

Monte Carlo Search Tree and Its Applications

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April 25, 2015

Kasparov vs Deep Blue



Kasparov vs Deep Blue

Great display of artificial intelligence Techniques employed by IBM

- ▶ Brute force deterministic approach
- ▶ human knowledge

Limitation

- ▶ scalability into larger search spaces

Outline

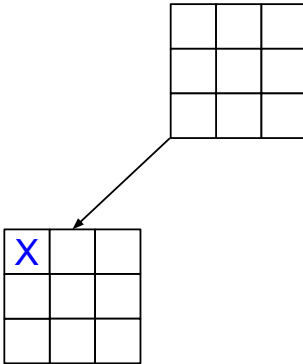
Introduction

Background

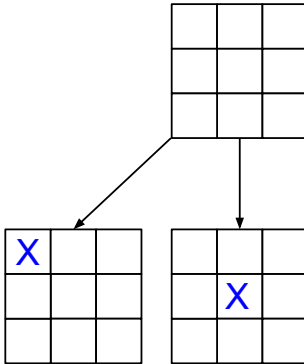
Monte Carlo Tree Search (MCTS)

- ▶ Combines random sampling and game trees
- ▶ Probabilistic not deterministic
- ▶ Useful for problems with larger search spaces
 - ▶ Game board for Chess: 8x8
 - ▶ Possible games of Chess: 10^{120}
 - ▶ Game board for Go: 19x19
 - ▶ Possible games of Go: 10^{761}

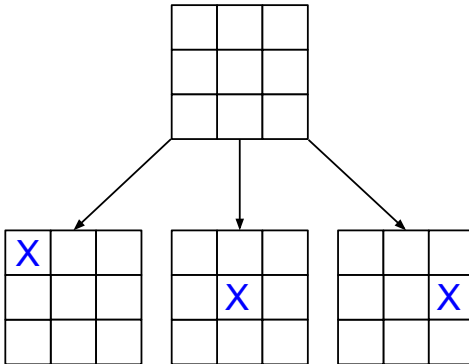
TicTacToe Diagram



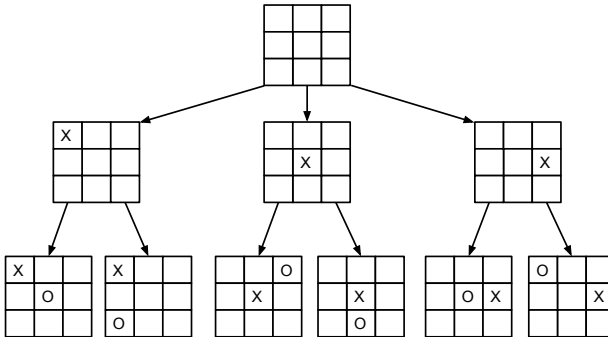
TicTacToe Diagram



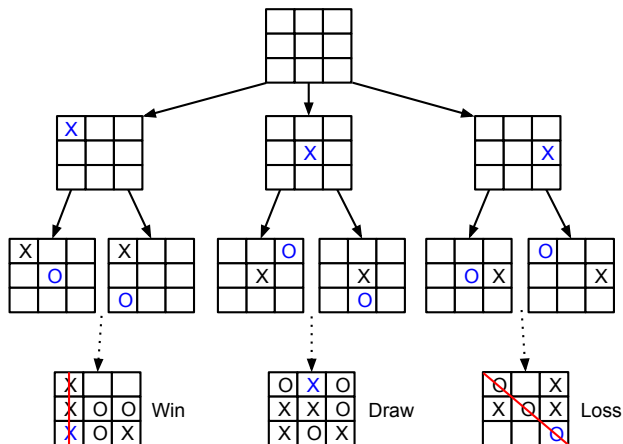
TicTacToe Diagram



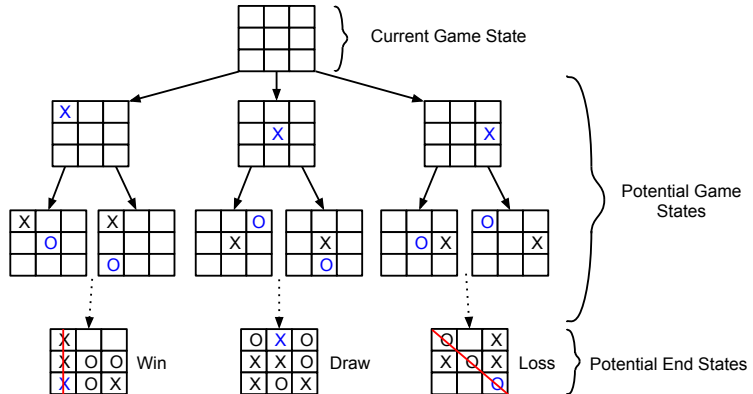
TicTacToe Diagram More Levels



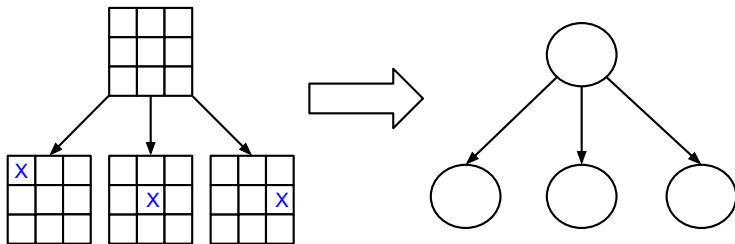
TicTacToe Diagram



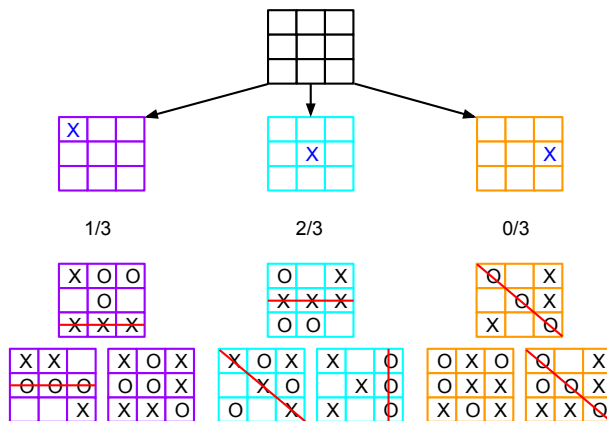
TicTacToe Diagram



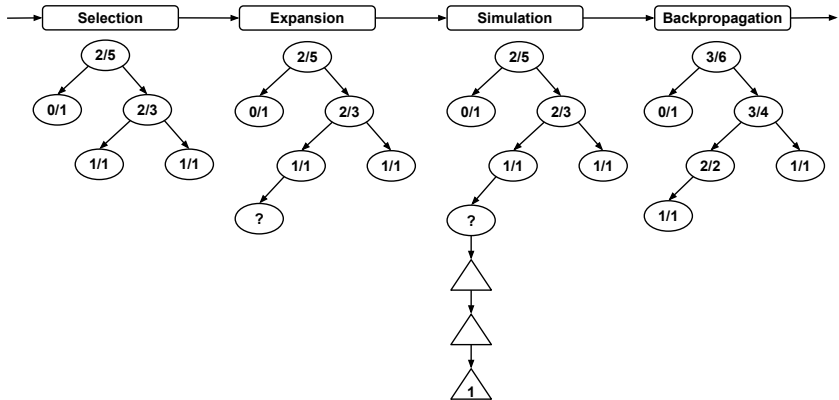
Tree Structure



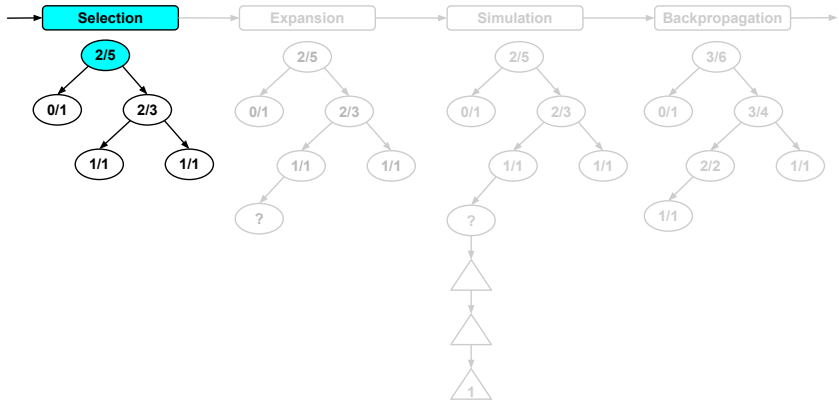
Sampling



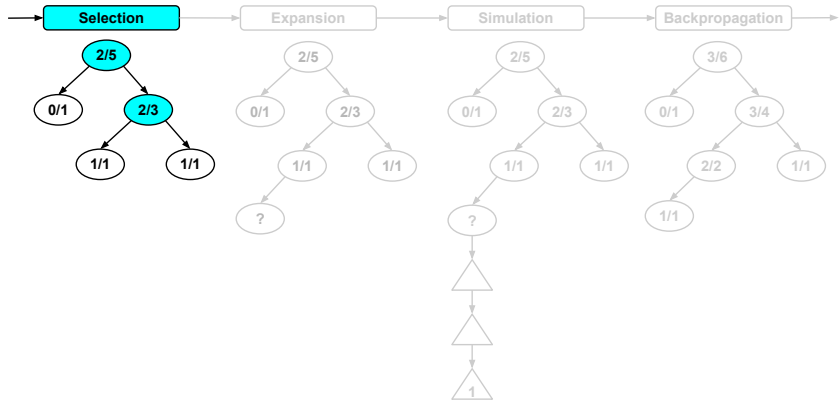
Four Steps Diagram



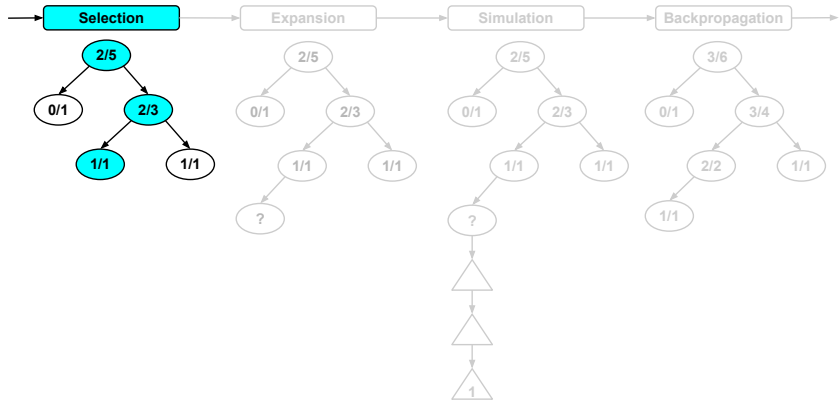
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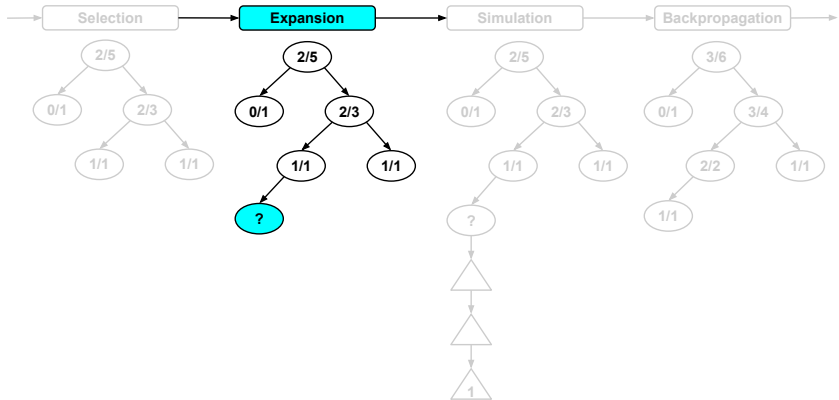
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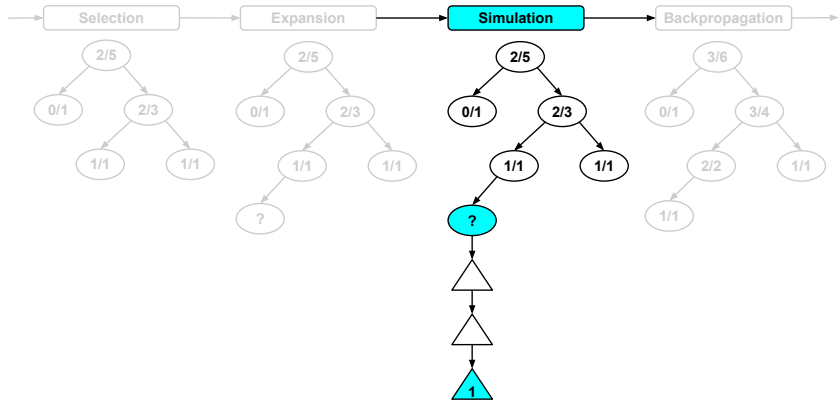
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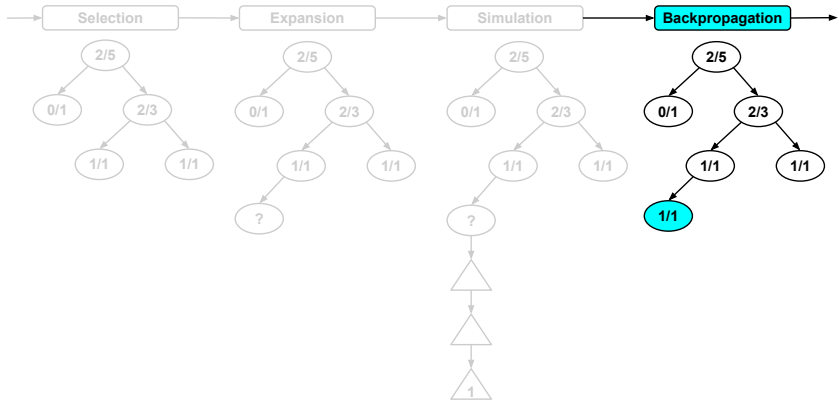
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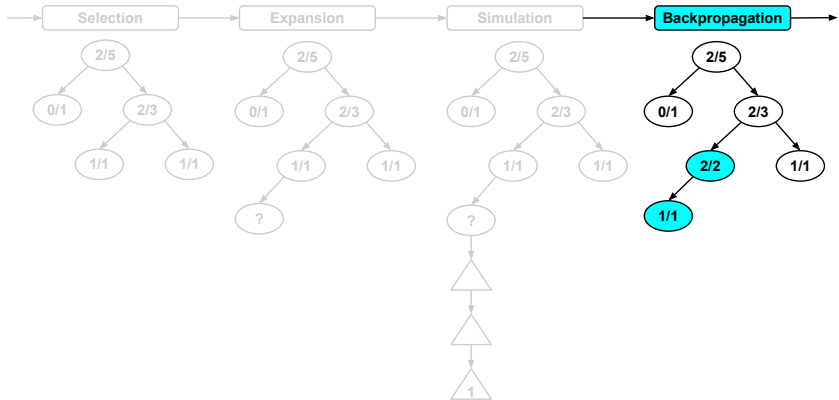
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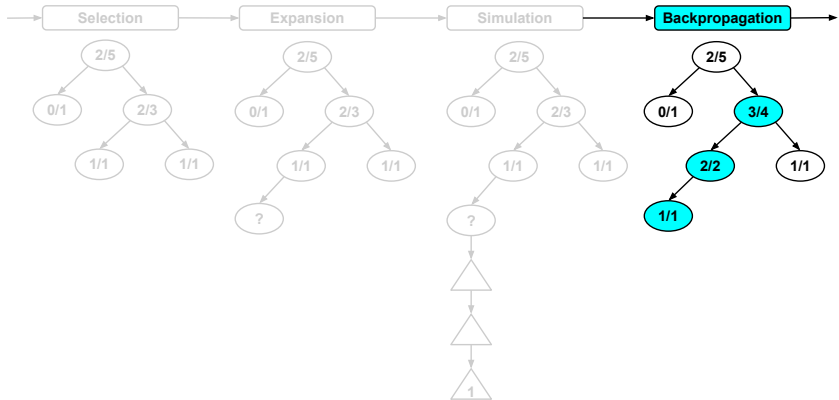
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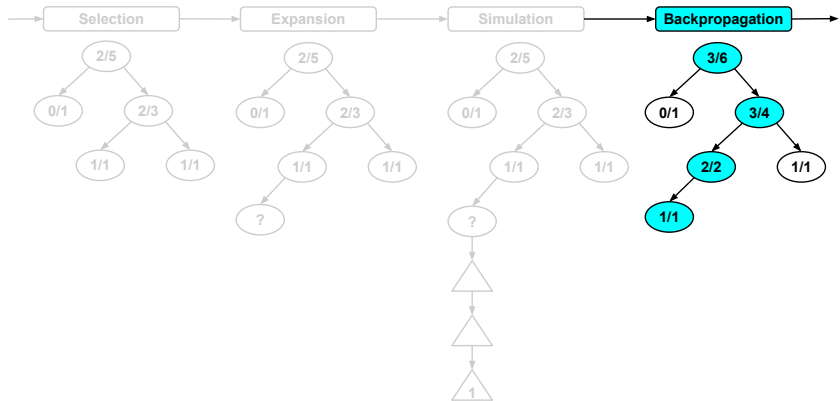
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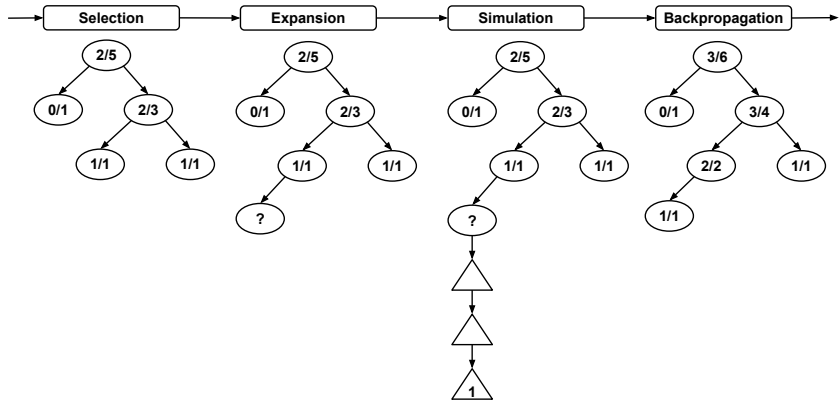
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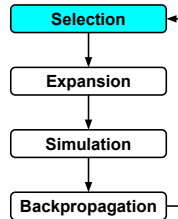
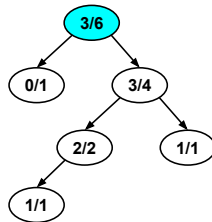
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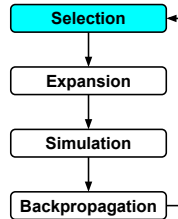
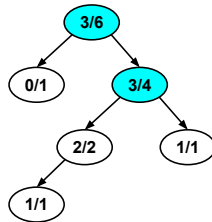
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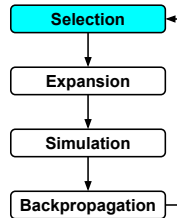
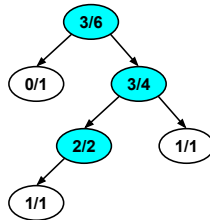
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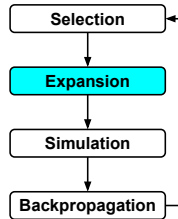
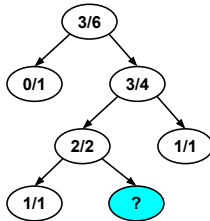
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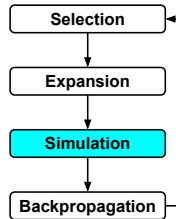
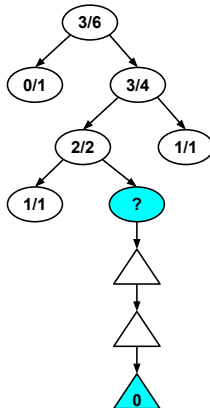
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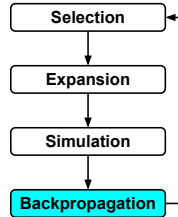
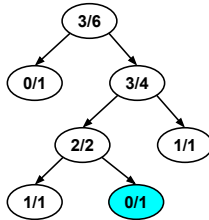
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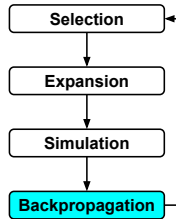
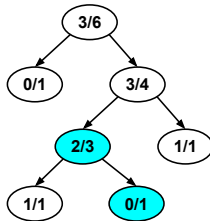
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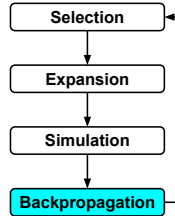
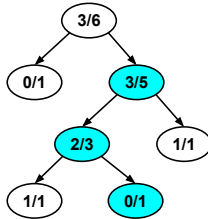
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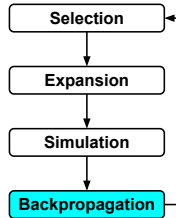
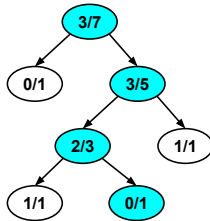
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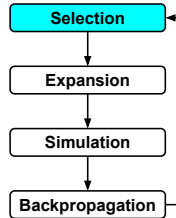
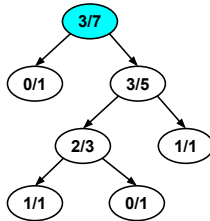
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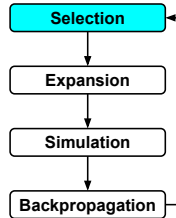
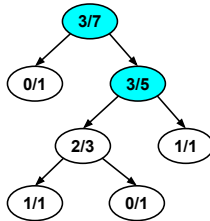
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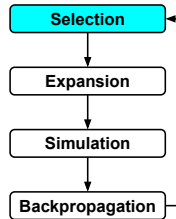
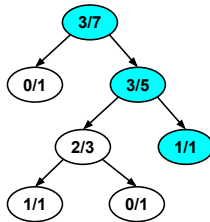
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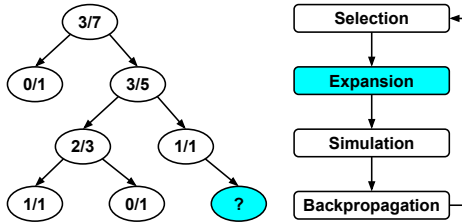
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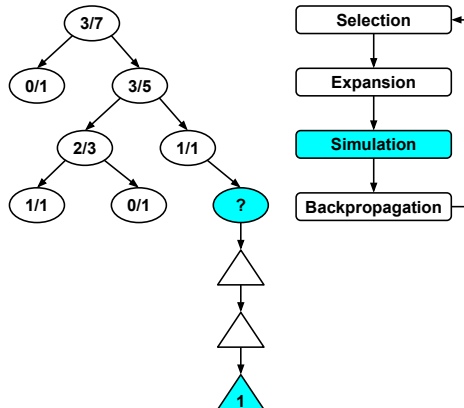
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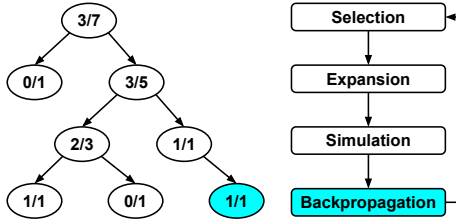
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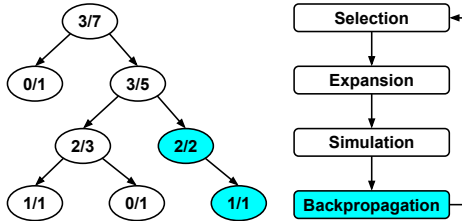
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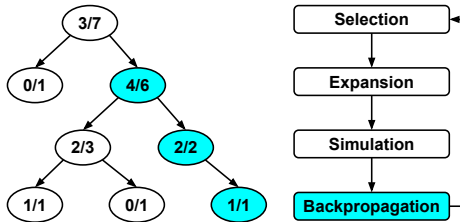
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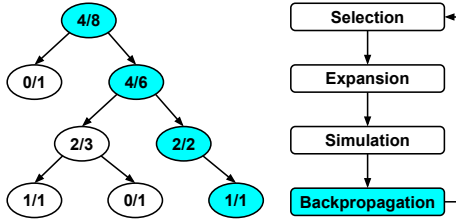
Four Steps Diagram



Four Steps Diagram



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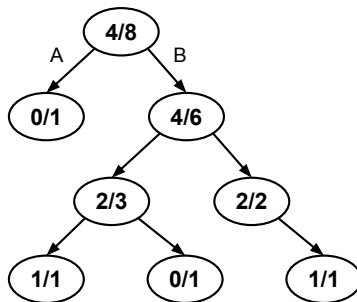
What Happens When We Choose a Move?

Now we have:

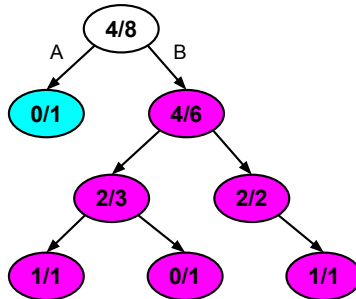
- ▶ A tree structure
- ▶ A method of generating the tree

What happens when we need to choose a move?

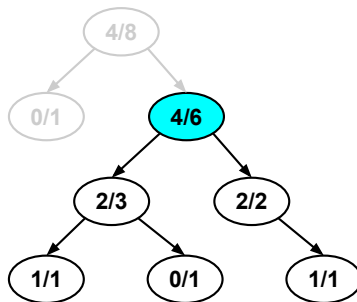
Choosing a Move



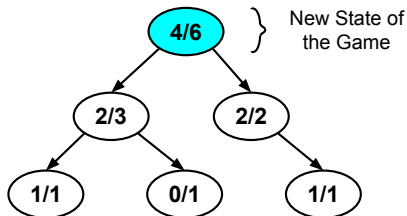
Choosing a Move



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

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

- ▶ W represents the number of simulated wins
- ▶ N represents the total number of simulations