Project Title: HexAI - AI Strategy for Hex Game

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1. Project Overview

Project Topic:
HexAI is an artificial intelligence project focused on the game of Hex, a strategic board game played on a hexagonal grid. The innovation introduced involves enhancing AI decision-making using the Minimax algorithm with Alpha-Beta Pruning and Monte Carlo Tree Search (MCTS). Additionally, reinforcement learning techniques will be explored to improve AI gameplay over time.

Objective:
The primary goal of this project is to develop an advanced AI for the game of Hex that can play against human players or other AI opponents. The AI will employ Minimax with Alpha-Beta Pruning for efficient decision-making, and reinforcement learning to improve its strategy dynamically.

2. Game Description

Original Game Background:
Hex is a two-player strategy board game played on a hexagonal grid. Each player is assigned a color (typically red and blue) and must connect their sides of the board with an unbroken chain of their colored pieces. The game has no draws due to the Hex Theorem, ensuring a winner in every match.

Innovations Introduced:

- Minimax with Alpha-Beta Pruning
- MCTS with optimization experiments to fine-tune parameters.
- Heuristic evaluations using Dijkstra's algorithm.
- Transposition Tables to improve search efficiency.

3. AI Approach and Methodology

AI Techniques to be Used:

- **Minimax Algorithm:** Adapted for a two-player zero-sum environment.
- **Alpha-Beta Pruning:** To optimize decision-making and reduce search space.
- **Monte Carlo Tree Search (MCTS):** For probabilistic decision-making in complex game scenarios.
- **Reinforcement Learning:** To enable AI to improve over time by learning from self-play.

Heuristic Design:

- Board control heuristics (influence mapping, path potential evaluation).
- Positional advantages (proximity to winning paths, blocking opponent moves).
- Evaluation based on historical AI self-play results.

Complexity Analysis:

- Minimax with Alpha-Beta Pruning: reduced to with pruning.
- MCTS: Complexity depends on the number of simulations per move.
- Reinforcement Learning: Complexity varies based on the number of training iterations.

4. Game Rules and Mechanics

Modified Rules:

- Standard Hex rules apply, with AI capable of playing against human or AI opponents.
- AI can adjust its difficulty level based on heuristics and learned strategies.

Winning Conditions:

- The first player to connect their sides with an unbroken chain of pieces wins.

Turn Sequence:

- Players take turns placing one piece per move.
- AI makes decisions using Minimax, MCTS, or reinforcement learning-based strategies.

5. Implementation Plan

Programming Language: Python

Libraries and Tools:

- **Pygame:** For GUI rendering (if applicable)

- **NumPy:** For data handling and computation
- **Scikit-learn:** For implementing machine learning algorithms
- **TensorFlow/PyTorch:** For reinforcement learning implementation

Milestones and Timeline:

- **Week 1-2:** Game rule implementation and board setup.
- **Week 3-4:** AI strategy development (Minimax, heuristics, and Alpha-Beta Pruning).
- **Week 5-6:** Monte Carlo Tree Search (MCTS) and reinforcement learning integration.
- **Week 7:** AI testing and performance optimization.
- **Week 8:** Final testing, documentation, and project report preparation.

6. References

- wikipedia