National University of Computer & Emerging Sciences
Karachi Campus

“SMART QWIRKLE”

Project Proposal
Artificial Intelligence
Section: CS-6J

Group Members:

1. 22K-4393 Syed Muhammad Hassan Naqvi
2. 22K-4254 Mishaal Bheraiya

Introduction

Smart Qwirkle is an innovative, AI-driven board game inspired by the classic Qwirkle. In this system, players place tiles—each defined by unique colors and shapes—onto a grid to form scoring lines. Unlike traditional implementations, our game integrates advanced AI techniques to serve as a dynamic opponent. This proposal highlights the introduction of new features, such as replacing the standard square grid with a hexagonal grid, integrating special power tiles, and including an optional fog-of-war mode to further challenge both players and AI.

Existing System

Current versions of tile-placement games like Qwirkle typically operate on standard square grids and use basic rule-based AI systems. These implementations:

- Rely on fixed square grid layouts that limit spatial complexity.
- Employ predictable decision-making algorithms that do not fully challenge experienced players.
- Lack innovative features like special tiles or mechanisms to introduce hidden information.

While these systems are accessible and fun, they do not leverage modern AI methods or explore alternative grid structures that could enhance strategic gameplay.

Problem Statement

The conventional Qwirkle game has notable limitations:

- **Traditional Grid Layout:** The square grid restricts strategic movement and limits the potential for spatially complex gameplay.
- **Predictable AI:** Basic rule-based opponents offer limited challenge, as they follow straightforward heuristics.

Additionally, there is an opportunity to introduce new gameplay dynamics:

- **New Grid Structure:** Replacing the normal square grid with a hexagonal grid to introduce a fresh spatial challenge.
- **Power Tiles:** Special tiles that trigger unique effects, such as blocking an opponent's move or granting bonus points.
- **Fog-of-War Mode (Optional):** Limiting the AI's board visibility to force more adaptive and nuanced decision-making.

These issues and opportunities form the basis for a significant upgrade in both gameplay mechanics and AI sophistication.

Proposed Solution

Our solution involves developing an AI-based strategic game that addresses the limitations of traditional systems by incorporating the following innovations:

- **Hexagonal Grid as a New Feature:** Transitioning from the standard square grid to a hexagonal grid introduces new spatial strategies and challenges, setting the game apart from its predecessors.
- **Power Tiles:** Special tiles will have unique effects—such as blocking moves or triggering combo bonuses—that add layers of strategy and unpredictability.
- **Optional Fog-of-War Mode:** This advanced feature will limit the AI's board visibility, requiring it to make decisions under uncertainty and further enhancing strategic complexity.
- **Multi-Level AI Strategy:**
    - **Basic Level (Rule-Based AI):** Implements simple, predictable heuristics for a straightforward gameplay experience.
    - **Intermediate Level (Minimax with Alpha-Beta Pruning):** Uses look-ahead algorithms to evaluate moves more intelligently by considering the opponent's possible responses.
    - **Advanced Level (Monte Carlo Tree Search – MCTS):** Employs simulation-based techniques to choose the optimal move under complex conditions.

These modifications not only elevate gameplay but also serve as an ideal platform for exploring and demonstrating advanced AI decision-making techniques.

Salient Features

- **Hexagonal Grid Layout:**
    - *New Feature:* Replaces the traditional square grid to provide a novel spatial challenge and enhance strategic depth.
- **Power Tiles:**
    - Special tiles introduce dynamic effects that can alter gameplay, such as move blocking or bonus scoring.
- **Optional Fog-of-War Mode:**
    - Limits the AI's view of the board, simulating uncertainty and forcing more adaptive strategies.
- **Multi-Level AI Strategy:**
    - **Rule-Based AI:** For basic gameplay scenarios.

    - **Minimax with Alpha-Beta Pruning:** For intermediate-level strategic decision-making.
    - **Monte Carlo Tree Search (MCTS):** For advanced, simulation-based move evaluation.
- **Turn Timer:**
    - Ensures timely decision-making by the AI, adding an element of urgency.

Tools & Technologies

- **Programming Language:** Python
- **Frameworks & Libraries:**
    - **NumPy & Pandas:** For data processing and heuristics.
    - **CustomTkinter:** For a modern, responsive GUI.
    - **Tkinter Canvas / Pygame:** For animations and interactive game elements.
- **AI Algorithms:**
    - **Minimax with Alpha-Beta Pruning:** For strategic foresight.
    - **Monte Carlo Tree Search (MCTS):** For advanced move simulation and decision-making.
- **Operating Systems:**
    - Development and testing will target both Windows and Linux environments for cross-platform compatibility.

Project Timeline (5 Weeks Plan)

- **Week 1:**
    - Finalize game rules and overall design.
    - Develop the board representation, including the new hexagonal grid layout.
    - Create a basic GUI and implement core tile placement logic.
- **Week 2:**
    - Implement and test the Basic AI (Rule-Based).
- **Week 3:**
    - Develop and integrate the Minimax AI with Alpha-Beta Pruning.
    - Optimize decision-making processes.
- **Week 4:**
    - Implement the advanced MCTS AI.
    - Integrate new game modifications: hexagonal grid, power tiles, and optional fog-of-war mode.
- **Week 5:**
    - Debug and perform comprehensive testing across different AI strategies.
    - Refine the GUI and complete final animations.

- Prepare the final report and presentation.

Conclusion

Smart Qwirkle redefines a classic tile-placement game by integrating modern AI strategies and innovative gameplay features. By replacing the normal square grid with a hexagonal grid, introducing power tiles, and optionally employing fog-of-war, this project promises to deliver a unique, challenging, and engaging experience. It stands as an exemplary model for leveraging AI in game development while providing a versatile platform for future enhancements, including adaptive and reinforcement learning-based strategies.