Project Title: AI for Hex Board Game

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1. Project Overview

Project Topic:

Hex is a two-player abstract strategy board game played on a hexagonal grid. The objective is to connect opposite sides of the board with a continuous chain of pieces. The game provides a rich strategic depth, making it an ideal candidate for AI development. In this project, we aim to implement an AI capable of playing Hex using advanced search algorithms and self-play reinforcement learning techniques.

Objective:

The primary objective of this project is to develop an AI capable of playing Hex efficiently. The AI will employ:

- **Monte Carlo Tree Search (MCTS)** to evaluate game states dynamically.
- **Self-play learning** to improve over multiple iterations.
- **Heuristic-based evaluations** to enhance decision-making efficiency.

2. Game Description

Original Game Background:

Hex was invented independently by Piet Hein and John Nash. The game is played on an **N x N hexagonal grid**, typically 11x11. Players take turns placing their pieces on empty hexagons, attempting to form a connected path between their designated edges. There are no draws in Hex—one player will always win.

Innovations Introduced:

- **AI Opponent Implementation**: The AI will be trained using reinforcement learning and tree search techniques to compete against human players.
- **Difficulty Adjustment**: We will implement multiple difficulty levels by tweaking MCTS parameters.

- **Visualization & Interaction**: A user-friendly interface will be created to allow players to compete against the AI.

3. AI Approach and Methodology

AI Techniques to be Used:

- **Monte Carlo Tree Search (MCTS)** for decision-making.
- **Self-Play Reinforcement Learning** for training the AI.
- **Heuristic Evaluation** to improve move selection efficiency.

Heuristic Design:

- Positional advantage heuristic to evaluate board states.
- Edge control heuristic to influence gameplay strategy.

Complexity Analysis:

- The complexity of Hex grows exponentially with board size.
- MCTS will be optimized to manage computational constraints efficiently.

4. Game Rules and Mechanics

Modified Rules:

- Standard Hex rules apply, with the addition of AI-driven gameplay.

Winning Conditions:

- A player wins by forming an unbroken connection between their designated sides.

Turn Sequence:

- Players take turns placing pieces until one connects their sides.

5. Implementation Plan

Programming Language:

- Python

Libraries and Tools:

- **Pygame** (for GUI visualization)
- **NumPy** (for data processing)
- **PyTorch/TensorFlow** (for reinforcement learning)
- **MCTS-based libraries** (for efficient game-tree searches)

Milestones and Timeline:

- **Week 1-2**: Game board implementation & GUI design
- **Week 3-4**: MCTS-based AI development
- **Week 5-6**: Self-play reinforcement learning integration
- **Week 7**: AI testing & performance evaluation
- **Week 8**: Final testing, report preparation, and submission

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6. References

- Research papers on **Monte Carlo Tree Search and Reinforcement Learning for board games**
- Hex strategy guides and AI development resources