Project Proposal: AI-Powered Halma with Strategic AI

Project Title: AI-Powered Checkers with Strategic Gameplay

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1. Project Overview

● Project Topic:

This project focuses on developing an **AI-powered Halma** game, a turn-based strategic board game. The AI opponent will use the **Minimax algorithm with Alpha-Beta Pruning** to make optimal moves. The project aims to create a challenging AI that evaluates board states using heuristics, enabling it to compete against human players effectively.

● Objective:

The primary objective is to develop an **AI-based Halma game** where:

- The AI opponent makes optimal moves using the **Minimax algorithm**.
- **Heuristics** are used to evaluate board positions and enhance AI decision-making.
- The game provides an interactive **graphical interface** for human vs. AI gameplay.
- The AI decision-making process is **optimized for performance** at different search depths.

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2. Game Description

● Original Game Background:

Halma is a **strategy-based board game** played on a square board with pieces that move in any direction. The objective is to move all pieces from the starting zone to the opponent's starting zone. Players can move one piece at a time or jump over other pieces. The game rewards **foresight, strategic planning, and positioning**.

● Innovations Introduced:

- **AI-powered opponent** using **Minimax with Alpha-Beta Pruning**.
- **Heuristic-based decision-making**, where the AI evaluates:
    - **Distance to target** (closer pieces are prioritized).
    - **Control of opponent's area** (AI attempts to block human moves).

    - **Penalty for idle pieces** (encourages proactive play).
- **Graphical visualization of AI moves** for better understanding.

Impact on Gameplay Complexity & Strategy:

- The AI plays **competitively**, adapting to player moves.
- Players must **strategize** against the AI rather than rely on random play.
- AI depth tuning allows for different **difficulty levels**.

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3. AI Approach and Methodology

● AI Techniques to be Used:

Minimax Algorithm – Implements a **decision-tree search** for AI moves.
Alpha-Beta Pruning – Optimizes Minimax by eliminating unnecessary branches.

● Heuristic Design:

- **Distance Heuristic:** Pieces closer to the target get a higher score.
- **Board Control:** AI prioritizes moves that **block the opponent**.
- **Piece Mobility:** Penalizes pieces that remain idle for too long.

● Complexity Analysis:

- **Minimax with Alpha-Beta Pruning:**
    - Best Case: **O(b^d/2)** (reduced search space due to pruning).
    - Worst Case: **O(b^d)** (without pruning).
- The main challenge is **optimizing depth** to balance **AI performance and computation time**.

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4. Game Rules and Mechanics

● Modified Rules:

- AI opponent with **strategic move planning**.
-**Visual representation** of AI's decision-making process.
-Different AI difficulty levels based on **Minimax depth settings**.

● Winning Conditions:

- The player who moves **all pieces to the opponent's start zone first wins**.
- If the AI **successfully blocks** all possible moves, it wins by default.

● Turn Sequence:

- **Turn-based system**: The human player and AI take turns moving pieces.
- AI evaluates **best move using Minimax** before executing it.

- The game continues until one player reaches the goal.

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5. Implementation Plan

● **Programming Language: Python**

● **Libraries and Tools:**

-**Pygame** (for GUI visualization).
-**Copy** (for deep-copying board states in AI simulation).
-**Mathematical Libraries** (for heuristics calculations).

● **Milestones and Timeline:**

Week	Task Description
1-2	Game mechanics, board setup, and rule implementation
3-4	Minimax algorithm integration & Alpha-Beta Pruning
5-6	AI heuristic optimization & move evaluation
7	AI testing, debugging, and GUI refinement
8	Final report, testing, and project presentation

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6. References

- **"Artificial Intelligence: A Modern Approach"** – Stuart Russell & Peter Norvig
- Research papers on **Minimax Algorithm & Alpha-Beta Pruning**
- Online resources on **Halma game rules and strategy**
- **Pygame Documentation** for game interface development