National University
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Advanced Tic-Tac-Toe(4x4)

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1. Project Overview

- **Project Topic:** A 4x4 Tic-Tac-Toe game with added power moves such as "Swap" and "Block" to increase complexity.
- **Objective:** Develop a strategic AI using the **Minimax algorithm with Alpha-Beta Pruning** to handle an expanded board size and new mechanics.

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2. Game Description

Original Game Background

- Traditional Tic-Tac-Toe is a **3x3** game where players take turns placing their marks (**X or O**) on the board.
- The goal is to align **three marks in a row**, column, or diagonal.
- In a 4x4 version, the objective is extended to **four marks in a row** instead.

Innovations Introduced

1. **4x4 Grid:** Expands the strategy space, making AI calculations more complex.
2. **Power Moves:** Each player gets a limited number of special moves to use strategically:
    - **Swap (2 uses per game):** Swap the position of any two marks on the board.
    - **Block (1 use per game):** Temporarily block a cell from being played for one turn.

3. **Win Condition:** Players must align **four of their marks** in a row, column, or diagonal.

Impact on Gameplay:

- Increases strategic depth, requiring players to plan ahead.
- Makes AI implementation more complex as it needs to factor in power moves.

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3. AI Approach and Methodology

AI Techniques to be Used:

1. **Minimax Algorithm:**
    - The AI will analyze possible moves and choose the best one based on future outcomes.
    - The algorithm will need to be modified to handle a 4x4 grid instead of a 3x3.
2. **Alpha-Beta Pruning:**
    - Optimizes Minimax by eliminating unnecessary calculations, improving efficiency.
3. **Heuristic Design:**
    - Board evaluation function to rank game states:
        - +1000 for a win, -1000 for a loss.
        - +50 for three marks in a row (potential win setup).
        - +10 for two marks together with an empty space next to them.
    - Power moves will add additional complexity to heuristics.
4. **Complexity Analysis:**
    - A standard 3x3 Tic-Tac-Toe has a **state space complexity of ~9!**
    - A 4x4 version with power moves increases complexity exponentially.
    - Alpha-Beta Pruning will help reduce the search space significantly.

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4. Game Rules and Mechanics

Modified Rules:

- Players take turns placing marks on the **4x4** board.
- Each player gets **2 Swap moves** and **1 Block move** per game.
- Swaps cannot be used **immediately after an opponent's move.**
- Blocked cells become available again after **one turn.**

Winning Conditions:

- A player wins when they align **four of their marks** in a row, column, or diagonal.

Turn Sequence:

1. Player places a mark (X or O).
2. Player may use a power move if available.
3. Turn ends, and the opponent plays.
4. Repeat until a player wins or the board is full.