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APPLICATION OF MULTI-CRITERIA PROMETHEE METHOD TO ASSIST CHARACTER SELECTION IN THE ENDLESS RUNNER GAME

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Abstract

The endless runner game is one of the most popular game genres, but selecting the optimal character for different map challenges poses a significant problem for players. In this context, this research was conducted to help select characters in the endless runner game using the PROMETHEE method. This selection is recommended based on the weight and difficulty of each map which varies, including the rice field map, road map and alley map. The implementation of calculating character recommendations uses the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) method with the highest score as the best ranking. Rank suitability can be determined by comparing the PROMETHEE method with the TOPSIS method on 15 characters alternatives with 6 criteria. As a result, the PROMETHEE method has significant value, but some still have the same best ranking as the TOPSIS method. Furthermore, usability testing was carried out on 57 respondents using the System Usability Scale (SUS) with an overall score from the evaluation of 78,8. The final score obtained based on the acceptance scale was included in the category suitable for use.

Keywords: *Game, Multicriteria, PROMETHEE*.

1. INTRODUCTION

When we talk about world economic development, the gaming industry has become one of the industries who has developed rapidly in recent years. The gaming market in Indonesia was relatively small at first. Over the years, many games have surfaced with various innovations that have attracted people's interest, including good graphics, advance features and interesting plots. The developments are more varied starting from board games to video games on multiple platforms.

The era of globalization has positioned Indonesia as one of the countries with the largest gaming market in Asia. In 2023, the video game market in Indonesia is expected to expand by 7.17% from 2023 to 2027 [1]. One of the reasons for this advancement is technological sophistication and the impetus to create various new techniques in the gaming sector.

Endless run is one of the most popular game genres of all time. Endless runner game is a game with a mechanism where players have to run endlessly while avoiding obstacles in front of them [2]. If the player hits an obstacle, the game ends. The player's goal [3] in this game is to get the highest score while collecting coins and playing as long as they can.

From an academic perspective, this type of game is widely used as a learning medium, for example in mathematics [4] and advice to stop smoking. Another study designed an endless runner game using several methods such as FSM for NPC behavior [5] and Genetic Algorithm for level design [6]. Other research applies dynamic dui using Pure Data to provide a richer and more enjoyable audio experience [7].

Previous research in 2022, an endless runner game was designed with an educational theme to introduce various medicinal plants that can be used as alternative medicines to cure diseases. This research proves that games are not only able to provide player satisfaction, but can also be used as an educational medium for the players [8].

The recommendation system is crucial [9], because it assists players in efficiently allocating coins earned from the game to select suitable characters. The existence of this system helps players to more easily decide which character to pick, preventing them from being too extravagant in spending their coins.

The recommendation system not only has a positive impact on the game, but also refers to the principles taught in various wisdom teachings, including in terms of managing economic resources as well as commands to carry out commendable actions and avoid bad ones. Therefore, it is important as a player to be able to make the best use of this recommendation feature, integrating wisdom in character decision making with principles that lead to benefits and efficiency.

The recommendation system developed by the author is calculated from various alternatives that have different criteria values [10]. One approach to obtaining the best alternative value is through multi-criteria decision making. A method that can be used to make character selection recommendation decisions is the PROMETHEE method. The PROMETHEE method is one of the multicriteria decision making methods that calculates by comparing relative preferences between existing alternatives [11].

The Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) method in this research is used to calculate the decision selection process in the recommendation system for character selection in the game "Avoid Najasa" in the selection menu. This PROMETHEE-based recommendation system will allow players to gain an advantage in choosing characters from various existing options by considering the relevant criteria for each character according to the coin budget.

According to a research journal in 2020, using the PROMETHEE-II method to develop a taxonomy for identifying and prioritizing security challenges in the context of DevOps practices in the software industry. [12]. In another study, this method also can rank fiber reinforced composite materials [13], combine with Fuzzy for problem based on distance and similarity measures [14], automated cognitive workload assessment [15], and selecting green suppliers who focus on preventing environmental pollution [16].

There are several conceptual references in designing and developing game scenarios to convey knowledge to players. In 2022, Research conducted aims to find out travel recommendations according to player preferences in serious games using two methods. First, the scenario design method used is a Hierarchical Finite State Machine to translate the stories chosen by players based on challenges according to the type of tourist attraction. Second, Dynamic Weight-Topsis recommends scenarios chosen by the player [17].

This is also applied to discussing the importance of selecting the right heroes in the online multiplayer game Dota 2 [18], developed a sequential recommendation mechanism for the ban-pick stage in MOBA games [19], and Dota2 lineup recommendations using the Continuous Bag of Words (CBOW) model [20]. The implemented model can recommend the final hero based on the first four heroes selected. This is in line with the concept of character recommendations that researchers want to carry out. For this reason, other methods are used that can help select character recommendations.

2. METHODS

The research consists of the following stages such observation for data collection and criteria, system design and modelling, system implementation, system testing, and result analysis.

2.1. Observation for Data and Criteria

The research began with observations through searching for several references to endless runner genre games and games that have a character selection basis before the game starts. The results of the observations show that several games have elements of character selection, store, obstacles, challenges, power ups, currency, and simple control. Thus, several elements were added to this game so as to obtain the final goal of this game. Apart from that, character recommendations have been added to make it easier for players to choose which character to play.

2.2. System Design and Modellling

Generally, at this stage an overview of the game is explained. The design of the game "Avoid Najasa" begins with the main menu page on the initial display including start, highscore, credit and quit. The PROMETHEE calculation application is used in character selection when the player enters the selection menu after pressing the start button. Then, in the selection menu there is a character selection with various different criteria values.

Players can immediately get character recommendations the first time they play by pressing the recommendation button to get recommendations for alternative characters with the best criteria values using the PROMETHEE method. The following is a game diagram shown in figure 1.

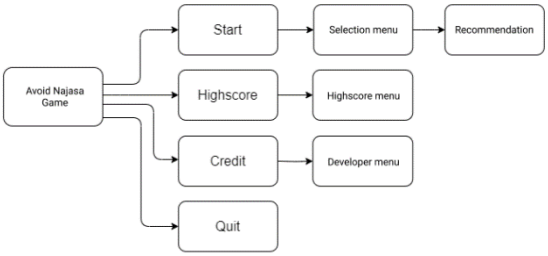

Figure 1. Game menu diagram.

2.3. System Implementation

The next stage is the implementation system, namely creating a game application with the following devices.

a. Hardware → Lenovo Laptop, i5-8265U
b. Software → Unity for building games, Blender and Figma for asset creation.

2.4. System Testing

System testing carried out in 2 stages, namely developer testing and user testing. Developer testing is carried out to check whether the entire system being built is working properly. In addition, a comparison of the best recommendations was carried out with the TOPSIS method. After this stage is completed, the new application is tested on users. The usability testing stage on 57 users using a rating scale using SUS.

2.5. Result Analysis

An analysis of the final features and functions is carried out from the user's side by providing suggestions on what needs to be improved. In addition, analyzing the effectiveness of the PROMETHEE method by comparing its recommendations with those of the TOPSIS method was carried out.

3. RESULT

3.1. Interface Design

The "Avoid Najasa" game interface design consists of several things, including the initial main menu display, selection menu display, map display, recommendation display, and gameplay.

a. Display main menu screen

When entering the game for the first time, players will be given a main menu display consisting of Start, Highscore, Instruction, Credit, and Quit. This menu can be seen in figure 2.

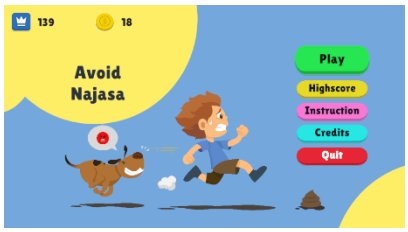

Figure 2. Main menu

b. Selection menu

This menu will appear after the player starts the game by pressing the Start button. Players will be given five characters for the price of zero coins. Therefore, players must collect as many coins as possible so they can buy other, better characters. The menu is shown in figure 3.

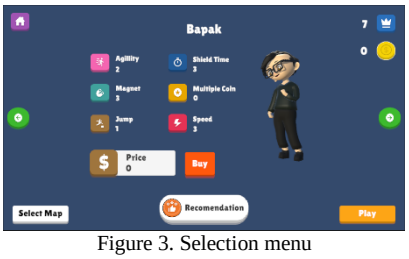

Figure 3. Selection menu

c. Select Map display menu

When the player has selected the desired character, the player can press the Select Map button to determine the location where the player will play. The maps or maps available, each have different criteria and interests. Map selection not only affects the battle atmosphere, but also has an impact on the character recommendations that will be given by the system. The menu display can be seen in figure 4.

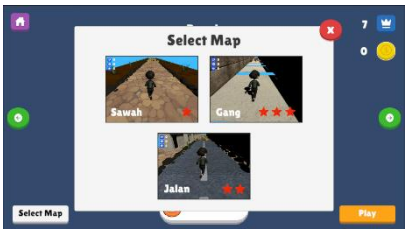

Figure 4. Select Map menu

d. Recommendation screen

The recommendation feature for using PROMETHEE is in the selection menu. Players can use this feature to choose recommended characters by paying attention to the coins the player has and the map location chosen by the player previously. This menu can be seen in figure 5.

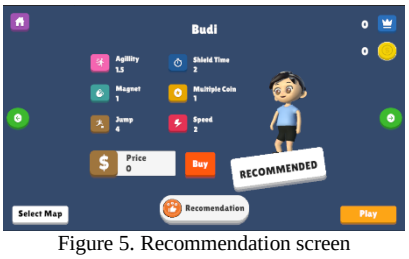

Figure 5. Recommendation screen

e. *Gameplay*

The display of the game that takes place is like this, using the A button (left), D button (right), and space button (jump) to control the character. Players have the ability to use the M button (magnet) which allows them to pick up coins that are far away. The menu is shown in figure 6.

Figure 6. Gameplay

3.2. System design

System design for implementing the method in the game 'Avoid Najasa' involves a design process that encompasses architecture, interface, and systems to integrate the PROMETHEE method into the selection menu. This stage comes after the system analysis has been carried out and the decision to apply the PROMETHEE method has been taken. Consequently, the system workflow diagram is created in the form of an FSM diagram regarding character recommendations for the game "Avoid Najasa" in figure 7.

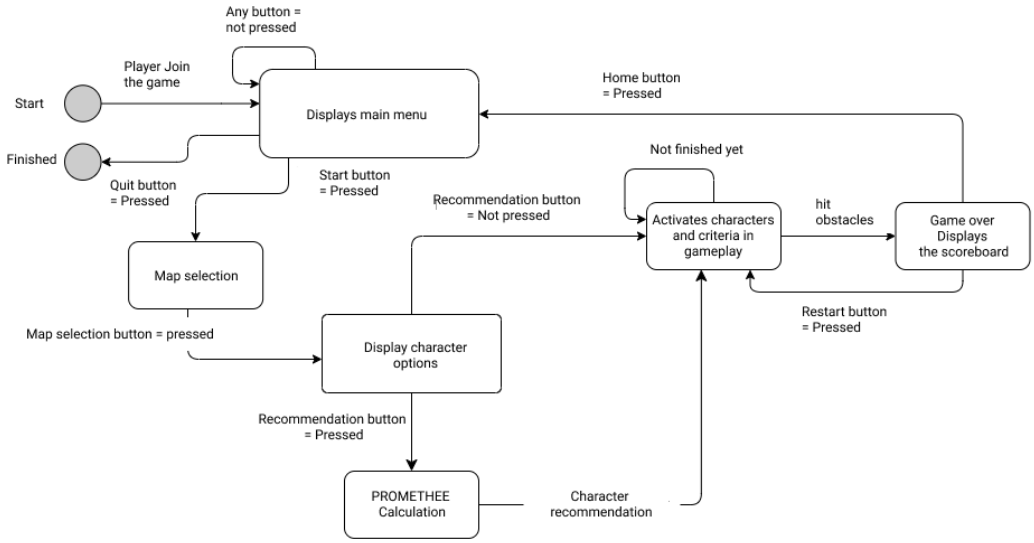

Figure 7. FSM system diagram

Figure 7 shows the design of the game scenario rules in the form of a Finite State Machine (FSM) to explain the system's activity [17]. When the game first starts, the screen displays the main menu. The main menu will show several primary menus. Next, the player is required to select the Start button to begin the game. The player then enters the Selection menu, where there are options for Map selection and Character selection. This is because the choice of map will affect the character criteria. Next, the player can choose a character in the selection menu, which displays various characters with different specifications and skills. Each character has a price that can be obtained through purchase. Additionally, the player can use the recommendation feature to get a character recommendation. The recommendation process uses PROMETHEE calculations. As the player collects more budget coins, the recommendations may change. The player can choose to use the recommendations or not. Finally, the character can be applied to the actual gameplay.

3.3. Implementation

Implementation of calculations on the system was carried out by testing the game selection menu "Avoid Najasa" using the multi-criteria based PROMETHEE method. This menu will give you a choice of characters with the values shown in table 1.

Table 1. Decision matrix

Criteria	A1	A2	A3	A4	A5	A6	A7	A8
Agility	2	1.5	2	2	1.5	2	2	3
Magnet	3	1	2	2	3	2	2	2
Jump	1	4	2	3	1	0.5	0.5	2
Shield Time	3	2	1	1	2	0	0	3.5
Multiple Coin	0	1	3	2	1	5	5	1
Speed	3	2	2	2	3	1.5	1.5	3.5

3.3.1. Determine the Preference Type

There are six types of preferences in this method (Usual, U-Shape, V-Shape, Level, Linear, and Gauss). Determining criteria that match this type of preference is considered through previous research. Then, if necessary, it will be considered by the decision maker. The types of preferences used in applying the PROMETHEE method in determining the best alternative in character selection are shown in table 2.

Table 2. Specifies the preference type

Criteria	Preference Type	Parameter	
		p	q
Agility	V	0.5	1
Magnet	V	0.5	1
Jump	V	0.5	1
Shield Time	V	0.5	1
Multiple Coin	V	0.5	1
Speed	III	-	1

3.3.2. Calculating Preference Index Values

Calculation of the preference index value involves each alternative. To calculate the preference index, you need to find the difference between two alternatives. After that, calculate the preference value for the previously selected type. The results of the preference values will be multiplied by the criteria weights and displayed in table 3.

Table 3. Calculating the preference index

	A1	A2	A3	A4	A5	A6	A7
A1	0	0.31	0.31	0.31	0.09	0.31	0.31
A2	0.6	0	0.35	0.35	0.42	0.35	0.35
A3	0.6	0.4	0	0.18	0.6	0.35	0.35
A4	0.6	0.4	0.26	0	0.6	0.35	0.35
A5	0.18	0.22	0.31	0.31	0	0.31	0.31
A6	0.42	0.48	0.26	0.26	0.42	0	0
A7	0.42	0.48	0.26	0.26	0.42	0	0

3.3.3. Calculation of Leaving Flow, Entering Flow and Net Flow

The next step after getting the multi-criteria preference index value is to calculate leaving flow, entering flow and net flow for each alternative. Leaving flow measures the extent to which an alternative surpasses other alternatives in terms of preferences. Entering flow measures the extent to which other alternatives beat this alternative. Net flow is the difference between leaving flow minus entering flow and reflects the relative ranking of alternatives based on preferences. These results are shown in table 4.

Table 4. Calculation of Leaving Flow, Entering Flow and Net Flow

Alternative	*Leaving flow*	*Entering flow*	*Net flow*	Rank
A1	0.28	0.48	-0.20	8
A2	0.42	0.38	0.03	3
A3	0.41	0.27	0.14	2
A4	0.46	0.26	0.20	1
A5	0.28	0.43	-0.15	7
A6	0.33	0.30	0.03	3
A7	0.33	0.30	0.03	3
A8	0.36	0.46	-0.09	6

The calculation trial produced the following conclusions.

a. a. The alternative with the highest leaving flow is A2, namely 0.46 and the lowest leaving flow is A5 with 0.28.
b. b. The alternative with the highest entering flow is A5, namely 0.48 and the lowest entering flow is A5 with 0.26.
c. The alternative with the highest net flow is A2, namely 0.20 and the lowest net flow is A3 with a value of -0.20.

3.4. System Testing

System testing is carried out after code implementation is complete. This stage includes game testing and presentation of test results. The game is tested on users with the aim of making the system work according to its function.

3.4.1. *Game Testing*

The testing phase begins with the user entering according to instructions to the Selection menu. Users are required to select one of three maps with various terrain. The different weights of each map will affect the character recommendation results because of the weights. This weight will later be included in the system calculations so that each map will have different character recommendations. This menu has a recommendation button shown in figure 8.

Figure 8. Recommendation button

The results of trials carried out using the PROMETHEE method were implemented into the C# Unity script. Next, calculations were added using the TOPSIS method as a comparison to the PROMETHEE method. The input provided is the character skill value that has existed since the start of the game, assuming the player has played the game several times and collected 70 coins. The coin value is stored in the coin score storage and is used as a reference for determining the number of characters to be counted. The following character data is presented in table 5.

Table 5. Input character data

Character	Budget (coin)	Price ≤ 70
Father	0	Yes
Budi	0	Yes
Mother	0	Yes
Martha	0	Yes
Brother	0	Yes
Grandpa	50	Yes
Grandma	50	Yes
Uncle	70	Yes
Aunt	80	No
Elementary students	100	No
Middle school students	150	No
High school student	200	No
Boarding School Students	250	No
Graduates	300	No
Ustadz	350	No

Based on table 5, there are 15 characters available, but only 8 meet the price requirement of less than 70 coins. The next step is to carry out calculations on each map using predetermined weightings.

Table 6. Weight of each map

Criteria	Weight		
	Rice field Map	Sreet Map	Alley Map
Agility	0.38	0.11	0.08
Magnet	0.05	0.15	0.22
Jump	0.12	0.08	0.26
Shield Time	0.19	0.15	0.09
Multiple Coin	0.09	0.30	0.18
Speed	0.17	0.21	0.16

Table 6 shows that three fields have several differences which cause the weight to be different. First, the Sawah map has the characteristics of coins, unclean obstacles and few shields. So, the highest weight is on the agility and shield time criteria. Second, the Road map is considered more difficult because there are fewer shields, but the obstacles are unclean and there are slightly more coins. Third, this Gang map is the most difficult map because there are obstacles in the form of large holes that players have to jump over every time, as well as more unclean obstacles that will appear.

The results of the system calculations have been multiplied by the weight, so the final value can be known. The character with the highest score is the choice recommended by the system. The following are the respective results from the various maps that have been mentioned, seen in table 7.

Table 7. The final calculated value for each map

Alternative	Rice field Map	Sreet Map	Alley Map
Father	-0.141	-0.269	-0.200
Budi	0.092	-0.096	0.034
Mother	0.018	0.146	0.140
Martha	0.044	0.095	0.200
Brother	-0.198	-0.184	-0.149
Grandpa	-0.058	0.241	0.034
Grandma	-0.058	0.241	0.034
Uncle	0.301	-0.174	-0.094

The difference in weights in the criteria for the three maps turns out to be very influential on the output recommended by the system. Therefore, setting the right weight for each criterion is very important to ensure that the recommendations given are in accordance with the characteristics of each map.

3.4.2. *System Usability Scale* (SUS)

Regarding usability testing carried out the System Usability Scale (SUS) test, SUS is used to measure how well the user experience interacts with the system that has been created especially in context of gaming applications [21]. This test is implemented in the game in the recommendation feature in the Selection menu. The goal is to identify potential problems that can affect player comfort, convenience and satisfaction when using these features and improve the player experience for the better. The SUS test has 10 questions as a testing tool with 5 answer choices. This calculation makes it easier and minimizes testing costs because it does not require a large number of samples. The following questions are shown in table 8.

Table 8. SUS usability testing questions

No.	Question
1	I think I will use this recommendation system again
2	I find this recommendation system complicated to use
3	I find this recommendation system easy to use
4	I need help from other people or technicians in using this recommendation system
5	I feel that the system features work as they should
6	I feel there are many things that are inconsistent (not harmonious in this recommendation system)
7	I feel like others will understand how to use this recommendation system quickly
8	I find this recommendation system confusing
9	I feel there are no obstacles in using this system
10	I need to get used to it first before using it

3.4.2.1. Usability Analysis

The usability testing stage on 57 users using a rating scale from 1 to 5, which refers to table 9. rating scale allows players to provide responses based on the level of satisfaction or effectiveness of the recommendation feature.

Table 9. Usability assessment scale

Scale	Value
Strongly Disagree (STS)	1
Disagree (TS)	2
Undecided (RG)	3
Agree (S)	4
Strongly Agree (SS)	5

After collecting data from respondents, calculations are carried out by considering several rules below.

a. Questions with odd numbers will have a score obtained from the user's score then subtracted by 1.
b. Questions with even numbers will have a final score of 5 minus the question score obtained.
c. The final SUS score is obtained from the sum of the scores for each question which is then multiplied by 2.5.

This score calculation rule applies to every single respondent. Then, find the average of the scores. The following is formula 1 for calculating the SUS score.

$$\bar{x} = \frac{\sum x}{n} \quad (1)$$

Where $\bar{x}$ = Average score
$\sum x$ = Total SUS score
n = Number of respondents

The conclusion from using the SUS method is to get the calculated results from the average score of the respondents. The assessment results are said to have a good level of usability if the average SUS score is more than 70. Meanwhile, results below 60 are considered unacceptable and require further improvement.

3.4.2.2. Demographic Analysis

Testing was carried out on 57 student and student respondents, with an age range of 10-24 years. Demographic data also revealed significant variations in the experience background, level of knowledge, and gaming experience of each respondent. Demographic details can be seen in table 10.

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Table 10. Demographic characteristics of respondents

Demographic Characteristics	Item	Respondents	Percentage (%)
Age	Adult (above 17 years)	18	31
	Teenagers (12 - 17 years old)	34	60
	Children (under 12 years old)	5	9
Playing experience	Ever	51	89
	Never	6	11
Platform	Smartphone	42	82
	PC	9	18
Playing experience	More than 3 months	35	69
	1 to 3 months	6	12
	Less than 1 month	10	19
One time to play	More than 6 hours	2	4
	3 to 6 hours	16	31
	Less than 3 hours	33	65
Playtime	Everyday	24	47
	2 to 3 times a week	22	43
	1 time a week	5	10

3.4.2.3. System Usability Scale (SUS) Score

Usability testing stage on 57 users using a rating scale from 1 to 5, which refers to table 10. This rating scale allows players to provide responses based on the level of satisfaction or effectiveness of the recommendation feature. The following are the results of the SUS trial for 57 respondents have been summarized in table 11.

Table 11. Results of respondent's SUS score

Respondents	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
R-1	3	3	3	4	4	2	4	3	3	1
R-2	4	3	4	4	3	4	3	4	4	3
…	…	…	…	…	…	…	…	…	…	…
R-56	4	4	4	2	4	4	4	4	4	3
R-57	4	4	4	1	4	4	4	4	3	0

Table 12. Respondent's SUS Score (after total multiplied by 2.5)

Respondents	Total	SUS Score (Total * 2.5)
R-1	30	75
R-2	36	90
…	…	…
R-56	37	93
R-57	32	80
Average Score (Final Result)		78.8

Based on table 12, the results of calculating the SUS score for each respondent, the highest score obtained was 98, the lowest score was 58, and the average score was 78,8. A more complete table of SUS calculation results can be seen in the attachment section. After calculating the average score, the application acceptance results were obtained as follows:

a. The final score obtained is based on the acceptance scale, the application made is included in the Acceptable category,
b. The final score is based on a ranking scale, the game created is included in the Good category. The final results can be seen in figure 9.

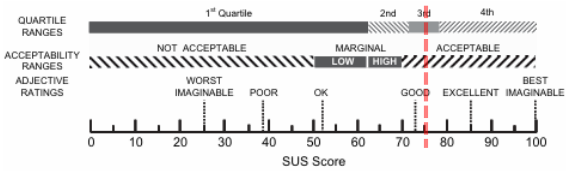

Figure 9. The final SUS rating scale for games

Based on the user's playing experience, there are unsatisfactory scores as seen from the lowest score obtained at 58. This shows that there are users who may experience difficulties or are dissatisfied with the game features that have been created. Therefore, one step that can be taken is to carry out further analysis to identify problems that need to be fixed.

4. DISCUSSION

Based on the results and explanation above, the author assumes that multi-criteria decision-making (MCDM) can be the basis for developing a more sophisticated character recommendation system in the future. This can be seen in the results of different character calculations on each map. Rice field Map gets the Uncle character with the highest score with 0.301. On Street Map, both characters Grandpa and Grandma have the highest score, both at 0.241. Meanwhile in Alley Map, the character Martha has the highest score with 0.200.

By considering several aspects such as type of criteria, weights, and game map, the system can provide recommendations according to the game environment. Additionally, this algorithm makes it possible to customize recommendations based on dynamic player preferences. The author realizes that this research has limitations due to the limitations of dynamically adjusting criteria weights based on real-time player feedback.

Therefore, future research needs to overcome this obstacle by developing adaptation techniques that are more sophisticated and responsive to changes in player preferences and behavior. Moreover, with the current development of artificial intelligence, it will be possible to obtain maximum suitability in terms of recommendations.

5. CONCLUSION

Based on the research results that have been provided, this paper discusses how to apply the PROMETHE method to calculate skill values as criteria and produce the best character ranking with the highest value as the best character recommendation. The differences in skill data and character prices also cause changes in alternative result. The PROMETHEE implementation indicates that the system has received input data from characters alternative. In the testing phase, PROMETHEE succeeded in producing the best character recommendations for players.

Next, usability testing was conducted on 57 respondents consisting of 18 adults, 34 teenagers and 5 children using the System Usability Scale (SUS). Overall average score of 78,8. Based on the acceptance scale, this final score falls into the Acceptable category, and according to the rating scale, the game is categorized as Good. Therefore, the results of the usability analysis indicate that the game is suitable for use.

Future studies plan to utilize various Multi-Criteria Decision Making (MCDM) methods combined with different machine learning techniques to determine the system with the highest accuracy, implementing it across diverse themes such as education and health to observe result variations across different scenarios and themes, while also integrating player preferences and historical data to enhance character selection considering factors beyond map difficulty, such as player behavior and preferences.

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