Heuristic-Based Multi-Agent Mind-Boggle UNO: A Strategic Card Game Simulation

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Project Overview

Project Topic

This project focuses on an innovative version of the traditional UNO game, combining elements of *Mind-Boggle* to create a chaotic, strategic card game. The goal is to introduce new game dynamics with strategic memory decay, agent decision-making, and uncertainty. This hybrid game emphasizes unpredictability and requires AI agents to adapt to evolving rules and uncertain conditions.

Objective

The objective is to develop a heuristic-based AI for the Mind-Boggle UNO game, simulating agents that make decisions under chaotic conditions. The AI will use a combination of heuristic functions, Bayesian probability, and memory decay to optimize decision-making. The project will explore how memory manipulation and rule changes can affect AI strategy in a multi-agent setting.

1 Game Description

Original Game Background

UNO is a popular card game where players attempt to be the first to get rid of all their cards by matching colors or numbers. The game includes action cards that can change the course of the game, such as skipping turns, reversing the order of play, or forcing players to draw cards.

Mind-Boggle, on the other hand, introduces chaotic rule changes, such as shuffling hands and altering card functionality. In this project, the combination of these two games introduces an innovative, unpredictable variation of UNO.

Innovations Introduced

The following innovations were introduced to the original UNO game:

- **Wild Card**: Allows players to reset and review their hand, adding an element of strategic self-reflection.
- **9 (Any Color)**: Enables players to shuffle and view an opponent's cards, causing memory decay and disrupting opponent strategies.
- **7 (Any Color)**: Facilitates card exchange with any opponent, increasing interaction and strategic decision-making.
- **Memory Decay**: Players' memory of opponents' hands decays over time, making decisions based on imperfect information and introducing an element of uncertainty.
- **Bayesian Network Integration**: AI agents infer the likelihood of specific cards in opponents' hands, adjusting their strategies based on uncertain information.

These modifications increase the complexity and unpredictability of the game, encouraging dynamic and adaptive strategies.

2 AI Approach and Methodology

AI Techniques to be Used

The AI for this project will use the following techniques:

- **Heuristic Evaluation**: AI agents evaluate the best card to play based on a set of custom weights, including color match, card power, and disruption potential.
- **Bayesian Networks**: Agents infer the likelihood of specific cards being in an opponent's hand using probabilistic reasoning, especially when memory is unreliable.
- **Memory Decay Logic**: A dynamic memory model where the agents' recollection of past states decays over time, influencing decision-making under uncertainty.
- **Probabilistic Decision Making**: AI agents use Bayesian inference to calculate the probability distribution of cards in an opponent's hand, helping to guide their strategy.

Heuristic Design

The AI uses a heuristic function to evaluate and select the best card to play:

$$\text{heuristic index} = \arg\max_i \text{weights}[card_i]$$

Where the weights reflect the strategic value of each card based on its potential to match the color, disrupt the opponent, and contribute to the AI's goal of winning.

Complexity Analysis

The time complexity of the heuristic evaluation is $O(n)$, where n is the number of cards in hand. The Bayesian inference involves probability distribution calculations that are generally more complex and may depend on the number of agents and the uncertainty in memory states. As the game progresses and more memory decay occurs, the complexity increases due to the probabilistic nature of the agents' decisions.

3 Game Rules and Mechanics

Modified Rules

The game follows the standard UNO rules with the following modifications:

- The deck includes the standard UNO cards but special cards with power-ups
- Players' memory decays over time, and their knowledge of other players' hands is updated based on shuffling actions (via the 9 card).
- The `shuffled` tracker monitors the state of memory decay and updates the AI's decision-making process accordingly.

Winning Conditions

The winner is the player with the cards with least weight values when the deck is empty, and, the chaotic nature of the game, with disrupted memory and shuffled hands, requires a more adaptive strategy to succeed.

Turn Sequence

In each turn:

- A player draws a card from the deck.
- The player must either swap his card with the drawn card or discard the drawn card.
- The AI agents make decisions based on their heuristic evaluation, Bayesian reasoning, and current memory state.
- The game ends when the deck is empty

4 Implementation Plan

Programming Language

Python 3.11

Libraries and Tools

- **Libraries**: random, typing, pgmpy (for Bayesian network and probabilistic reasoning)
- **Tools**: Python IDE (e.g.VS Code), GitHub for version control

Milestones and Timeline

- **Week 1-2**: Game design and finalization of modified rules
- **Week 3-4**: Development of AI logic (heuristics, Bayesian networks, memory decay)
- **Week 5-6**: Implementation of game mechanics and testing of basic gameplay
- **Week 7**: AI integration, strategic testing, and performance evaluation
- **Week 8**: Final testing, documentation, and report preparation

5 References

- pgmpy Documentation for Bayesian Networks.
- Python 3.11 Documentation.