Project Title: *Dynamic Dots and Boxes*

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1. Project Overview

- **Project Topic:**
  Dynamic Dots and Boxes is a reimagined version of the classic Dots and Boxes game. In this variant, in addition to capturing boxes for points, players can acquire and use "power tokens" by completing boxes. These tokens enable extra actions (e.g., drawing additional lines, modifying opponent moves, or triggering bonus effects) and introduce dynamic board events (like bonus boxes that change over time).
- **Objective:**
  *The project aims to develop a strategic AI opponent that uses advanced search techniques such as **Min-max** (with Alpha-Beta Pruning), to compete in Dynamic Dots and Boxes. The goal is to handle the increased complexity from dynamic rules and power-ups, ultimately comparing classic adversarial search with simulation-based methods in this modified game environment.*

2. Game Description

- **Original Game Background:**
  Dots and Boxes are traditionally played on a grid of dots. Players alternate drawing horizontal or vertical lines between adjacent dots. If a player completes the fourth side of a box, they claim that box and earn a point (and receive another turn). The game ends when no more lines can be drawn, and the player with the most boxes wins.
- **Innovations Introduced:**

- ***Power Tokens:***
  When a player completes a box, they not only capture it for one point but also earn a power token.

- ***Bonus Boxes:***

  Certain boxes (marked at game start or dynamically re-assigned every few turns) are designated as bonus boxes. Capturing a bonus box awards extra points and may grant additional power tokens.
- ***Power Actions:***

  Players can spend power tokens on special actions, such as:
  Double-Line Draw: *Draw two lines in a single turn.*
  Line Reversal: *Remove an opponent's recently drawn line.*
  Extra Move: *Gain an extra turn even if no box is completed.*
- ***Dynamic Board Events:***

  At set intervals (e.g., every 5 turns), the board may trigger a "power surge" event that reassigns bonus box positions or temporarily increases the value of captured boxes.

Impact on Gameplay:
These modifications deepen strategic planning. Players must decide whether to use tokens immediately for tactical advantages or save them to trigger board events. The shifting bonus zones and power actions introduce uncertainty, requiring players—and the AI—to anticipate multiple future outcomes.

3. AI Approach and Methodology

- **AI Techniques to be Used:**
  - ○ Minimax Algorithm:

    The AI will simulate moves ahead, evaluating possible board states and deciding on the best action. It will be modified to handle multiplayer scenarios and incorporate the new power-up decisions.
  - ○ Alpha-Beta Pruning:

    To reduce the computational cost of the minimax search by eliminating moves that will not influence the final decision.
  - ○ Reinforcement Learning:

    Future work may integrate reinforcement learning for self-play, allowing the AI to adapt its heuristic over time.
- **Heuristic Design:**

  The evaluation function will score game states by considering:
  Current Score: *Total boxes and bonus boxes captured.*

Token Advantage: *Number of power tokens available.*

Board Control: *Proximity of tokens to potential bonus boxes and safety zones.*

Future Potential: *Estimation of chain reactions from power actions (e.g., potential for extra turns or board events).*

- **Complexity Analysis:**

The minimax search has a worst-case complexity of $O(b^d)$ (with b as branching factor and d as depth). With added power actions, b increases, making pruning vital.

Challenges: *Handling randomness from dynamic board events and designing heuristics that effectively capture the strategic depth of power plays.*

4. Game Rules and Mechanics

- **Modified Rules:**

Power Tokens: *Capturing any box awards one power token.*

Bonus boxes *(designated either at game start or every 5 turns) yield extra points (e.g., 2 points) and an extra token.*

Special Power Actions (spend tokens):

Double-Line Draw*: Spend 1 token to draw two lines in a turn.*

Line Reversal: *Spend 2 tokens to remove one of an opponent's recently drawn lines.*

Extra Move: *Spend 1 token to gain an additional turn.*

Dynamic Board Events*:*

Every 5 turns, a board event occurs that reassigns bonus box positions or temporarily boosts box values.

Standard Moves:

Players continue drawing a single line per turn if they choose not to or cannot spend tokens.

- **Winning Conditions:**

The game ends when all lines have been drawn.

The winner is the player with the highest total score, calculated as the sum of:

Standard boxes (1 point each)

Bonus boxes (2 points each)

Extra points for unused tokens (optional bonus scoring which can be chosen at the start of the game)

- **Turn Sequence:**

A player draws a line between adjacent dots.
If the drawn line completes one or more boxes:
They capture those boxes, score points, and earn corresponding power tokens.
They may immediately choose to spend tokens for a power action.
They get an extra turn.
If no box is completed, play passes to the next player.
Every 5 turns, trigger a board event that modifies bonus box positions or values.

5. Implementation Plan

- **Programming Language:** *Python*
- **Libraries and Tools:**
  - Pygame *(for GUI)*
  - NumPy *(for data handling)*
  - Scikit-learn (*for data handling for any heuristic tuning or data analysis)*
- **Milestones and Timeline:**
  - **Week 1-2:**

    Finalize game design and modified rules.
    Develop a prototype of the dynamic board mechanics.
  - **Week 3-4:**

    Implement basic AI using Minimax with Alpha-Beta Pruning.
    Define and test heuristic evaluation functions.
  - **Week 5-6:**

    Integrate dynamic elements (power actions, board events).
  - **Week 7:**

    AI integration: Run simulation tournaments and tune AI performance.
  - **Week 8:**

    Final testing, debugging, and preparation of the project report.

6. References

- *Will take references with the search techniques and algorithms from geeksforgeeks or other useful websites.*
  https://www.geeksforgeeks.org/minimax-algorithm-in-game-theory-set-1-introduction/
  https://www.geeksforgeeks.org/minimax-algorithm-in-game-theory-set-4-alpha-beta-pruning/