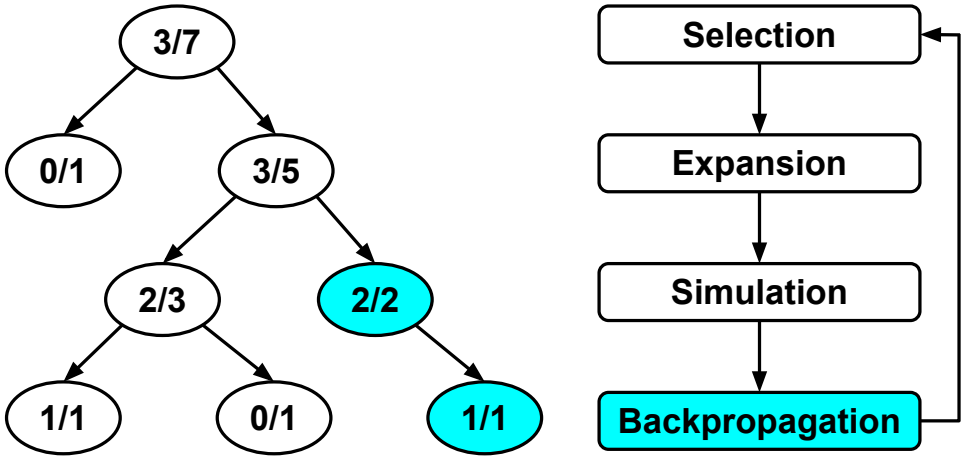
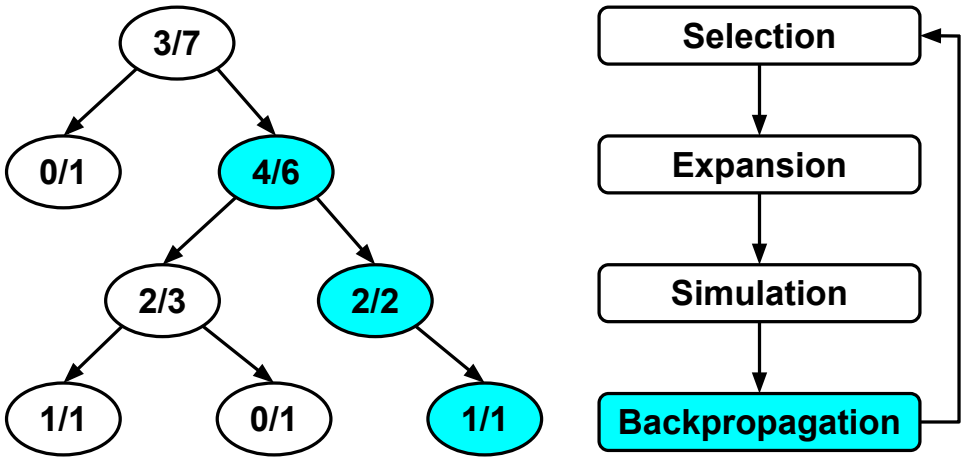
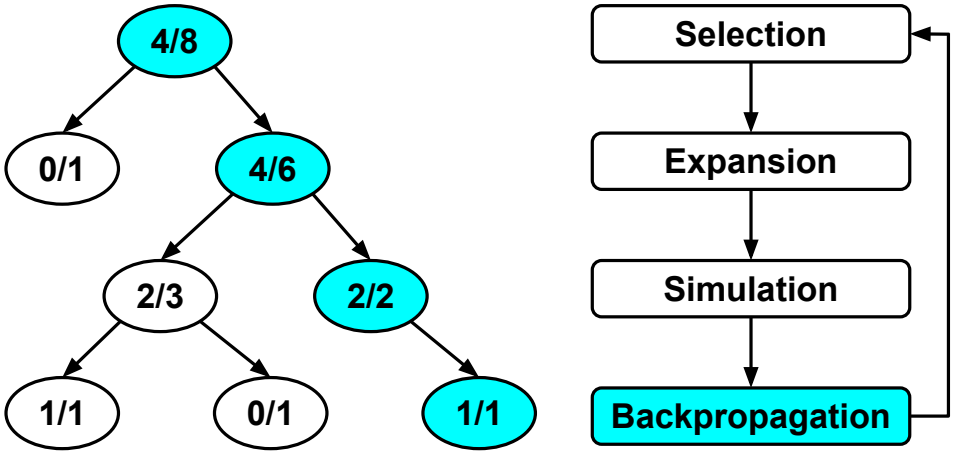


Four Steps Diagram



Four Steps Diagram



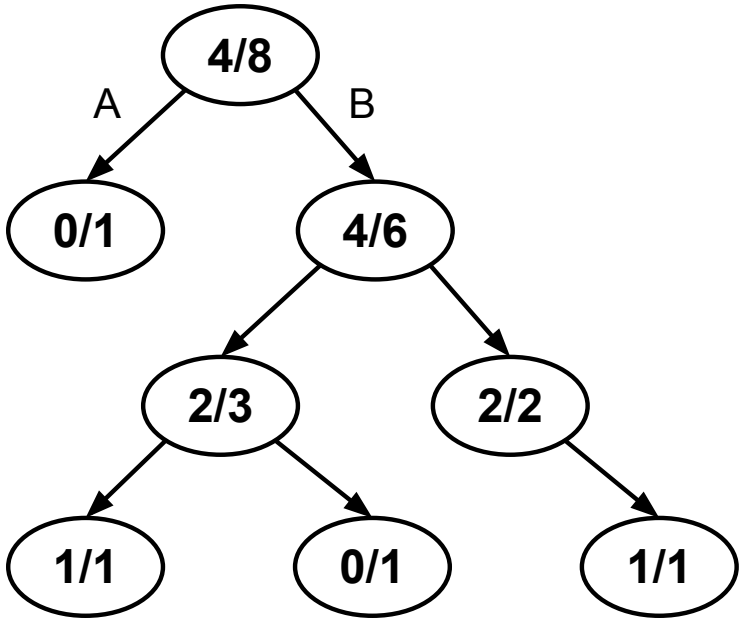
What Happens When We Choose a Move?

Now we have:

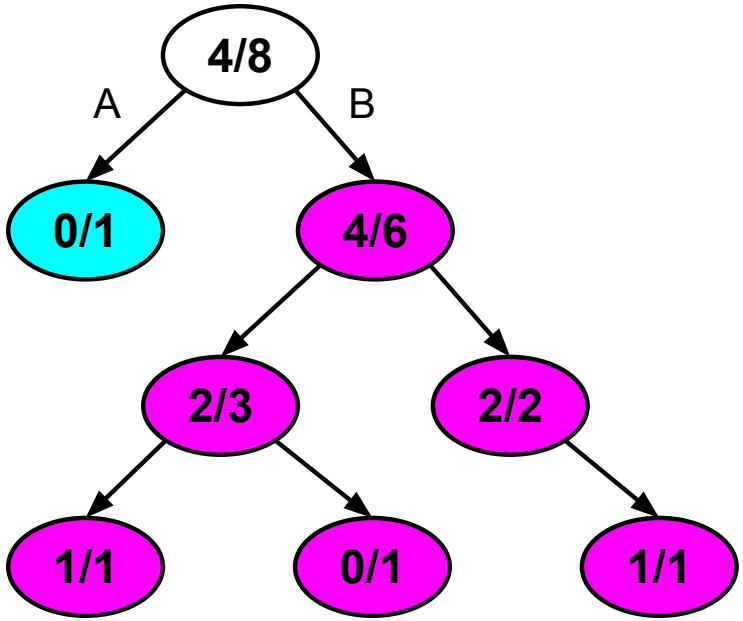
- A tree structure
- A method of generating the tree

What happens when we need to choose a move?

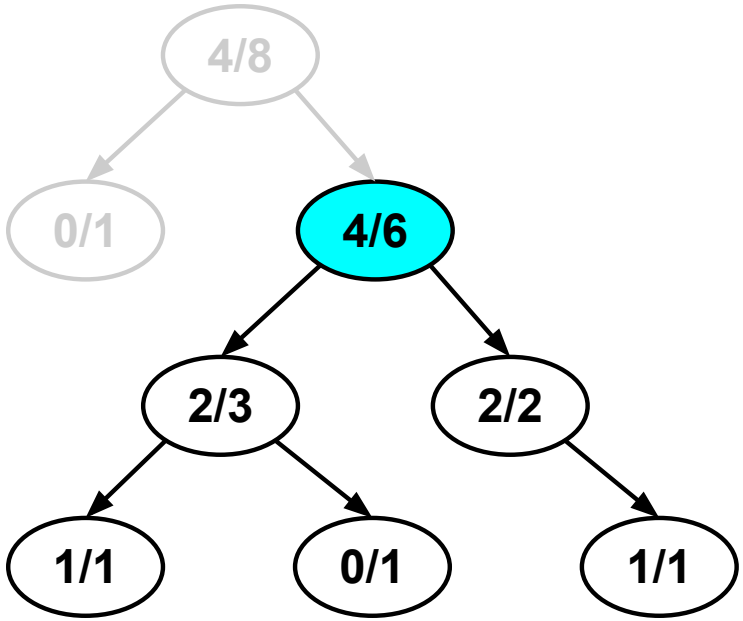
Choosing a Move



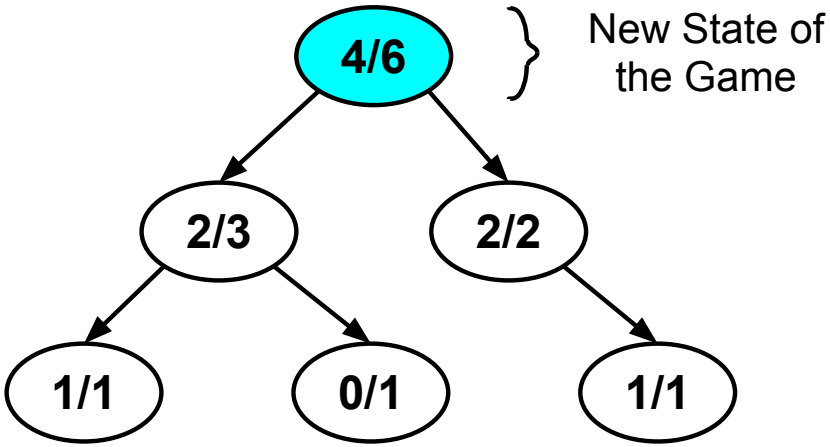
Choosing a Move



Choosing a Move



Choosing a Move



Exploration vs Exploitation

- We might overlook better paths
- Exploration vs Exploitation
  - Exploration looks at more options
  - Exploitation focuses on the most promising path
- Must find a balance between the two

Upper Confidence Bound Applied to Trees (UCT)

$$UCT(node) = \underbrace{\frac{W(node)}{N(node)}}_{\text{Value of the Node}} + \underbrace{c\sqrt{\frac{ln(N(parentNode))}{N(node)}}}_{\text{Exploration Bonus}}$$

- W represents the number of simulated wins
- N represents the total number of simulations
- C is an experimental constant
- Used during tree traversal
- Balances exploration vs exploitation

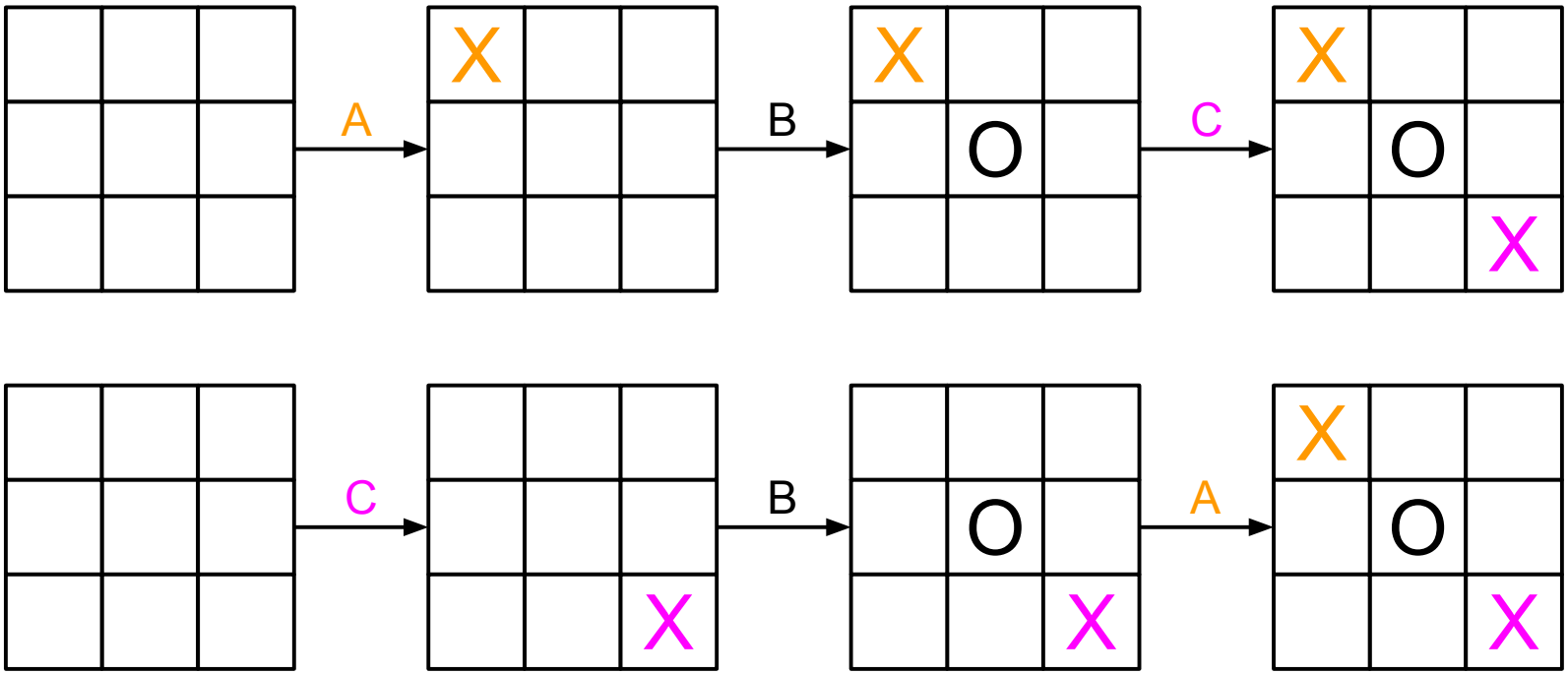
Outline

MCTS applied to Go

What variations can we make specific to Go?
In Go each player takes turn placing pieces on a game board

- How much does the order of these moves matter?
- Can we use this to improve MCTS in the context of Go?

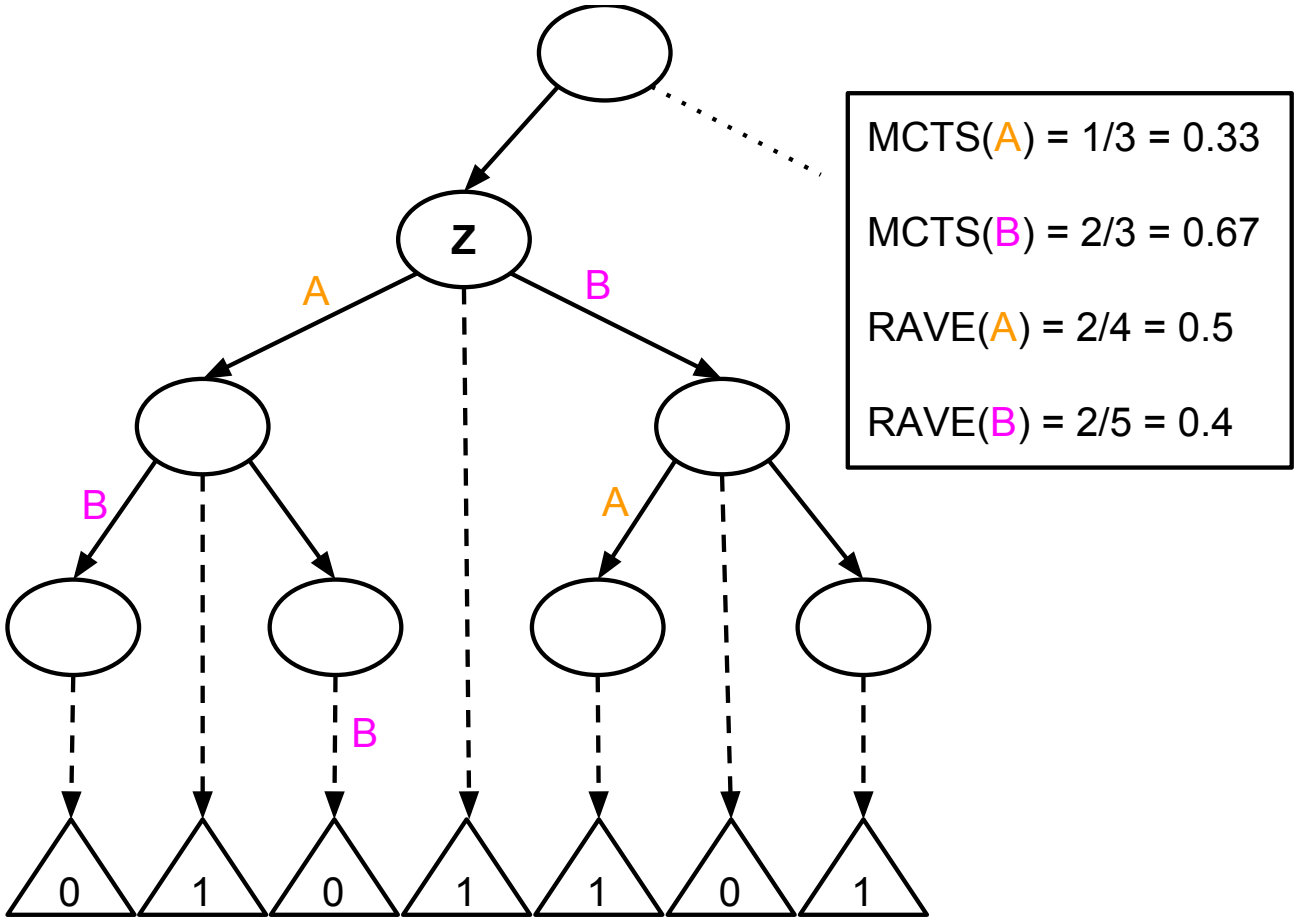
Tree Redundancy



Rapid Action Value Estimate (RAVE)

- Takes advantage of tree redundancy
- Stores the value of a move with in a subtree at each node

RAVE Diagram



RAVE

- Very powerful approach
- Each simulation provides us with more information
- This approach is used by the top computer Go programs

Results

- Deterministic approaches could hardly defeat low level amateurs
- Computer Go programs use RAVE with MCTS
  - MoGo
  - Crazy Stone
- Can compete against top pros in 9x9 Go
- Can compete against top pros in handicapped 19x19 Go