APPLICATION OF FUZZY LOGIC AND GENETIC ALGORITHM APPROACHES IN EVALUATION OF GAME DEVELOPMENT

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Abstract— *The gaming industry is undergoing rapid evolution, presenting developers with intricate challenges in selecting compelling and successful game concepts. To tackle these challenges, decision support systems (DSS) play an increasingly crucial role in facilitating accurate decision-making. Despite their growing importance, the adoption of DSS within the gaming sector remains limited. Therefore, scientific research focused on developing DSS to evaluate optimal game concepts is essential to foster innovation in gaming industries. This study aims to construct a decision support system utilizing fuzzy logic and optimized with genetic algorithms to assess and identify game concepts with the highest potential for success in the market. Evaluation results highlight the system's effectiveness in recommending top-quality games like "Clash of Clans," "Honor of Kings," and "Genshin Impact," renowned for delivering exceptional gaming experiences and receiving high ratings. The system evaluation achieved an average Mean Squared Error (MSE) of 0.0246, indicating accurate prediction of game ratings with minimal error. The significance of this research extends beyond advancing decision support systems in gaming, opening avenues for further advancements in optimizing game evaluations and similar technologies across industries grappling with data-driven decision-making challenges.*

Keywords: *Decision Support Systems, Games, Fuzzy Logic, Genetic Algorithms.*

Abstrak— Industri game sedang mengalami evolusi cepat, memberikan tantangan kompleks bagi pengembang dalam memilih konsep game yang menarik dan sukses. Untuk mengatasi tantangan ini, sistem pendukung keputusan (DSS) memainkan peran yang semakin penting dalam memfasilitasi pengambilan keputusan yang akurat. Meskipun pentingnya semakin meningkat, adopsi DSS dalam sektor game masih terbatas. Oleh karena itu, penelitian ilmiah yang berfokus pada pengembangan DSS untuk mengevaluasi konsep game optimal sangat penting untuk mendorong inovasi dalam industri game. Studi ini bertujuan untuk membangun sistem pendukung keputusan yang menggunakan logika fuzzy dan dioptimalkan dengan algoritma genetika untuk menilai dan mengidentifikasi konsep game dengan potensi kesuksesan tertinggi di pasar. Hasil evaluasi menunjukkan efektivitas sistem dalam merekomendasikan game berkualitas tinggi seperti "Clash of Clans," "Honor of Kings," dan "Genshin Impact," yang terkenal karena memberikan pengalaman bermain game yang luar biasa dan mendapatkan rating tinggi. Evaluasi sistem ini mencapai Mean Squared Error (MSE) rata-rata sebesar 0.0246, menunjukkan prediksi rating game yang akurat dengan kesalahan minimal. Signifikansi dari penelitian ini tidak hanya berdampak pada kemajuan sistem pendukung keputusan dalam industri game, tetapi juga membuka jalan untuk kemajuan lebih lanjut dalam mengoptimalkan evaluasi game dan teknologi serupa di berbagai industri yang menghadapi tantangan pengambilan keputusan berbasis data.

Kata Kunci*: Sistem Pendukung Keputusan, Game, Fuzzy Logic, Algoritma Genetika.*

INTRODUCTION

The modern gaming industry continues to experience rapid growth, making it one of the most dynamic and innovative sectors worldwide (Rahajaan & Yaurwarin, 2022). The accessibility of games across various platforms, such as computers

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and mobile devices, has provided users with a wide range of entertainment options while creating profitable business opportunities for game developers, e-sports athletes, and sellers of gaming accessories (Dhanandjaya et al., 2022).

As the gaming industry continues to expand rapidly, game developers face a multitude of complex challenges in creating games that not only capture attention but are also favored by gamers. To achieve success, developers must demonstrate ingenuity and originality in their selection of concepts, designs, and features that most appeal to players (Dimitriadou et al., 2021). A game can no longer rely solely on technical aspects such as graphics and gameplay; careful consideration must also be given to elements such as game mechanics, design aesthetics, and complexity levels (Spieler & Kemeny, 2020).

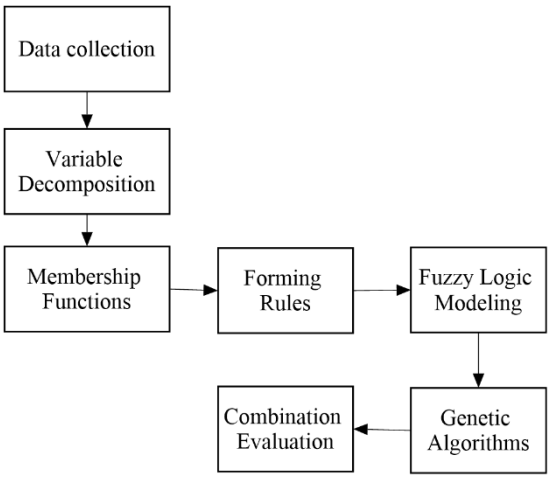
The role of Decision Support Systems (DSS) is becoming increasingly vital in aiding developers in making accurate decisions. A DSS is a system designed to facilitate the decision-making process by providing essential information, models, and tools for evaluating and analyzing data(Mahendra et al., 2023), (Aziz et al., 2024), without replacing the input from decision-makers (Novita et al., 2022). Specifically in the gaming industry, DSS can contribute to assessing the quality of a game based on a set of predetermined criteria, thereby enabling developers to make more precise and efficient decisions (Mu'alimin & Latipah, 2021).

The concept of Decision Support Systems (DSS) has been applied in various commercial and industrial scenarios (Wibowo et al., 2020), (Aziz et al., 2020), (Su et al., 2023), (Kabadurmus et al., 2023), (Purnamawati et al., 2023), (Prasetyo & Prasetyaningrum, 2023). Research on decision support systems in the gaming world has been conducted (Altanny & Johan, 2023), where a website was designed to rank the best characters in the game Genshin Impact based on five combat roles. Using the Simple Additive Weighting (SAW) method, it successfully helped F2P players choose the most suitable character. Previous research by (Mu'alimin, 2021) developed an application to help parents select games for young children according to predetermined criteria using the Topsis method. While decision support systems can serve as a reference for future evaluations, no study has specifically implemented fuzzy methods and genetic algorithms to evaluate the best game concepts from a developer's perspective. Evaluating game concepts often faces high uncertainty and complexity due to the numerous factors that must be considered, making conventional evaluation methods potentially ineffective in addressing these issues.

This research aims to develop a decision support system to assist game developers in evaluating and selecting game concepts that possess the greatest potential for success in the market. This system takes into account various key aspects such as graphics, gameplay, narrative, innovation, sound quality, and developer reputation. By implementing fuzzy methods and optimizing with genetic algorithms, this study aims to create an evaluation model that can enhance accuracy and effectiveness in the selection process of the most likely successful games, while addressing the uncertainties and complexities in evaluation. Therefore, this research is expected to make a positive contribution towards improving the quality and performance of games under development.

MATERIALS AND METHODS

The following represents the research stages conducted by the researcher, as shown in Figure 1. The dataset used in this study was obtained from the Kaggle website, which contains data on mobile and PC games for the game development process (Fadly, 2023). This dataset includes information about various well-known games on mobile platforms. This information encompasses several assessment factors used to determine the quality of each game, covering aspects such as graphics, gameplay, storyline, innovation, audio quality, and developer. The evaluation for each of these factors employs a scale from 1 to 10, with higher numbers indicating superior quality.



Source: (Research Results, 2024)
Figure 1. Research methodology

In complex decision-making, we often encounter situations where available data is

incomplete or uncertain, and the criteria used to evaluate alternatives can be highly diverse and difficult to measure directly. It is in this context that the strengths of two distinct approaches, namely fuzzy logic and genetic algorithms, can be combined to provide a more effective solution.

Fuzzy logic is a mathematical algorithm that utilizes computers to mimic the way humans comprehend and make decisions in the real world (Kharisma et al., 2023). This technique simplifies problem modeling by allowing for uncertainty and ambiguity in human judgment. Through fuzzy logic, we can create criteria that are more flexible and precise for evaluating complex situations, thereby handling uncertain data more efficiently (Junaidi, 2023). For example, in game evaluation, criteria such as "graphics," "gameplay," and "storyline" are often difficult to measure accurately, and fuzzy logic enables us to describe these criteria in finer shades of gray.

On the other hand, genetic algorithms have the advantage of being adaptable and efficient without requiring gradient information (Acampora et al., 2023). Their ability to explore search spaces globally and locally makes them highly effective in solving various optimization problems. Genetic algorithms are also easy to implement, parallelizable, and flexible (Junaidi, 2023), (Acampora et al., 2023). With genetic algorithms, we can tackle various optimization challenges and search for solutions (Aziz et al., 2024).

The combination of fuzzy logic and genetic algorithms can enhance system performance by addressing uncertainty, optimizing parameters, and identifying optimal input combinations. This enables stronger solutions that are more adaptable to complex problems. Therefore, their combination can offer superior decision-making solutions, particularly when dealing with uncertain data and evaluations involving numerous complex criteria.

RESULTS AND DISCUSSION

A. Datasets

Table 1 presents several datasets of mobile and PC games containing various criteria, including game title, publisher, rating, graphics, gameplay, storyline, innovation, sound, and developer (Fadly, 2023).

Table 1. Mobile and PC Game Data

Game Title	Publisher	Rating	Graphics	Gameplay	Storyline	Innovation	Sound	Developer
Clash of Clans	Supercell	4,7	6	7	5	6	6	7
Honor of Kings	Tenc	4,7	8	8	5	7	8	8
Genshin Impact	miHoYo	4,6	9	9	9	8	9	9
Minecraft	Mojang	4,6	8	9	6	8	8	6
Candy Crush Saga	King	4,6	6	7	5	6	6	6

Source: (Fadly, 2023)

B. Variable Decomposition

In this stage, fuzzy variables are initialized for each assessed aspect of the game, with antecedents for inputs and consequents for outputs within the control system. The input variables include graphics, gameplay, storyline, innovation, sound, and developer, while the output variable is the rating. These input variables are considered to have a significant influence on the overall quality of the game. Each variable is defined within a range of values from 0 to 10, with an interval of 1, as depicted in Figure 2.

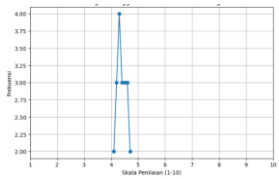


Figure 2(a) Rating Scale

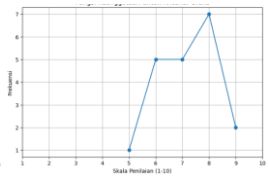


Figure 2(b) Graphic Scale

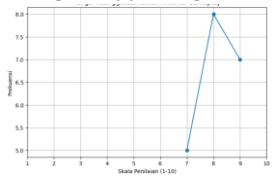


Figure 2(c) Gameplay Scale

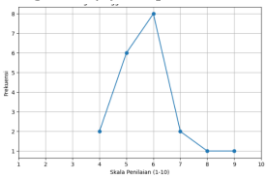


Figure 2(d) Story Scale

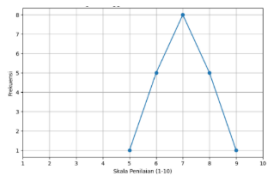


Figure 2(e) Innovation Scale

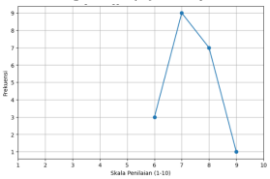


Figure 2(f) Sound Scale

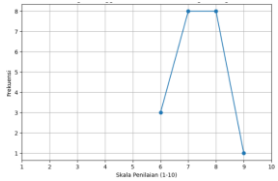


Figure 2(g) Developer Scale

Source: (Research Results, 2024)

Figure 2. Scale of Each Variable

In Figure 2, the horizontal axis of each image represents the rating scale from 1 to 10, which is

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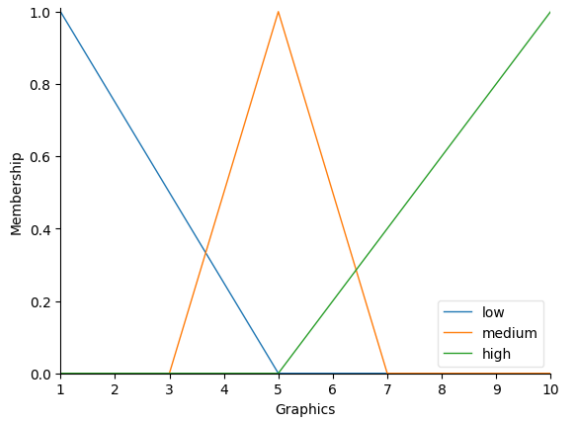
used to assess the games based on the established criteria. The vertical axis indicates the frequency or the number of games receiving a particular rating on this scale. Each point on the plot signifies how many games have received a specific rating. The higher the position of the point, the greater the number of games that have obtained that rating.

C. Defining Membership Functions

The researcher then employed the automf(3) function, also known as the simple triangular membership function, as it is straightforward to implement and sufficiently effective for the system. The automated process generates membership functions divided into three categories: low, medium, and high. These membership functions determine how input values are categorized into each linguistic label. An illustration of the membership function for one of the variables defined in Figure 3 below is provided, where the low criterion resides in trimf [1, 1, 5], the medium criterion in trimf [3, 5, 7], and the high criterion in trimf [5, 5, 10].



Source: (Research Results, 2024)

Figure 3. One of the Membership Functions in Graphic Variables

D. Forming Fuzzy Rules

In this stage, fuzzy rules are formulated based on fuzzy logic as elucidated in Table 2. These rules dictate how the combination of fuzzy input values will yield specific fuzzy output values.

Table 2. Fuzzy Rules

Rules	Description
Rules 1	If any of the graphics, gameplay, story, innovation, sound, or developer is 'low', then the rating is 'low'
Rules 2	If all graphics, gameplay, story, innovation, sound, and developer are 'medium', then the rating is 'medium'
Rules 3	If any of the graphics, gameplay, story, innovation, sound, or developer is 'high', then the rating is 'high'

Source: (Research Results, 2024)

E. Fuzzy Logic Modeling and Genetic Algorithms

In this stage, a fuzzy logic model is constructed to evaluate games based on predetermined criteria. In this model, both input and output variables are utilized to determine the quality rating of the games using fuzzy rules. The outcomes triggered by the rules are then aggregated to produce the final fuzzy output, which is subsequently defuzzified (converted from fuzzy values to crisp/single values) using the centroid method to generate the final rating score.

The model is constructed by inputting values for each variable, namely graphics, gameplay, storyline, innovation, sound, and developer, with scores of 8, 9, 7, 8, 9, and 8 respectively. The fuzzy control system generates a rating of 8.1, involving the evaluation of various predefined fuzzy rules that integrate diverse assessment aspects to produce a comprehensive output. The system yields a relatively high rating because many rules supporting high outputs are triggered, particularly emphasizing graphics and gameplay, which are crucial factors in this evaluation, both obtaining high scores.

Table 3. Game Rating Scores Using the Fuzzy Logic Model

Game Title	Publisher	Rating	Graphics	Gameplay	Storyline	Innovation	Sound	Developer	Rating score
Fortnite	Epic Games	4.2	9	9	6	7	7	8	8.277778
Genshin Impact	miHoYo	4.6	9	9	9	8	9	9	8.277778
Roblox	Roblox Corporation	4.4	8	8	7	8	8	8	8.142857

Source: (Research Results, 2024)

In Table 3, games such as "Fortnite" and "Genshin Impact" obtained high scores, reflecting their high quality in various aspects such as graphics, gameplay, and developers. The next step

involves the application of genetic algorithms to select combinations of games that provide the highest total rating. This process is conducted by representing each game as an individual in the population, where each individual has genes to indicate whether the game is selected or not.

Genetic algorithms execute an evolutionary process using the described genetic operators and run for 50 generations with a crossover probability of 0.5 and a mutation probability of 0.2. In each generation, individuals with the best fitness values are selected, and this process repeats to create a new generation. Through this evolutionary process, the population of individuals is analyzed and modified to search for optimal solutions.

Table 4. Best Games Based on Genetic Algorithm Rating Scores

Game Title	Publisher	Rating	Graphics	Gameplay	Storyline	Innovation	Sound	Developer	Rating score
Clash of Clans	Supercell	4.7	6	7	5	6	6	7	7.740741
Honor of Kings	Tencent	4.7	8	8	5	7	8	8	8.142857
Genshin Impact	miHoYo	4.6	9	9	9	8	9	9	8.277778
Candy Crush Saga	King	4.6	6	7	5	6	6	6	7.740741
Minecraft	Mojang	4.6	8	9	6	8	8	6	8.142857

Source: (Research Results, 2024)

After the genetic algorithm explored through various combinations of populations, the top 5 games with the highest ratings from the best-found population are Clash of Clans, Honor of Kings, Genshin Impact, Candy Crush Saga, and Minecraft as seen in Table 4 above.

F. Combination Evaluation

After the model optimization process is completed, an evaluation is conducted on the best population to select the recommended games. The selected games are then assessed based on ratings and other criteria. From the five selected games, we can observe a good diversification both in terms of publishers (Supercell, Tencent, miHoYo, King, Mojang) and the types of gameplay offered, ranging from strategy and adventure to puzzle, indicating that the algorithm successfully selects games that are not only high in ratings but also offer a variety of experiences for players. All selected games have relatively high ratings, indicating that the algorithm successfully selects games that are not only popular but also of high quality in various aspects such as graphics, gameplay, and storyline.

The system evaluation was conducted using cross-validation by calculating the Mean Squared Error (MSE) to measure the accuracy of the predicted ratings compared to the actual values. The average MSE obtained was 0.0246, indicating that the fuzzy system is quite accurate in predicting game ratings with a low prediction error.

CONCLUSION

The evaluation results demonstrate that this system is capable of providing high-quality game recommendations based on aggregate values generated through the defuzzification process. The recommended games, including "Clash of Clans," "Honor of Kings," "Genshin Impact," "Candy Crush Saga," and "Minecraft," indicate that the model can select games that are not only popular but also have high ratings and offer a quality gaming experience. Furthermore, this study opens up opportunities for further development and research in optimizing game evaluation systems and similar technologies in other sectors facing similar challenges in data-driven decision making. This includes expanding the dataset to encompass more types of games and user data, as well as integrating other machine learning techniques such as deep learning and reinforcement learning. A more comprehensive evaluation with cross-validation techniques and real-world testing is necessary for further validation.

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