Project Title: Quantum Chess: A Mind-Bending Strategy Game
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1. Project Overview

Project Topic:

Quantum Chess is an innovative twist on traditional chess that incorporates principles of quantum mechanics. Unlike classical chess, where moves are deterministic, Quantum Chess introduces elements such as superposition, probabilistic movement, entanglement, and quantum attacks, making strategy and adaptation crucial.

Objective:

The primary goal of this project is to create an AI-driven Quantum Chess game that simulates quantum mechanics principles while maintaining engaging strategic gameplay. The AI will use advanced techniques to handle probabilistic decision-making and optimize strategy under uncertainty.

2. Game Description

Original Game Background:

Chess is a two-player strategy game with a fixed set of movement rules. Each piece moves deterministically, and players aim to checkmate the opponent's King. The game is widely studied in AI and strategy development.

Innovations Introduced:

- **Superposition of Pieces:** Except for the King, pieces can exist in multiple locations until observed (moved, attacked, or blocked).
- **Quantum Movement:** Some pieces move probabilistically, such as a Knight having a 70% chance of landing on a chosen square and 30% on an adjacent one.
- **Entanglement Mechanic:** Moving one entangled piece can unpredictably affect another.

- **Quantum Attack:** Capturing a piece involves a probability of success based on quantum uncertainty.
- **Decoherence:** When an opponent moves close to a piece, its superposition collapses, revealing its actual position.

These mechanics add unpredictability, requiring players to strategize using probability rather than fixed movement rules.

3. AI Approach and Methodology

AI Techniques to be Used:

- **Expectiminimax Algorithm:** An extension of the minimax algorithm that handles probabilistic events, suitable for games involving chance elements.
- **Monte Carlo Tree Search (MCTS):** For handling uncertainty in movement and attacks by simulating numerous possible future game states.
- **Reinforcement Learning (Optional):** Training an AI to play Quantum Chess optimally through self-play and learning from outcomes.

Heuristic Design:

- Evaluation of game states based on piece probability distributions.
- Positional advantages considering quantum mechanics.
- Calculation of expected values for moves based on probabilistic outcomes.

Complexity Analysis:

- Traditional chess has a large branching factor, and Quantum Chess significantly increases complexity due to multiple possible states for each piece.
- AI implementation will require efficient search techniques to handle quantum uncertainties.

4. Game Rules and Mechanics

Modified Rules:

- Pieces exist in multiple positions until observed.

- Movement and attacks have probabilistic success rates.
- Entangled pieces affect each other when moved.
- Opponent’s proximity collapses superposition states.

Winning Conditions:

- A player wins by capturing the opponent’s King, which remains in a classical state throughout the game.

Turn Sequence:

- Players take turns moving pieces, collapsing superposition when necessary.
- Moves and attacks resolve probabilistically.
- Entanglement effects apply dynamically.

5. Implementation Plan

Programming Language:

- Python

Libraries and Tools:

- **Pygame** (for GUI implementation)
- **NumPy** (for probability calculations)
- **Scikit-learn / TensorFlow** (if using reinforcement learning)

Milestones and Timeline:

- **Week 1-2:** Finalizing game design, rules, and mechanics.
- **Week 3-4:** AI strategy development (Expectiminimax, MCTS, heuristics).
- **Week 5-6:** Coding and testing game mechanics.
- **Week 7:** AI integration and testing.

- **Week 8:** Final testing and report preparation.

6. References

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