

Project Title: Adaptive AI Game for Nine Men's Morris
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1. Project Overview

Project Topic:

Nine Men's Morris is an ancient two-player strategy board game where the objective is to form mills (three pieces in a row) to remove the opponent's pieces. This project aims to develop an adaptive AI opponent for Nine Men's Morris using the Minimax algorithm with Alpha-Beta Pruning.

Objective:

The main objective is to develop a **strategic AI opponent** for Nine Men's Morris using **Minimax with Alpha-Beta Pruning**. The AI will be capable of playing optimally by evaluating potential moves and game states, simulating intelligent decision-making.

2. Game Description

Original Game Background:

Nine Men's Morris is a two-player strategy board game that dates back to ancient times. The game is played on a board with twenty-four intersections, forming a grid of three concentric squares connected by lines. Each player starts with nine pieces (or men), aiming to form mills—three of their pieces aligned in a straight line either horizontally or vertically.

The game has three distinct phases:

1. **Placing Phase:** Players take turns placing their nine pieces on vacant intersections. If a player forms a mill, they can remove an opponent's piece, with the restriction that pieces

in mills can only be removed if no other options exist.

2. **Moving Phase:** Once all pieces are placed, players take turns moving their pieces to adjacent intersections to form new mills and remove opponents' pieces. If a player's pieces are completely blocked (unable to move), they lose the game.
3. **Flying Phase:** If a player has only three pieces left, they can move to any open intersection on the board instead of just adjacent ones. This phase allows for greater movement flexibility to prevent an immediate loss.

A player wins when their opponent is reduced to two pieces (making mills impossible) or if the opponent has no legal moves left.

Innovations Introduced:

Even though we retain the original rules, **Nine Men's Morris itself introduces several unconventional elements:**

- **Three Distinct Game Phases:** Placement, movement, and flying phases demand different strategies and AI adaptations.
- **Mill Formation Mechanic:** Strategic formation and blocking of mills create complex branching possibilities beyond traditional piece capture games.
- **"Flying" Mechanic:** The sudden switch in movement freedom (when a player has only three pieces left) adds a dynamic strategic layer uncommon in most board games.
- **Symmetry and Board Geometry:** The unique square-in-square layout with connected midpoints results in spatial patterns that challenge typical heuristic design.

These intrinsic design features inherently increase **strategic depth**, **game tree complexity**, and **AI adaptability**, making Nine Men's Morris a compelling subject for implementing classical and modern AI techniques.

3. AI Approach and Methodology

AI Techniques to be Used:

- **Minimax Algorithm:** Used for decision-making, evaluating possible moves to maximize the AI's advantage while minimizing the opponent's.
- **Alpha-Beta Pruning:** Enhances the Minimax algorithm by eliminating unnecessary branches, reducing computational complexity.

Heuristics will evaluate:

- Number of mills formed.
- Number of blocked opponent pieces.
- Number of two-in-a-row formations (potential mills).
- Phase of the game (placement vs movement vs flying).
- Positional strength of pieces (central control vs corner pieces).

Complexity Analysis:

- **Minimax Complexity:** $O(b^d)$, where b is the branching factor and d is the depth of the search tree.
- **Alpha-Beta Pruning:** Reduces complexity significantly, often cutting it down to $O(b^{(d/2)})$.
- **The game has three phases, increasing the complexity of state transitions.**
- **Implementing accurate heuristics for each phase adds to the challenge**

4. Game Rules and Mechanics

No major modifications. The classic rules of Nine Men's Morris will be implemented.

Winning Conditions:

- A player wins by reducing the opponent to two pieces, making it impossible for them to form mills.
- A player also wins if the opponent has no legal moves left.

Turn Sequence:

- Players take turns placing pieces during the placement phase.

- In the movement phase, players move pieces to adjacent points.
- If reduced to three pieces, the flying phase allows movement to any vacant point.

5. Implementation Plan

Programming Language:

- Python

Libraries and Tools:

- **Pygame:** For GUI development.
- **NumPy:** For handling AI computations.

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.

6. References

https://en.wikipedia.org/wiki/Nine_men%27s_morris

<https://github.com/sauermar/Nine-men-s-morris>