National University of Computer & Emerging Sciences
Karachi Campus

CONNECT-FOUR USING MINIMAX ALGORITHM WITH ALPHA-BETA PRUNING

Artificial Intelligence [AI]
Section: BCY-6B

Instructor: Miss Mehak Mazhar
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Group Members:

22K-4796 Fakhur ul Din
22K-4718 Muhammad Hasnain
22K-4761 Ayesha Siddiqui

1. Project Overview

Project Topic:

Our project aims to develop a Connect Four game software system. Connect Four is a classic strategy game where two players take turns dropping colored discs into a vertically suspended grid with the objective of connecting four of their own discs in a row, either horizontally, vertically, or diagonally, before their opponent does.

Objective:

The main goal of this project is to develop strategic AI for Connect Four using the Minimax algorithm with Alpha-Beta pruning. The AI will be capable of competing at various difficulty levels and providing challenging experience for players.

2. Game Description

Original Game Background:

Connect Four is a two-player board game played on a 6x7 grid. Players take turns dropping colored discs into the grid. The first player to connect four discs in a row (vertically, horizontally, or diagonally) wins. If the grid fills up without a winner, the game ends in a draw.

Innovations Introduced:

- AI Opponent: A single-player mode with an AI opponent that uses the Minimax algorithm with Alpha-Beta pruning for strategic decision-making.
- Customizable Board Sizes: Players can select different board dimensions for varied gameplay.
- Adjustable Difficulty Levels: The AI difficulty can be tuned to match different skill levels.
- Efficient Win Condition Checking: Optimized algorithms to enhance performance.

- User-Friendly Interface: Intuitive controls and an interactive UI using Pygame.

These innovations will improve gameplay complexity, making the game more engaging for players of all skill levels.

3. AI Approach and Methodology

AI Techniques to be Used:

- Minimax Algorithm: Implemented to evaluate possible moves and make optimal decisions.
- Alpha-Beta Pruning: Used to optimize the Minimax search by reducing the number of nodes evaluated.

Heuristic Design:

- Board state evaluation based on potential connections, blocking opponent moves, and maximizing AI advantage.
- Weighting moves that contribute towards a winning streak while preventing opponent victories.

Complexity Analysis:

- The standard Minimax algorithm has an exponential time complexity of O(b^d), where b is the branching factor and d is the depth.
- Alpha-Beta pruning significantly reduces the number of nodes evaluated, optimizing performance without affecting decision quality.

4. Game Rules and Mechanics

Modified Rules:

- The game follows the standard Connect Four rules with additional features like AI play, difficulty levels, and board size customization.

Winning Conditions:

- A player wins by forming a sequence of four consecutive discs in a row, column, or diagonal.
- If the board is full and no player has connected four discs, the game results in a draw.

Turn Sequence:

- In two-player mode, players take alternate turns.

- In single-player mode, the human player goes first by default, followed by the AI making its move based on the Minimax algorithm.

5. Implementation Plan

Programming Language:

- Python

Libraries and Tools:

- Pygame (for GUI implementation)
- NumPy (for handling data structures)

Milestones and Timeline:

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

Conclusion

Our project strives to enhance the Connect Four gaming experience, providing players with new features and challenges. We'll assess any deviations from the plan to ensure alignment with project goals.