Project Title: 5x5 Hexapawn

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1. **Project Overview**

Project Topic: Development of a 5x5 Hexapawn game with an AI opponent using the Minimax algorithm and alpha-beta pruning.
Objective: To create a fully functional 5x5 Hexapawn game where a human player can compete against an AI opponent. The AI will be designed to make strategic decisions using the Minimax algorithm with alpha-beta pruning to provide a challenging opponent.

2. **Game Description**

Original Game Background: Hexapawn is a deterministic game invented by mathematician John Nash to demonstrate machine learning concepts. The original game is played on a 3x3 board with pawns that can move forward one square or capture diagonally forward one square. The player who advances a pawn to the opposite side of the board or captures the opponent's last pawn wins.

Innovations Introduced:

The game will be played on a 5x5 grid instead of the traditional 3x3 grid, increasing the complexity and the number of possible game states.

An AI opponent will be implemented using the Minimax algorithm with alpha-beta pruning to provide a strategic challenge to the human player.

Impact of Innovations:

The 5x5 grid significantly increases the game's complexity compared to the 3x3 version, requiring more sophisticated AI strategies.

The Minimax algorithm with alpha-beta pruning will enable the AI to evaluate multiple moves ahead, leading to more strategic and challenging gameplay.

3. **AI Approach and Methodology**

AI Techniques to be Used:

Minimax Algorithm: The Minimax algorithm will be used to determine the AI's optimal move by exploring the game tree and evaluating possible outcomes.

Alpha-Beta Pruning: Alpha-beta pruning will be implemented to optimize the Minimax algorithm by reducing the number of nodes evaluated, thus improving the AI's decision-making efficiency.

Heuristic Design:
The heuristic function will evaluate the game state based on the position of the pawns. Pawns closer to the opponent's side will be given a higher score. The number of remaining pawns for each player will also be factored into the evaluation.

Complexity Analysis:
The time complexity of the Minimax algorithm is O(b^d), where b is the branching factor and d is the depth of the search tree. Alpha-beta pruning will reduce this complexity but in the worst case, it's still exponential. Implementing the AI for the 5x5 Hexapawn game presents a significant challenge due to the increased branching factor compared to the 3x3 version.

4. **Game Rules and Mechanics**

Modified Rules:

The game is played on a 5x5 grid.

Each player starts with 5 pawns, placed on opposite rows.

Pawns move forward one square or capture diagonally forward one square.

The rules for movement and capture are the same as in the original Hexapawn.

Winning Conditions:

A player wins by advancing one of their pawns to the opposite side of the board or by capturing all of the opponent's pawns.

Turn Sequence:

The human player makes the first move.

Players alternate turns until a player wins.

5. **Implementation Plan**

Programming Language: Python
Libraries and Tools:

NumPy

Milestones and Timeline:

Week 1-2: Game design and rule finalization, initial codebase setup

Week 3-4: Implementation of the game board and game mechanics

Week 5-6: Development of the Minimax algorithm and alpha-beta pruning

Week 7: AI integration and testing

Week 8: Final testing, report preparation, and submission

6. **References**

Russell, S. J., & Norvig, P. (2021). Artificial Intelligence: A Modern Approach (4th ed.). Pearson.