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Explore Ludi Systems: Game Design and Evaluation based on Evolutionary algorithms

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ABSTRACT

In today's rapidly developing game industry, the demand for automated game design and evaluation tools is growing. This paper evaluates the formulas and concepts proposed in Cameron Browne and Frederic Maire's "Evolutionary Game Design" and explores their effectiveness and applicability in practical applications. The study focuses on the Ludi system, which uses evolutionary algorithms to generate and evaluate combinatorial games. Key aspects such as the game description language (GDL), the concept of ludemes, and the performance of evolutionary algorithms in game generation are analyzed. Limitations and future research directions are also discussed to provide valuable insights for the field of automated game design.

KEYWORDS

Automated game design; Evolutionary algorithms; Game evaluation; Combinatorial games; Ludemes

1. INTRODUCTION

In today's rapidly developing game industry, the need for automated game design and evaluation tools has become increasingly urgent. In their paper "Evolutionary Game Design" (Browne, 2014), Cameron Browne and Frederic Maire proposed a game design method based on evolutionary algorithms and developed a system called Ludi for automatically generating and evaluating combinatorial games. This paper aims to evaluate the various formulas and concepts proposed in this literature and explore their effectiveness and applicability in practical applications.

Game design has always been a complex and diverse field. Traditional game design mainly relies on the experience and intuition of designers. However, with the development of artificial intelligence and computational intelligence, more and more research has begun to explore how to use algorithms and computational models to assist or even automate the game design process, like PuzzleScript. "PuzzleScript is an open-source web-based puzzle game engine designed to help users make tile-based puzzle games." (Card et al., 2021) In particular, combinatorial games are very suitable for algorithm research and automated design because their rules are relatively simple and clear. Classic combinatorial games such as chess, go, and checkers have been widely studied, and artificial intelligence has made many important breakthroughs in these studies. "Two decades later, computers regularly beat humans at chess. Nowadays, we all know computation power has increased drastically." (Karia et al., 2022) However, despite significant progress in developing strong artificial players, there is relatively little research on how to automatically evaluate game quality and generate new games.

In the article "Evolutionary Game Design", the authors raised a key question: How to define and measure the quality of a game? They proposed a set of automated measurement methods based on self-play simulation, which evaluates key attributes of the game such as depth, clarity, drama, and decisiveness by simulating the actual game process. The Ludi system can not only evaluate the quality of existing games, but also generate new games with high quality through evolutionary algorithms. The core idea of the system is to describe the rules and structure of the game through "ludemes" (game information units). This method can not only capture the basic elements of the game, but also generate new game rule combinations by reorganizing these elements.

This paper will explore the effectiveness of various formulas and concepts proposed in "Evolutionary Game Design" in practical applications by analyzing and evaluating them in detail. We will focus on the framework design of the Ludi system, the rationality of game quality measurement indicators, and the performance of evolutionary algorithms in game generation. At the same time, this paper will also discuss the limitations of the research methods of this literature and put forward suggestions for further research. Through this review, it aims to provide valuable references and inspiration for future research on automated game design.

2. LITERATURE REVIEW

2.1. Framework and Implementation of Ludi System

The design of the Ludi system is one of the most innovative parts of Evolutionary Game Design. It not only provides an effective platform for automated game design, but also realizes the automated evaluation of game quality through evolutionary algorithms and self-playing simulation. The core framework of the Ludi system consists of multiple modules, including game description language (GDL), general game player (GGP), strategy module, criticism module and synthesis module. Each module plays an important role in the entire system, ensuring the complete process of game definition, evaluation and generation.

2.2. Game Description Language(GDL)

Ludi's GDL is a high-level description language designed to define the basic elements and rules of a game through "ludemes". Ludemes are the basic information units of a game, similar to the basic data types in programming. With this language, designers can use simple, intuitive syntax to describe complex game rules and structures. This approach not only improves the efficiency of game design, but also enables the system to easily parse and manipulate game rules. Other studies have also shown that similar high-level description languages have significant advantages in design and automation system design. "To address this, we have designed TDL (Task Definition Language), an extension of C++ that simplifies the development of robot control programs by including explicit syntactic support for task-level control capabilities." (Simmons & Apfelbaum) As Simmons said, through high-level description languages, designers' work efficiency is greatly improved, not only because high-level description languages improve design efficiency, but also because of the improvement in the speed of reading the design process. The application of GDL in game design reflects the advantages of high-level description languages. It makes the description of complex rules concise and intuitive, and improves design efficiency. However, compared with other high-level description languages, GDL may have certain limitations in versatility and extensibility. In the future, we can learn from the design concept of TDL to further optimize the syntax and functions of GDL, so that it has stronger adaptability in professional fields. "Task trees encode the hierarchical decomposition of tasks into subtasks, as well as synchronization constraints between tasks." (Simmons & Apfelbaum) TDL uses a task tree structure to represent the parent-child relationship and synchronization constraints between tasks. This structure makes the dynamic generation and execution of tasks more intuitive and flexible.

GDL can use a similar task tree structure to represent game rules and logical relationships, which will help to manage the state and behavior in the game more intuitively and flexibly.

2.3. Ludeme Discussion

Ludemes is a key concept in evolutionary game design. It represents the basic unit or information fragment of the game rules. Through the combination of these basic units, a complete game rule system can be constructed. The introduction of this concept has greatly promoted the development of automated game design.

First, the use of Ludemes simplifies the representation and operation of game rules. In traditional game design, rules are often complex and difficult to modify, while Ludemes breaks down rules into basic units, making the representation of rules more intuitive and easier to operate. This not only helps to automatically generate game rules, but also makes it easier to analyze and optimize the rules. "The software is easy to use for those who are not technically inclined, while also providing the functionality for integrating existing agents and AI techniques." (Stephenson et al., 2019)

However, the application of Ludemes also has some limitations. First, the definition and selection of Ludemes is a challenge, and different definitions and combinations may lead to differences in the quality of generated games. How to define and select suitable Ludemes is still an issue that needs further research. "This taxonomy, while comprehensive within the scope of essential gameplay mechanics, represents only a portion of a potential hierarchical model of learning skills, competencies, and capabilities facilitated by TTRPG participation". (Riel & Monahan, 2024) This literature also shows a point about Ludemes. When using Ludemes for game research, it is very important for researchers to define and use Ludemes in the scenario. So, when a large number of different types of games use Ludemes for prediction, perhaps this model will cause large deviations due to unclear usage scenarios and definitions of Ludemes in specific games.

Secondly, some studies have shown that using Ludeme alone is not a very rigorous solution. "Rather than using only the ludemes within our game descriptions, including additional game features or concepts may provide better results. " (Stephenson et al., 2021) In other words, as more and more games are derived, the number of games that can be predicted by Ludeme becomes limited.

In general, Ludemes provides an effective method and tool for automated game design. Its modularity, flexibility, and ease of operation make it of great application value in evolutionary game design. Future research can further optimize the definition and selection of Ludemes and explore more application scenarios to improve the efficiency and quality of automated game design.

3. ANALYSIS AND EVALUATION

The evolutionary algorithm and Ludi system proposed in "Evolutionary Game Design" have made important contributions to the field of automated game design, but there are also some aspects of its methods and results that deserve critical thinking. First, although the aesthetic standards used in the literature (such as depth, clarity, drama, and decisiveness) provide a framework for evaluating game quality, these standards are highly subjective, and different players may have different evaluations of the same game. Therefore, aesthetic standards may be unstable and inconsistent in practical applications, and this problem needs further research and optimization. "As people differ in how they respond to artworks [3], unlike general quality assessment, aesthetic assessment is associated more with high-level components of the contents in terms of emotions, composition, and beauty." (Schlotz et al., 2021)

In addition, the Ludi system mainly focuses on the design and evaluation of combinatorial games, while its applicability to other types of games (such as multiplayer games and non-combinatorial games) has not been fully verified. Combinatorial games have relatively simple and clear rules, which

are suitable for the study of evolutionary algorithms, but multiplayer and non-combinatorial games are more complex and require more complex algorithms and evaluation methods. This research gap limits the wide application of the Ludi system, and future research should further explore the applicability of evolutionary algorithms in different types of games.

4. RESEARCH STATUS

The paper "Evolutionary Game Design" conducted an in-depth study on the application of evolutionary algorithms in game design and proposed a method for automated game evaluation and generation. However, there are still some noteworthy research status and controversies in the practical application of this method. First, the experimental results in this paper show that the quality of games can be effectively evaluated and innovative new games can be generated through the combination of self-play simulation and aesthetic standards. This finding is of great significance to automated game design, especially in reducing game development time and improving design efficiency (Browne, 2014).

Nevertheless, there is still some controversy over the subjectivity and applicability of the game quality measurement indicators proposed in the literature. For example, although aesthetic standards such as depth, clarity, drama, and decisiveness can reflect the quality of the game to a certain extent, due to the subjectivity of these standards, different players may have different evaluations of the same game. This subjectivity may lead to instability and inconsistency in the evaluation results, and further research is needed to optimize and standardize these measurement indicators.

In addition, the experiments in this literature mainly focus on combinatorial games, and whether they are also applicable to other types of games (such as multiplayer games and non-combinatorial games) has not been fully verified. The literature points out that combinatorial games are suitable for the study and application of evolutionary algorithms due to their clear rules and simple structure. However, multiplayer games and non-combinatorial games are more complex and may require more complex algorithms and evaluation methods. This research gap needs further exploration to verify the applicability and effectiveness of evolutionary algorithms in a wider range of game types.

Finally, although the Ludi system has demonstrated its innovation and potential in generating new games, the quality of the generated games is still unstable. This may be due to the randomness and complexity of the evolutionary algorithm. In the generation process, how to avoid over-complexity of the generation rules is still an important problem that needs to be solved.

5. CONCLUSION

This paper analyzes and evaluates the evolutionary algorithm and Ludi system proposed by Cameron Browne and Frederic Maire in Evolutionary Game Design in detail. By evaluating various formulas and concepts in this paper, we explore their effectiveness and applicability in practical applications.

First of all, as an innovative method for automated game design, the Ludi system realizes the complete process from game definition, evaluation to generation through the combination of high-level game description language (GDL), general game player (GGP), strategy module, criticism module and synthesis module. GDL uses ludemes to define the basic elements and rules of the game, which simplifies the description and operation of complex game rules and improves design efficiency and flexibility. However, compared with other high-level description languages, GDL still has certain limitations in versatility and extensibility. In the future, we can learn from the design concept of TDL to further optimize the syntax and functions of GDL, so that it has stronger adaptability in more professional fields.

Secondly, the evolutionary algorithm of the Ludi system generates new game rule combinations through selection, crossover and mutation operations, and evaluates the quality of the game through

self-play simulation and aesthetic standards. Although this method improves the innovation and quality of the generated games to a certain extent, the subjectivity of the aesthetic standards and the instability of the evaluation results are still issues that need further research and optimization. In addition, the Ludi system mainly focuses on the design and evaluation of combinatorial games, and its applicability to multi-player games and non-combinatorial games has not been fully verified. Future research should further explore the applicability of evolutionary algorithms in different types of games.

Overall, Evolutionary Game Design has made important contributions to the field of automated game design, but there is still room for improvement in terms of aesthetic standards, algorithm applicability, and quality of generated games. By optimizing existing methods, expanding the scope of research, and interdisciplinary collaboration, future research on automated game design is expected to make greater progress and bring more innovation and development opportunities to the game industry.

Future research can focus on the following aspects: optimizing aesthetic standards to reduce the subjectivity and instability of evaluation results; exploring the application of evolutionary algorithms in multiplayer games and non-combinatorial games; improving the stability and quality of generated games; combining research in fields such as psychology and cognitive science to gain a deeper understanding of players' needs and preferences; and testing and verifying the performance of Ludi systems and evolutionary algorithms in practical applications through actual game development projects. These efforts will help further promote the development and application of automated game design and provide more valuable tools and methods for game designers and researchers.

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