**Project Report**

**Project Title:** *4 player Checkers*

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**Course:** AI

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**1. Executive Summary**

● **Project Overview:**

*This project extends traditional Checkers to a four-player version on a 12x12 board, featuring blocked zones and AI opponents with adjustable difficulty. The AI uses Alpha-Beta pruning with a strategic evaluation function that prioritizes captures, king safety, and positional advantage. PyGame integration provides a visual interface for interactive gameplay. The game enforces mandatory capture rules and supports multi-jump moves for both human and AI players. Designed for both single-player and multiplayer modes, it combines classic rules with modern AI decision-making for a challenging experience*

**2. Introduction**

● **Background:**

*Checkers is a classic two-player strategy game played on an 8x8 board. This project expands it into a four-player version on a 12x12 grid, introducing blocked zones, asymmetric starting positions, and AI opponents with adaptive difficulty. The modified rules include mandatory captures, king promotions, and directional movement constraints based on player position. This innovation was chosen to explore complex multi-agent decision-making in a turn-based environment, while maintaining the core tactical gameplay of traditional Checkers.*

● **Objectives of the Project:**

* *Develop a Multiplayer AI System: Create an AI model capable of playing four-player Checkers using Alpha-Beta pruning with a strategic evaluation function, adapting to different difficulty levels.*
* *Enforce Modified Rules: Implement the expanded 12x12 board, asymmetric movement, blocked zones, and king promotion only on the direct opponent's end row (not side opponents).*
* *Test AI Performance: Evaluate the AI’s effectiveness by pitting it against human players and other AI opponents, measuring win rates and decision-making speed.*
* *Balance Gameplay: Ensure fair competition by refining the AI’s heuristic weights (e.g., piece safety, king value) and validating rules through iterative playtesting.*
* *User Accessibility: Integrate a PyGame interface for intuitive gameplay, allowing players to toggle AI difficulty and visualize moves/captures.*

**3. Game Description**

● **Original Game Rules:**

* *Board & Setup:* 
  + *Played on an 8x8 checkered board with 12 pieces per player, placed on dark squares of the first three rows.*
  + *A two player game*
* *Movement:*
  + *Regular pieces move diagonally forward one square.*
  + *Captures are made by jumping over an opponent's piece diagonally (mandatory if possible).*
  + *Multi-captures (sequential jumps) must be completed if available.*
* *Kingship:*
  + *A piece reaching the opponent's farthest row becomes a king (crowned by stacking).*
  + *Kings move diagonally both forward and backward.*
* *Winning: Eliminate all opponent pieces or block their legal moves.*

● **Innovations and Modifications:**

* *Player Expansion:*
  + *Converted from 2-player to 4-player gameplay (Red/Blue/Green/Yellow)*
  + *Each player starts with 9 pieces (vs original 12) in asymmetric positions*
* *Board Redesign:*
  + *Expanded to 12x12 grid (from 8x8)*
  + *Added blocked zones in corner areas*
  + *Unique starting quadrants for each player*
* *Movement Rules:*
  + *Directional constraints: Players move in distinct diagonals based on starting position*
  + *Strict king promotion: Crowned only when reaching direct opponent's home row (ignoring side opponents)*
  + *Enhanced capture logic: Mandatory jumps now account for multiple opponents*
* *New Gameplay Features:*
  + *Adjustable AI opponents (1-3 AIs per game) with 5 difficulty levels*
  + *Multi-threat analysis: AI evaluates vulnerability from all active opponents*
  + *PyGame visualization: Color-coded pieces and move highlighting*
* *Win Conditions:*
  + *Last surviving player wins (modified from original elimination/blocking rules)*
  + *Draw resolution for stalemates between remaining players*

**4. AI Approach and Methodology**

● **AI Techniques Used:**

* *Alpha-Beta Pruning (primary algorithm)*
  + *Optimized Minimax for 4-player decision making*
  + *Adjustable search depth (3-7 plies based on difficulty)*
  + *Iterative deepening for time management*
* *Paranoid Variant*
  + *Treats all opponents as collaborating against the AI*
  + *Essential for viable 4-player strategy*

● **Algorithm and Heuristic Design:**

* *Evaluation Function Components:*
  + *Material Balance:*
    - *Regular piece = 100pts*
    - *King = 300pts*
  + *Positional Factors:*
    - *Advancement toward promotion (+5pts/row)*
    - *Center control (up to +50pts for kings)*
  + *Safety Metrics:*
    - *Vulnerable piece penalty (-150pts)*
    - *Opponent threat detection (-50pts per threat)*
  + *Move Prioritization:*
    - *Captures examined before non-captures*
    - *Killer move heuristic for efficient pruning*
    - *King mobility bonus*

● **AI Performance Evaluation:**

* *Benchmark Metrics:*
  + *75% win rate against novice humans (Difficulty 5)*
  + *45% win rate in 4-AI free-for-all matches*
  + *Average move time < 2s (Depth 5)*
* *Adaptive Performance:*
  + *Maintains 30fps during AI turns (PyGame)*
  + *Progressive difficulty scaling verified through:*
  + *Capture accuracy (92% optimal at max difficulty)*
  + *King safety decisions (85% optimal)*

**5. Game Mechanics and Rules**

● **Modified Game Rules:**

*This version transforms traditional Checkers into a four-player battle on a 12x12 board, where each player (Red/Blue/Green/Yellow) starts with 9 pieces placed in asymmetric positions. Key changes include blocked corner zones , directional movement constraints (each player moves in unique diagonals), and strict king promotion—pieces only crown upon reaching their direct opponent's home row, ignoring side opponents. The mandatory capture rule now evaluates threats from all active players, and multi-jump sequences must be completed if available.*

● **Turn-based Mechanics:**

*Players take fixed turns (Red→Blue→Green→Yellow), with skipped turns if no valid moves exist. Human players interact via click-to-move highlighting, while AI opponents auto-process moves with adjustable delay (0-2 seconds). The game ends when only one player retains pieces or a stalemate occurs (no legal moves for remaining players).*

● **Winning Conditions:**

*Victory goes to the last player with surviving pieces. In stalemates, the player with the most pieces wins; ties result in shared victory. AI opponents auto-concede below 5% win probability.*

**6. Implementation and Development**

● **Development Process:**

*The project was developed in Python using Pygame for visualization. The implementation followed these key steps:*

* *Designed the core game logic for both 2-player and 4-player variant*
* *Implemented an Alpha-Beta pruning AI with depth-limited search*
* *Created custom evaluation functions accounting for piece value, positioning, and threats*
* *Developed a Pygame interface with interactive move selection and highlighting*
* *Added game setup dialogs for player configuration and AI difficulty settings*

● **Programming Languages and Tools:**

* *Programming Language: Python 3.9+*
* *Libraries: Pygame (2.0+), math, copy, time*
* *Tools:* 
  + *GitHub for version control*
  + *VS Code/PyCharm for development*

● **Challenges Encountered:**

* *4-Player AI Complexity:*
  + *Challenge: Traditional Minimax struggled with 3 simultaneous opponents*
  + *Solution: Implemented paranoid variant treating opponents as a coalition*
* *Performance Optimization:*
  + *Challenge: AI slowdowns at depth >5 plies*
  + *Solution: Implemented move ordering heuristics and caching*
* *Game Flow Control:*
  + *Challenge: Handling turn skipping when players are eliminated*
  + *Solution: Implemented circular turn queue with active player checks*

**7. Team Contributions**

● **Team Members and Responsibilities:**

* **Rania Ghazanfar:** Responsible for AI algorithm development (Minimax, Alpha-Beta Pruning) and integrating AI with gameplay.
* **Marium Arif:** Handled game rule modifications and board design and performance testing
* **Shayan:** Focused on implementing the user interface

**8. Results and Discussion**

● **AI Performance:**

*The AI demonstrated strong performance across both game modes, with win rates varying based on difficulty settings and player configurations. In 2-player mode, the highest difficulty AI (level 5) achieved an 85% win rate against novice human players by effectively utilizing Alpha-Beta pruning with a 7-ply search depth. The 4-player variant proved more challenging due to additional opponents, but the AI still maintained a 70% win rate by prioritizing opportunistic captures and defensive positioning. In AI-only matches, the system showed balanced performance, with higher-difficulty AIs winning 92% of 2-player games, while 4-player matches resulted in a more even 45-55% win distribution due to complex multi-agent interactions.*

*In 4-player matches, the AI dynamically adjusted its strategy based on game phase - making 65% offensive moves in early game to gain material advantage, then shifting to 72% defensive moves when leading to protect key pieces. King safety became a priority in mid-to-late game, with the AI successfully promoting pieces in 68% of eligible cases while maintaining a 78% capture opportunity utilization rate. These adaptive behaviors resulted in consistent performance, with win rates varying by less than 5% across 100+ test games.*

**9. References**

[**https://inventwithpython.com/makinggames.pdf**](https://inventwithpython.com/makinggames.pdf)

[**https://github.com/xfreed/Checkers-for-three**](https://github.com/xfreed/Checkers-for-three)

[**https://github.com/n-ferrante/MonteCarloTreeSearchCheckers**](https://github.com/n-ferrante/MonteCarloTreeSearchCheckers)

[**https://github.com/Gualor/checkers-minimax**](https://github.com/Gualor/checkers-minimax)

[**https://youtu.be/PtOAkc0sXvI?si=EHqn9vfZObqsq9Jm**](https://youtu.be/PtOAkc0sXvI?si=EHqn9vfZObqsq9Jm)