Project Title: Hexagonal Nine Men's Morris

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1. Project Overview

Project Topic:

This project introduces a modified version of Nine Men's Morris played on a **hexagonal board** instead of the traditional square board. The hexagonal layout increases movement options, making the game more complex and strategically diverse.

Objective:

The main goal of this project is to develop an AI for Hexagonal Nine Men's Morris using **Minimax with Alpha-Beta Pruning** to enhance decision-making in a multi-player setting. The innovation aims to introduce **new strategic depth** by modifying board geometry and movement options.

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2. Game Description

Original Game Background:

Nine Men's Morris is a classic two-player strategy game where players place and move pieces to form **three-in-a-row mills**. A formed mill allows a player to remove an opponent's piece. The game proceeds in three phases: **placing, moving, and final capture.**

Innovations Introduced:

- **Hexagonal Board Layout**: Unlike the original square board, the hexagonal grid allows movement in **six directions** instead of four, making strategies more complex.
- **Expanded Mill Formations**: Mills can now be formed diagonally as well, increasing tactical possibilities.
- **Additional Movement Patterns**: Players can move in ways that weren't possible in the traditional game, leading to **longer, more strategic gameplay.**

- **New AI Challenges**: The AI needs to evaluate **more paths** due to the increased movement options.

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3. AI Approach and Methodology

AI Techniques to be Used:

- **Minimax Algorithm**: Evaluates game states to make optimal moves. Modified for multi-player adaptability.
- **Alpha-Beta Pruning**: Reduces computation by eliminating unnecessary game tree branches.

Heuristic Design:

- **Piece Value**: Weight assigned based on the number of pieces remaining.
- **Mill Potential**: Evaluates board positions where a player is close to forming a mill.
- **Opponent Disruption**: Assigns value to moves that block an opponent's mills.

Complexity Analysis:

- The traditional **Nine Men's Morris** has a manageable game tree complexity, but **adding a hexagonal grid increases possible moves**, making AI calculations more expensive.
- Expected **time complexity for Minimax with Alpha-Beta Pruning**: O(b^d) where **b = branching factor** and **d = search depth**.

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4. Game Rules and Mechanics

Modified Rules:

- Players place pieces on a **hexagonal grid** instead of a square one.
- Pieces can move in **six directions** instead of four.
- Mills can be formed **horizontally, vertically, and diagonally**.
- The win condition remains the same: **reduce the opponent to two pieces or block all moves**.

Winning Conditions:

- A player wins if the opponent has **fewer than three pieces** remaining.
- A player wins if the opponent has **no legal moves available**.

Turn Sequence:

- **Phase 1: Placement** - Players take turns placing pieces.
- **Phase 2: Movement** - Players move pieces to adjacent positions.
- **Phase 3: Capture** - Mills allow removing an opponent's piece.
- **Final Phase** - If a player has only **three pieces left, they can jump** to any open position.

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5. Implementation Plan

Programming Language:

- **Python** (for AI and game logic)

Libraries and Tools:

- **Pygame** (for GUI development)
- **NumPy** (for data structures and handling game states)

Milestones and Timeline:

Week	Task
1-2	Game design and rule finalization
3-4	AI strategy development (Minimax and heuristics)
5-6	Coding and testing game mechanics
7	AI integration and testing
8	Final testing and report preparation

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6. References

- Research papers on **Minimax and Alpha-Beta Pruning**.

- Studies on **hexagonal board games**.
- Existing implementations of **Nine Men's Morris AI**.