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Artificial Intelligence for the Card Game Durak

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Abstract: Because of its potential to improve the efficiency and effectiveness of many different fields, Artificial Intelligence (AI) has been the subject of extensive research and continues to be a major area of study. Given the numerous approaches to AI implementation, games provide a convenient and effective environment for testing and evaluating these algorithms. Nevertheless, card games with imperfect information present a unique challenge for many common game-playing algorithms because of their hidden game state. As a result, making them an active area of research in the field of game theory and AI. The objective of this thesis is to create a framework for implementing and testing various AI agents in the popular imperfect information card game "Durak" to identify the most effective approach in this environment. This paper presents a theoretical and experimental comparison of agents using various techniques, including rules-based heuristics, minimax search, and Monte Carlo tree search, to evaluate their effectiveness in the given context. In our analysis, we found that the Monte Carlo Tree Search agent performed the best among the implemented AI agents, whereas the rule-based heuristic agent and the minimax agent were less effective in the context of the imperfect information card game Durak.

Keywords: artificial intelligence card game Durak

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Introduction

Artificial Intelligence (AI) is a fast-growing field of computer science that focuses on the creation of intelligent machines that can simulate human cognition. In recent years, AI technology has been applied in a wide range of fields, including healthcare, finance, and transportation, with the goal of improving efficiency, accuracy, and decision-making. To gain insights into the capabilities and limitations of AI algorithms and techniques, many researchers turned to games as a testing platform to evaluate and compare different methods as they provide a convenient and controllable environment to achieve the aforementioned goals.

In recent decades, computer games have also gained popularity, similar to the growth of AI as a field of study. Due to its utility, the game industry has become one of the many fields that have sought to use AI to their advantage. Being a subject of extensive research, perfect information in two-player games has been a common focus in game theory, which allowed the development of algorithms for a greater understanding of games. However, in a manner similar to the real world, situations in which all relevant information is available are not always present. Given the inherent characteristics of their environment, the design of algorithms for imperfect information games is more challenging. Therefore, this thesis seeks to contribute to this field by developing algorithms for the game "Durak".

Durak is a strategic card game that originated in Russia. It is played with a deck of cards and typically involved two to six players. Unlike the other games, the aim of the Durak is not to find a winner, but to find a loser. Players take turns attacking and defending in a series of rounds. During an attack, the attacking player leads with one or more cards, and the defending player must attempt to beat them by playing a higher-ranked card. If the defending player is unable or unwilling to do so, they must pick up all the cards. The goal of the game is to get rid of all of one's cards, and the player left holding cards at the end is declared the fool. Lobashev [2022]

Given the intricate nature of the game, a key objective is to ensure its correct development with all relevant details. As the game will include various AI agents, it is essential for the game model to provide a suitable interface for the integration of AI agents.

Another goal of this thesis is to implement a range of AI players for the given game model. One of the benefits of introducing the agents for this game is that it will provide an opportunity to examine potential challenges associated with implementing AI for games of this type, as well as verify the suitability and usability of the game's API for this purpose.

After implementing the AI agents, the aim is to compare their performance in a mutual play, with the objective of identifying the most effective technique. The AI players must not only win against all other agents but must also make a move in an average time of less than 200ms. This requirement reflects the need for AI players to be both effective and efficient in their decision-making. This comparison will provide valuable insights into the strengths and weaknesses of the various AI approaches and will help to guide future work in this area.

1. Game Description

The objective of this thesis is to develop a simulation of the Durak game, which would serve as an experimental environment for artificial intelligence agents using various techniques. By implementing the full range of gameplay mechanics, our aim is to create a comprehensive simulation that could be used to evaluate the performance of previously mentioned agents.

There are many variations of the Durak game that are played around the world. However, this thesis focuses on the most well-known version of the game, which is called Podkidnoy Durak (also known as "fool with throwing in"). In this chapter, we will provide a thorough description of this particular variation in depth, providing an in-depth analysis of its rules and gameplay mechanics. It should be noted that the description provided below pertains only to the two-player variant of the game. While the official rules allow for more than two players to participate, this description is limited to the two-player version.

1.1 Terminology

In this section, any unfamiliar or potentially confusing terminology is defined to facilitate understanding of the material.

- | | |
|---|---|
| <ol style="list-style-type: none">1. Trump card2. Bout3. Discard pile | <ol style="list-style-type: none">1. It is a playing card that belongs to a deck and has a higher rank than any other card from a different suit. This card is typically used strategically during gameplay to defeat the other player's cards and gain an advantage.2. It is a process of exchange of attacks and defenses between the players. The bout continues until either the attack is successfully defended or the defender is unable to play a suitable card, at which point the attacker wins the bout and the defender is forced to take the played cards into their hand.3. During a bout, if an attack is successfully defended, all of the cards played during this process are placed face down on a discard pile and are not used again for the remainder of the game. |
|---|---|

1.2 Players

While the game of Durak is typically played with a range of two to six players, allowing for the possibility of team play, this work only focuses on the two-player variant of the game. This decision is made in order to maintain a consistent and focused scope for the analysis

1.3 Cards

The game is played with a 36-card pack, with each suit ranked from high to low as follows: ace, king, queen, jack, 10, 9, 8, 7, 6.

1.4 Dealing the cards

At the beginning of the game, cards are dealt to each player until each has a hand of six cards. The final card of the deck is then placed face up, and its suit is used to determine the trump suit for the game. The remaining undealt cards are then placed in a stack face down on top of the trump card.

During the first hand of a session, the player who holds the lowest trump card plays first. If no one holds the trump 6, the player with the trump 7 plays first; if no one holds that card, the player with the trump 8 plays first, and so on. The first play does not have to include the lowest trump card; the player who holds the lowest trump card can begin with any card they choose.

1.5 Drawing from the deck

Once the bout is over, all players who have fewer than six cards in their hand must, if possible, draw enough cards from the top of the deck to bring their hand size back up to six. The attacker of the previous bout replenishes their hand first, followed by the defender. If there are not enough cards remaining in the deck to replenish all players' hands, then the game continues with the remaining cards.

1.6 Beating the card

Before discussing the gameplay, it is necessary to establish what it means for an attacking card to be successfully defended. A card that is not a trump can be beaten by playing a higher card of the same suit, or by any trump card. A trump card can only be beaten by playing a higher trump card. It is important to note that a non-trump attack can always be beaten by a trump card, even if the defender also holds cards in the suit of the attack card. There is no requirement for the defender to "follow suit" in this case.

1.7 Game play

The play consists of a series of bouts, during which one player, the attacker, plays a card and their opponent, the defender, responds by playing a card.

During each bout, the attacker begins by playing a card from their hand face up on the table in front of the defender. The defender must then attempt to beat this card by placing its own face up and any subsequent cards played by the attacker. Alternatively, if the defender is unable or unwilling to beat the attacking card, they must pick up that card along with other played cards on the table.

1.7.1 Conditions on the attack

Every attacking card except for the first one must meet the following conditions in order to be played by the attacker.

- Each new attacking card played during a bout must have the same rank as a card that has already been played during that bout, whether it was an attacking card or a card played by the defender.
- If the defender had fewer than six cards in their hand before the bout began, the number of attacking cards played must not exceed the number of cards in the defender's hand.

The first attacking card can be any card from the attacker's hand.

1.7.2 Successful defense

The defender successfully beats off the entire attack if either of the following conditions is met:

- the defender has successfully beaten all of the attack cards and the attacking player is unable or unwilling to continue the attack.
- the defender has no cards left in hand while defending.

Upon successful defense of an attack, all cards played during the bout are placed in the **discard pile** face down and are no longer eligible for use in the remainder of the game. On top of that, the roles of the players change i.e. the defender becomes the attacker and the attacker becomes the defender for the next bout.

Furthermore, if the defender decides to take the cards, the attacker may play additional cards as long as doing so does not violate the conditions of the attack.

1.8 Endgame and Objective

Once the deck is run out of cards, there is no further replenishment and the goal is to get rid of all the cards in one's hand. The player who is left holding cards at the end is the loser, also known as the fool (durak). As it was mentioned before, this game is characterized by the absence of a winner, with only a loser remaining at the end.

However, it is not always the case. It is possible for the game to end as a draw. In the event that both the attacking and defending player possess the same number of cards and all of the attacking player's cards are successfully defended, the game ends in a draw.

2. Game Analysis

2.1 Title of the first subchapter of the second chapter

2.2 Title of the second subchapter of the second chapter

3. Game Implementation

3.1 Title of the first subchapter of the second chapter

3.2 Title of the second subchapter of the second chapter

4. Artificial Intelligence Agents

4.1 Title of the first subchapter of the second chapter

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5. Experiments

5.1 Title of the first subchapter of the second chapter

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Conclusion

Bibliography

Alexey Lobashev. Durak (fool), March 2022. URL <https://www.pagat.com/ beating/durak.html>.

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A. Attachments

A.1 First Attachment