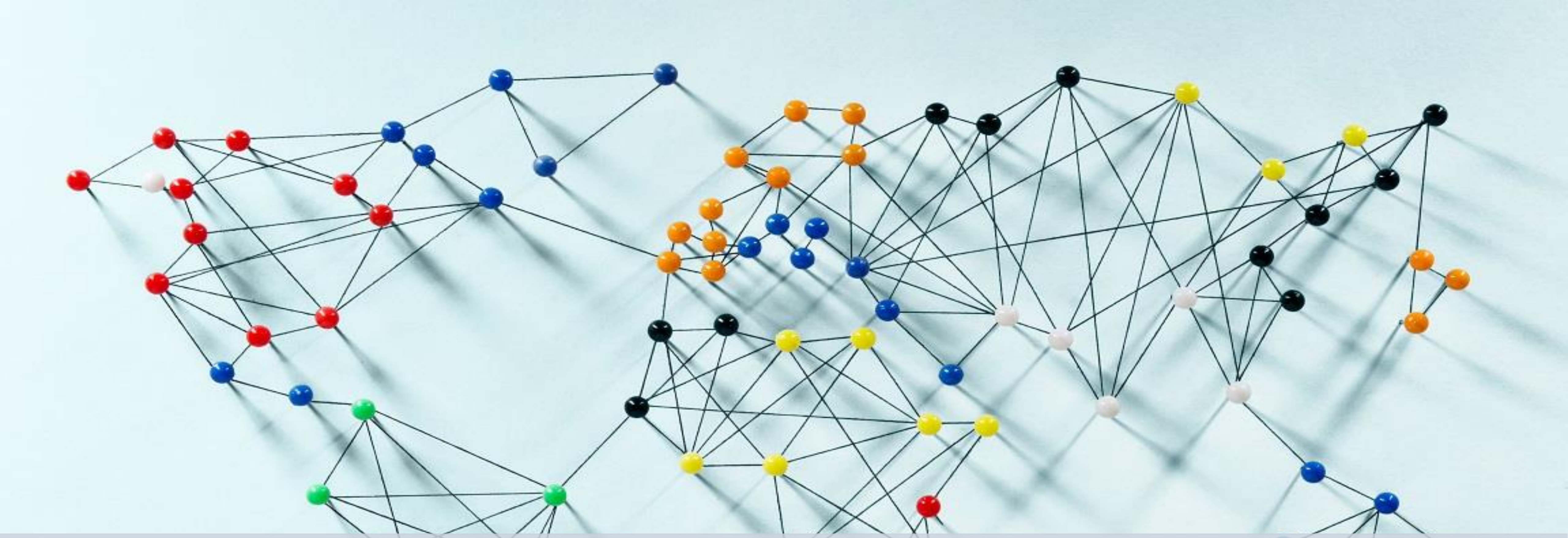

Graph theory, Recursion and its implementation in board games

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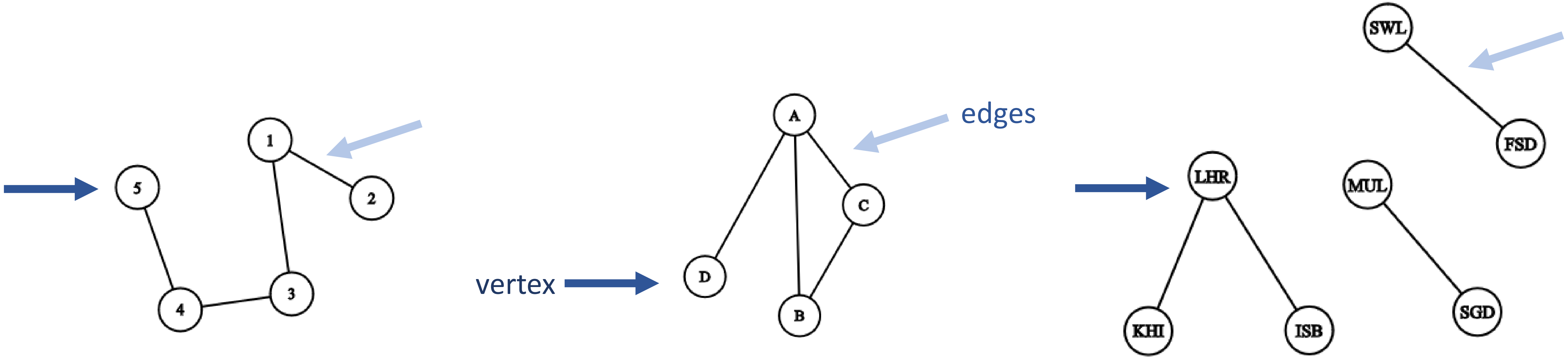
GRAPH : a list of pairs of "things" called nodes/vertices, and lines between those points, called edges

A = {(1, 2), (1, 3), (3, 4), (4, 5)}

B = {(A, B), (B, C), (A, C), (A, D)}

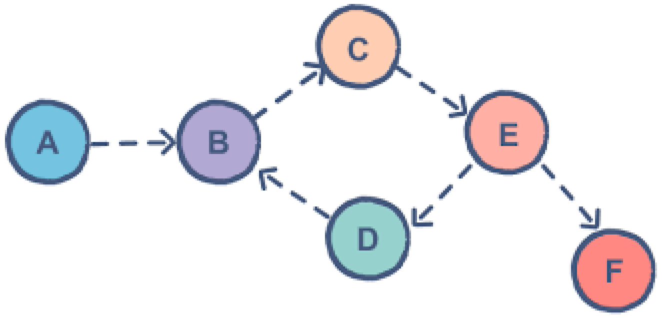
C = {(LHR,KRA), (LHR,ISB), (FSD,SWL), (STD,MUL)}



Directed and undirected graphs?

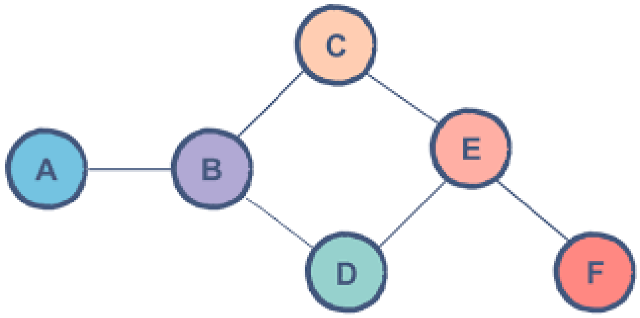
Directed Graphs:

directed graphs are typically used to model sequential games, information flow, or influence



Undirected Graphs:

Graphs where the direction in not required.



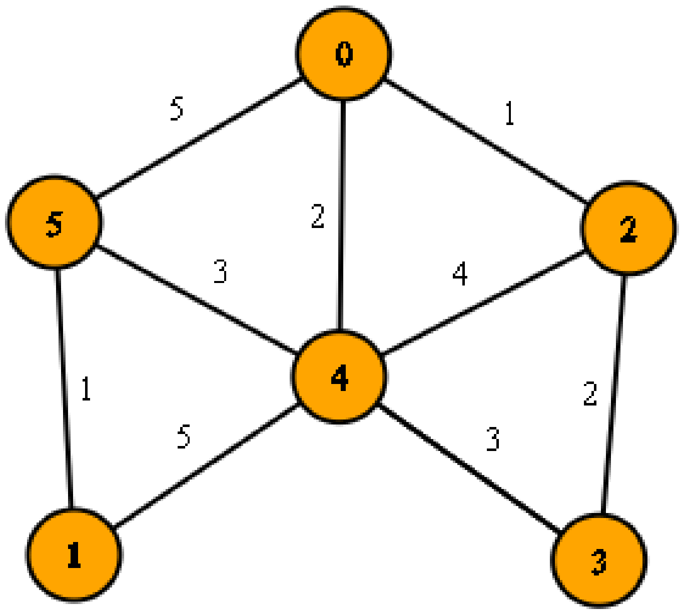
Weighted Graphs

Graphs where not all edges are equal, but they have different ‘weights’ allocated to them.

The weight represents the cost or benefit of a particular action in context of board games.

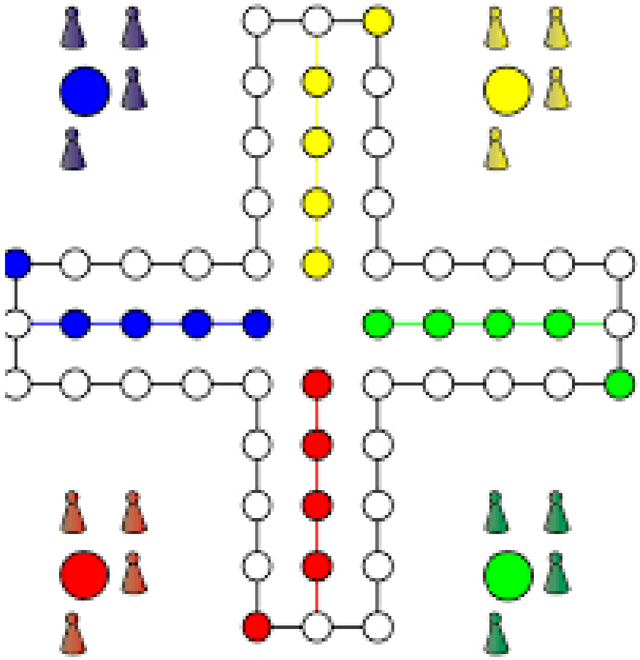
USE IN GAME:

- Weights give value to moves:
    - Prioritize winning
    - Not letting opponent win
    - Maximize advantage and minimize losses

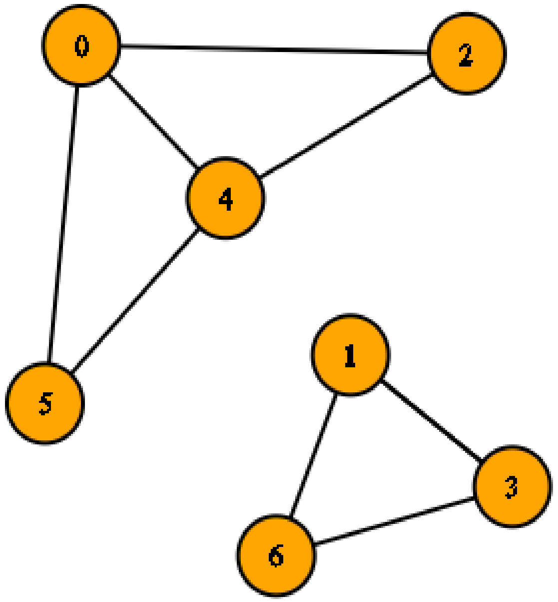


Connected vs Disconnected Graphs

A graph is called connected when a path exist between all of its vertices.



A graph is called disconnected when a path doesn't exist between all of its vertices.



RECURSION:

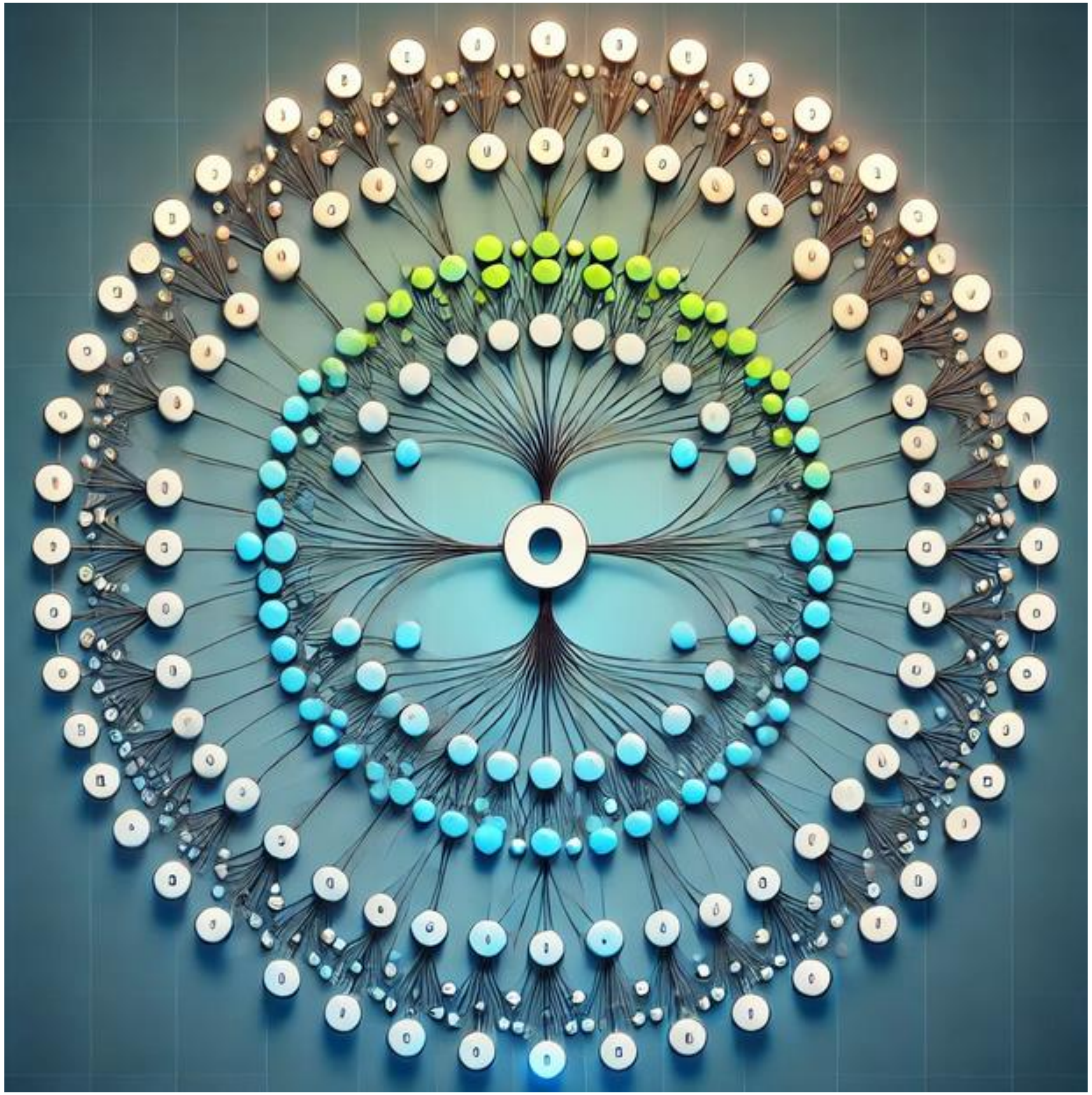
- Recursion is a process where a function calls itself to solve a problem.
- It stops at a **defined base case** to avoid infinite loop
- In board games, recursion helps explore possible future game states to evaluate optimal moves.

GRAPHS AND RECURSION:

•Graph theory identifies the structure of the game (e.g., win paths).

•Recursion explores these structures, simulating possible moves and counter-moves.

•Together, they form the backbone of AI strategies in complex board games like Gomoku and chess

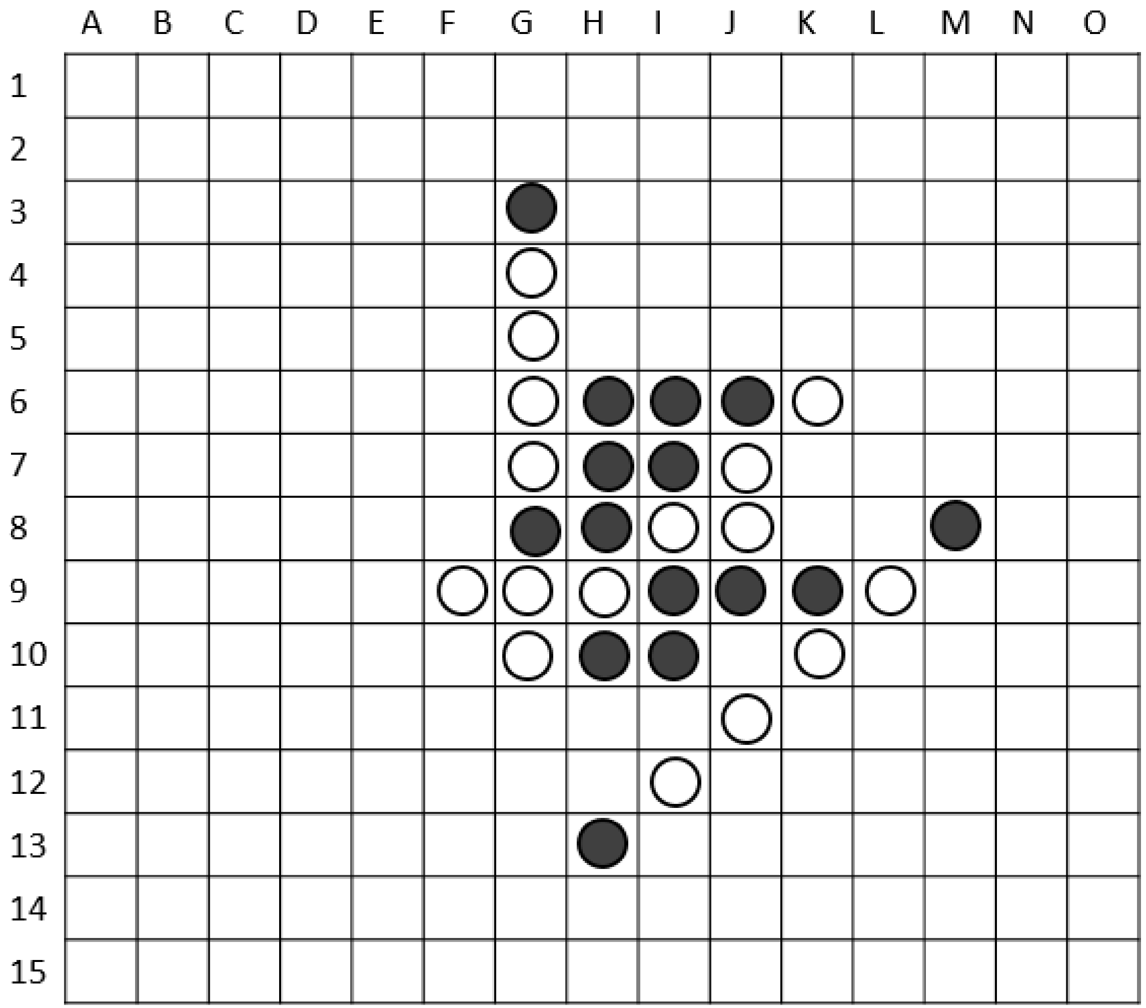


Graph in Board Games

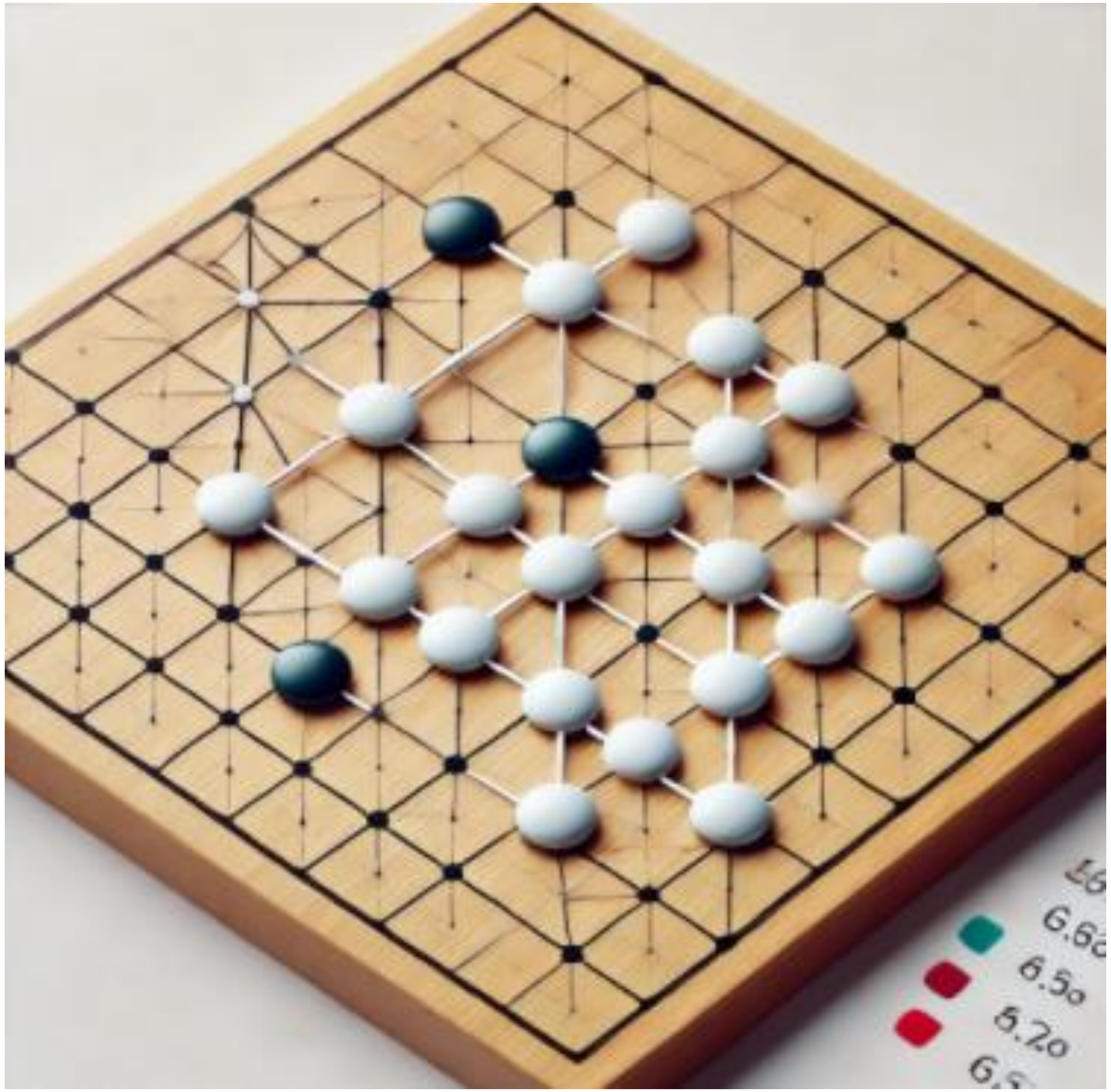
Most board games are played two-dimensional grid.

• Nodes represent the cells where game pieces are placed.

• Winning conditions involve finding paths (edges) with consecutive stones.



WHAT IS GOMOKU?



Introduction to Gomoku

Gomoku (**Five in a Row**) is a board game played on a grid where players place stones to form a line of five consecutive stones.

Graph Model:

- **Vertices (Nodes)** represent each cell.
- **Edges** represent possible moves between adjacent positions.

Graph theory is used to model the **entire board** and analyze the **connections** between stones.

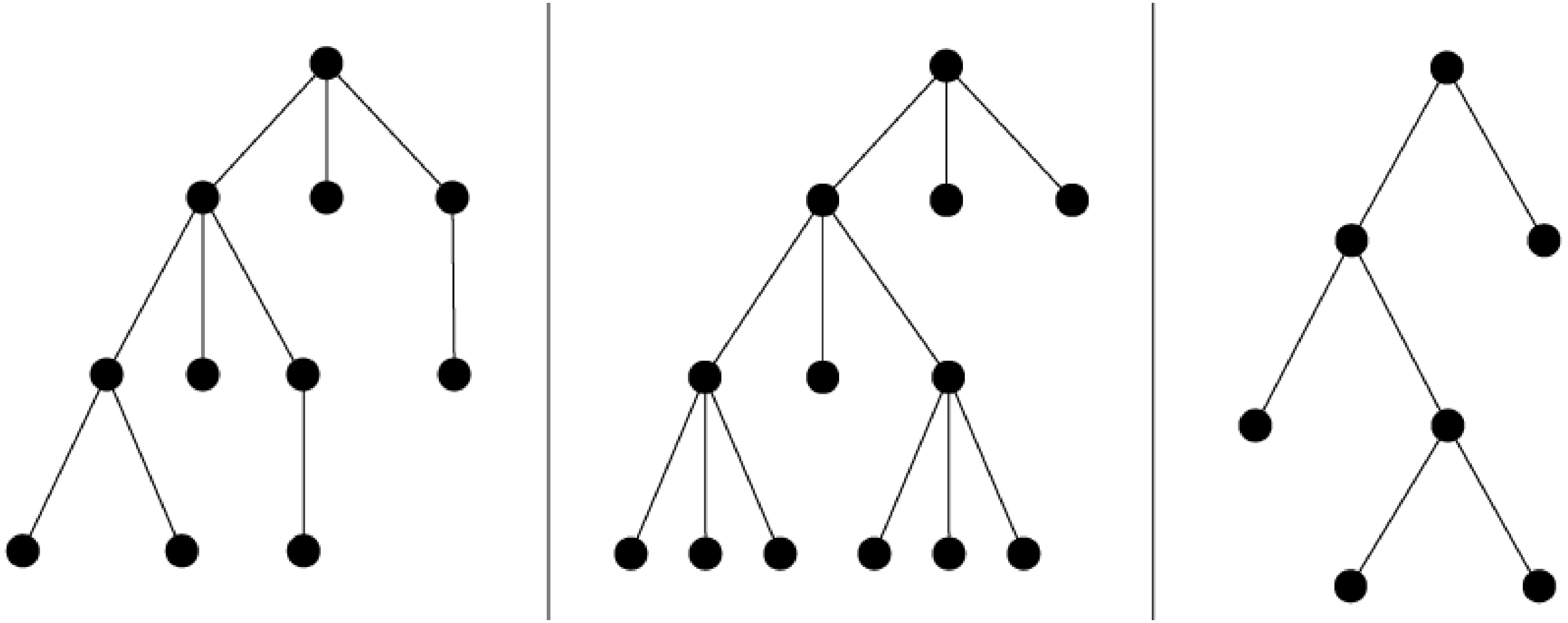
ROLE OF RECURSION

- **Exploring Moves:**
  - AI can use recursion to evaluate multiple future moves, creating a **game tree** structure.
  - Each recursive call simulates a potential move, building layers of possible future game states.

- **AI Strategy:**
  - **Find Winning Moves**
  - **Block Opponent Moves**

TREES

- The **root** represents the current game state.
- Each **branch** represents a move by either the AI or the opponent.
- The **leaf nodes (no branches)** represent the terminal game states (win, loss, draw).



Path finding

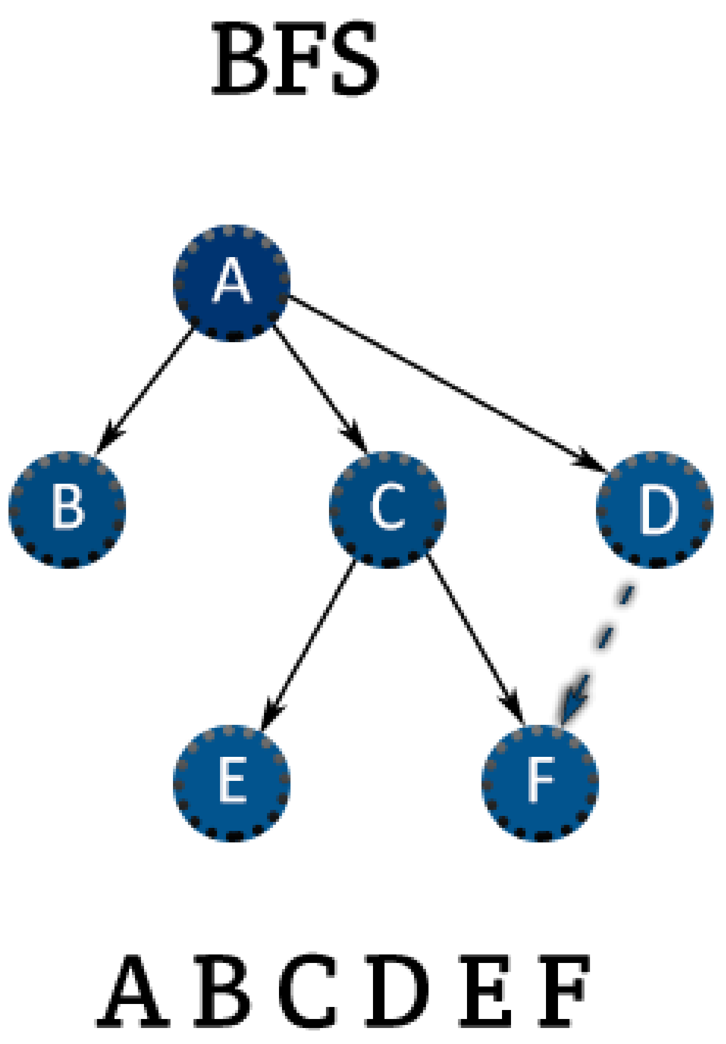
“**Pathfinding** refers to the process of finding a path from one point (vertex) to another in a graph.”

Although not as crucial in Gomoku as other games, pathfinding can help determine the most optimal moves by analyzing unblocked paths or identifying potential threats (e.g., blocking an opponent’s path to five pieces).

For our Gomoku case study we used the BFS algorithm…

Breadth-First Search

- BFS starts by exploring adjacent moves and extends outward
- AI uses this to play ‘best moves’
- Extends outwards until end of board, or winning move found



Minimax Algorithm

The game is represented as a **tree.**

The algorithm alternates:

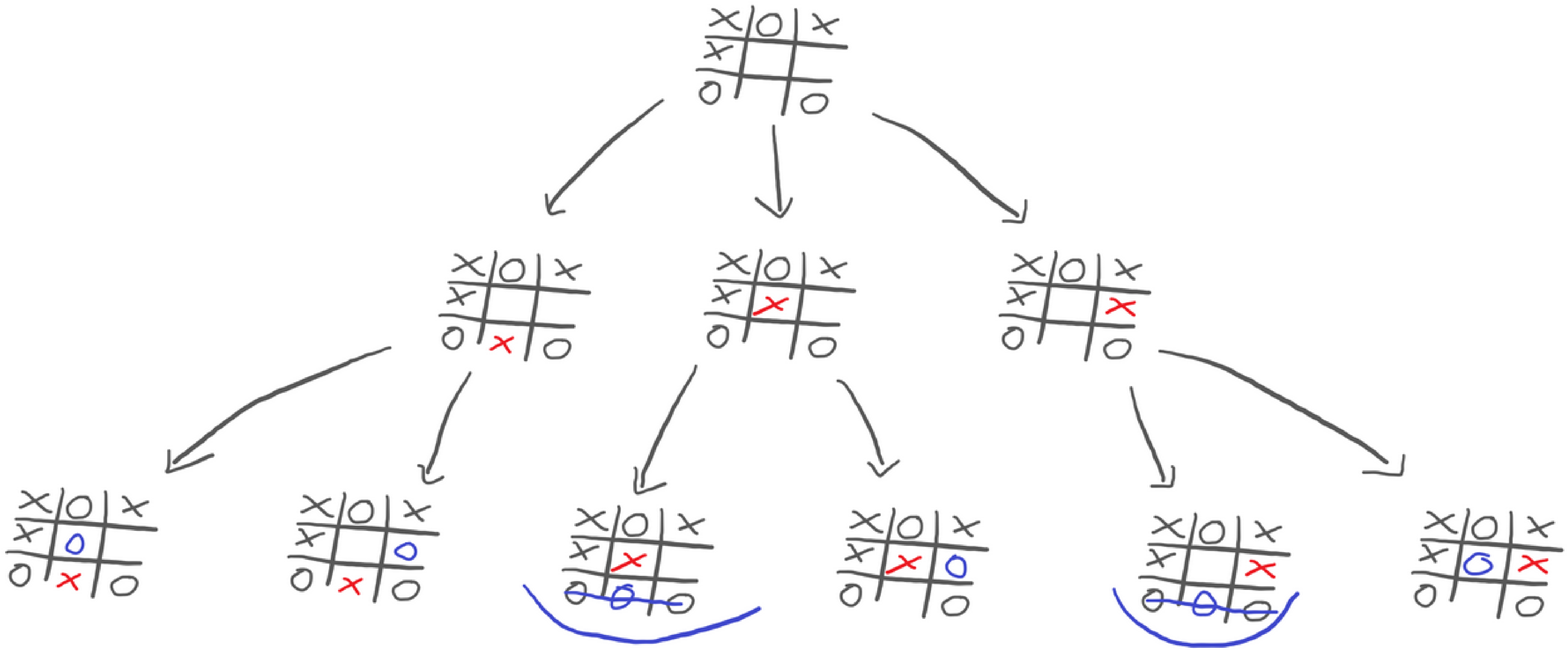
- **Maximizer**: Tries to maximize the score
- **Minimizer**: Tries to minimize the score

It **recursively** evaluates all possible game states down to the terminal states

Backtracking from the terminal states, it assigns a score to each move by choosing the best option for the player whose turn it is.

Minimax Algorithm:

Chooses the best possible move for a player by simulating all possible future moves and their outcomes.



Alpha-Beta Pruning

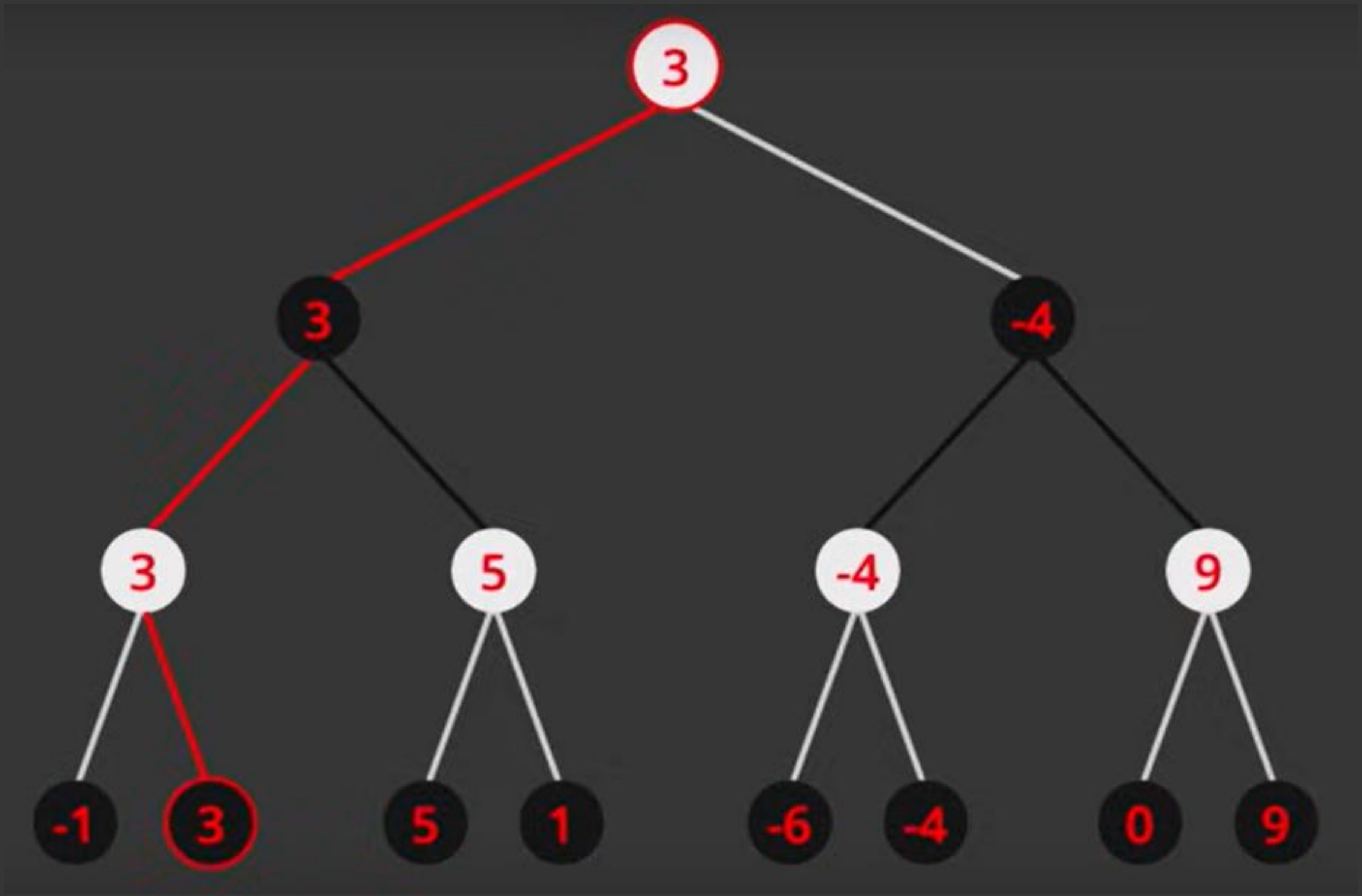
- an optimization technique for minimax algorithm.
- Reduces total number of notes to be evaluated by eliminating or pruning them if they don’t affect final evaluation.

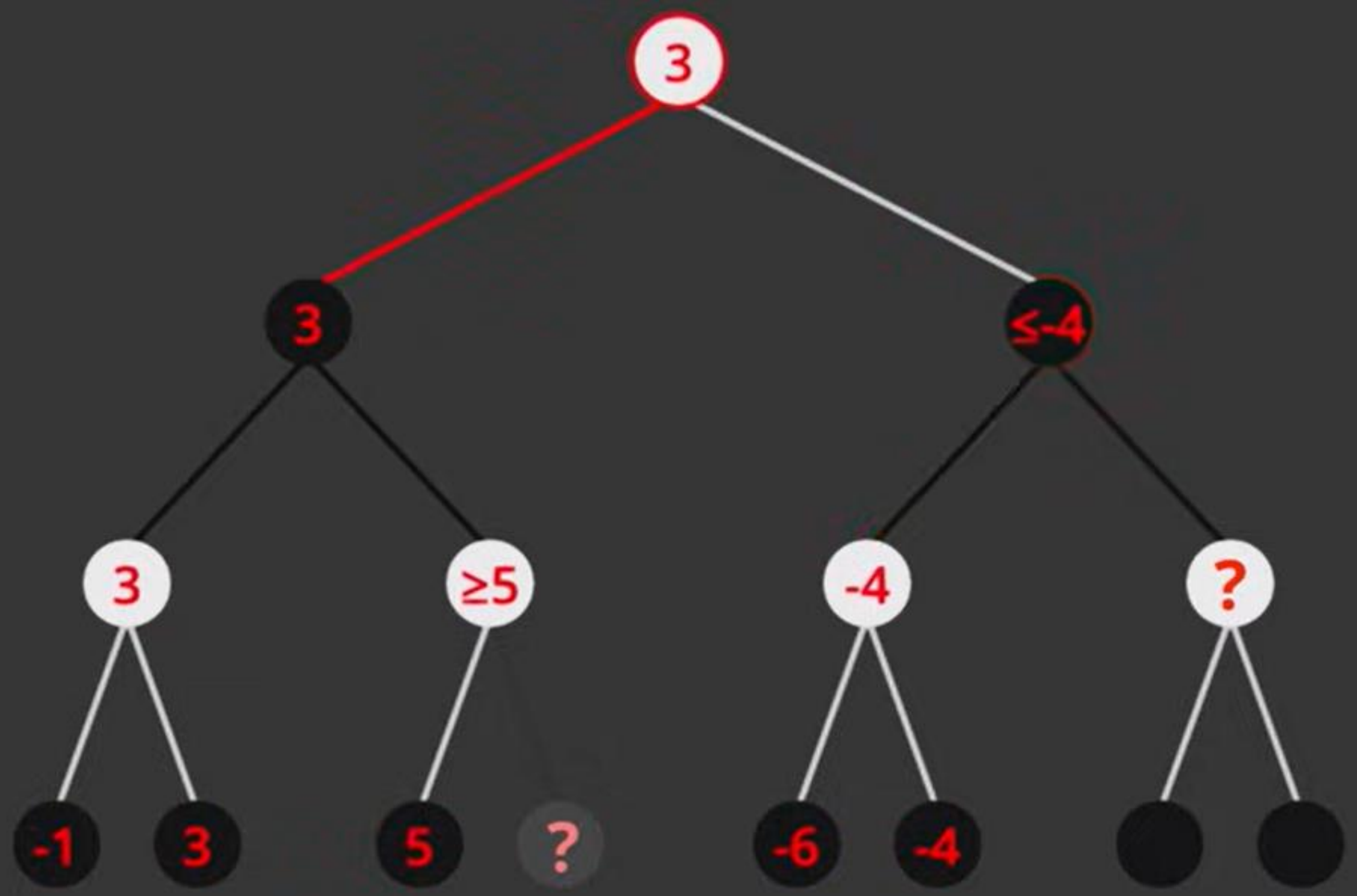
Alpha (α): The best value the maximizer currently can guarantee.

Beta (β): The best value the minimizer currently can guarantee.

During the traversal:

If a branch's potential outcome is worse than an already evaluated branch for either player, that branch is eliminated.


3
3
-4
3
5
-4
9
-1
3
5
1
-6
-4
0
9


3
3
≤-4
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≥5
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-1
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5
?
-6
-4

```
X O . . . . . .
. O X . X . . .
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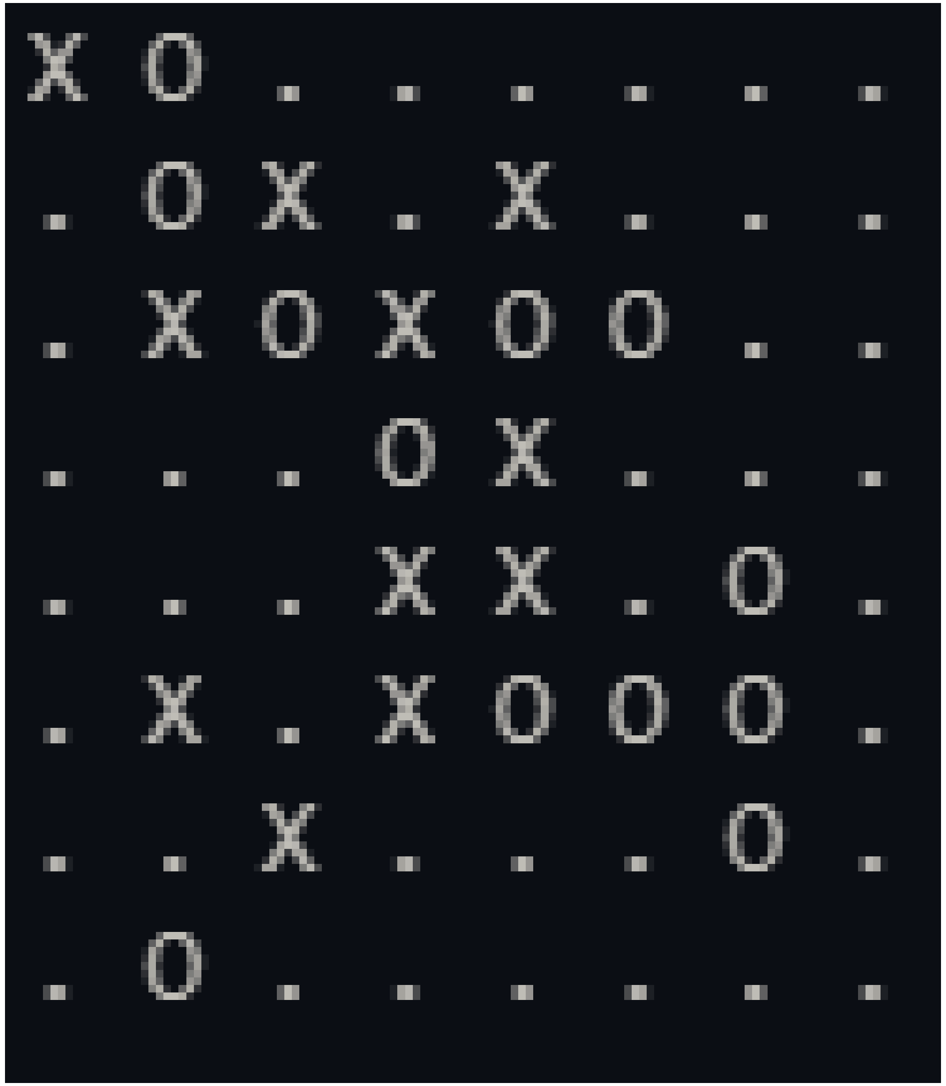
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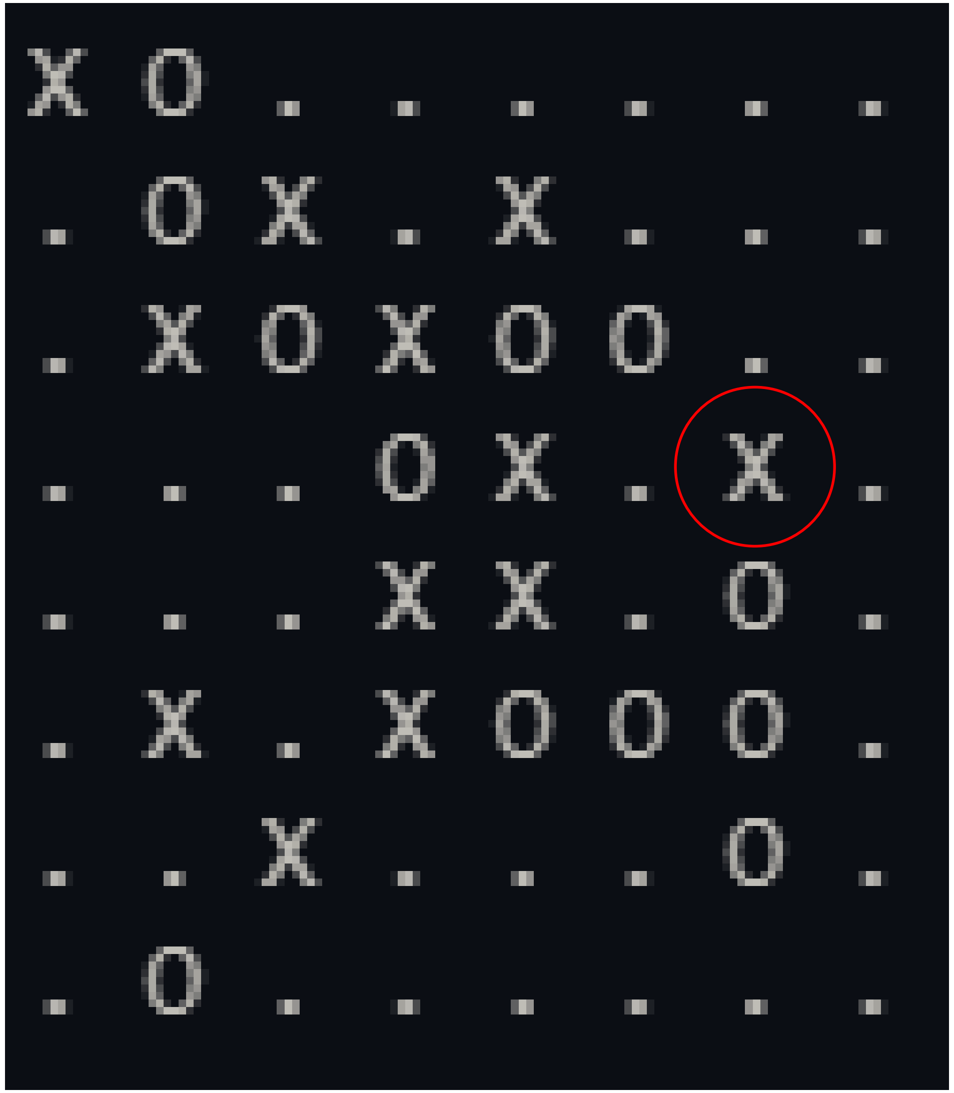
X O . . . . . .
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CONCLUSION

- **Graph Theory:**

  Models the game board and simulates moves, creating a network of possibilities.

- **Recursion:**

  Explores future game states, building a game tree for move evaluation.

- **AI in Board Games**

  Graph theory and recursion work hand-in-hand to make AI in board games like Gomoku capable of simulating, evaluating, and choosing the best moves.

Graph theory and recursion deepens our understanding of mathematical structures while transforming practical areas like game development. These concepts enable smarter AI, richer game mechanics, and effective problem-solving, bridging gap between theoretical knowledge and real-world applications.

- Group5

Thank you for your attention!

Feel free to ask any questions, share thoughts or discuss further.

Looking forward to insightful discussions!