Project Title: AI-Powered Hex Board Game

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Course: AI
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1. Project Overview

Project Topic:

The project is based on the Hex board game, an abstract strategy game where two players compete to create an unbroken path connecting opposite sides of the board. Our implementation enhances the traditional game by integrating an AI opponent that uses Minimax with Alpha-Beta Pruning for decision-making.

Objective:

The primary goal of this project is to develop an AI-powered Hex game where players can compete against a computer opponent. The AI will employ advanced search techniques such as Minimax to make optimal moves.

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2. Game Description

Original Game Background:

Hex is a two-player strategy game played on a hexagonal grid. Each player has a designated side of the board and must connect their respective sides with an unbroken path of their own pieces. The game was invented by Piet Hein in 1942 and later popularized by John Nash. The game is known for its strong combinatorial complexity and deep strategic play.

Innovations Introduced:

- **AI Opponent:** The project features a challenging AI that utilizes Minimax with Alpha-Beta Pruning for decision-making.
- **Multiple Difficulty Levels:** The AI's search depth can be adjusted to create varying difficulty levels.
- **Pathfinding Heuristics:** AI evaluates board positions using shortest path algorithms, enhancing move selection.

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3. AI Approach and Methodology

AI Techniques to be Used:

- **Minimax Algorithm:** Determines the best move by simulating all possible moves and their outcomes.
- **Alpha-Beta Pruning:** Optimizes Minimax by reducing the number of nodes evaluated.
- **Pathfinding Heuristics:** AI will assess the shortest path to victory using graph-based algorithms.

Heuristic Design:

- The AI evaluates the board using metrics such as connectivity, piece placement, and potential blocking moves.

Complexity Analysis:

- **Minimax (without pruning):** $O(b^d)$, where $\boldsymbol{b}$ is the branching factor and $\boldsymbol{d}$ is the depth.
- **Minimax with Alpha-Beta Pruning:** $O(b^{\frac{d}{2}})$, significantly reducing the search space.

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4. Game Rules and Mechanics

Modified Rules:

- Standard Hex rules apply.
- Players take turns placing pieces to connect their respective sides of the board.
- The AI will automatically play when in single-player mode.

Winning Conditions:

- A player wins by successfully connecting their two opposite edges with an unbroken path of their pieces.

Turn Sequence:

- Players take alternating turns.
- The AI responds instantly after the player moves, using a search algorithm to determine its optimal move.

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5. Implementation Plan

Programming Language:

- Python

Libraries and Tools:

- **NumPy** (for data handling)
- **NetworkX** (for pathfinding and graph analysis)

Milestones and Timeline:

- **Week 10-11:** Game design and rule finalization
- **Week 12-13:** AI strategy development (Minimax and heuristics)
- **Week 14-15:** Coding and testing the game mechanics
- **Week 16:** AI integration and testing
- **Week 17:** Final testing and report preparation