A Multi-Criteria Recommender System For NFT Based IAP In RPG Game

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***Abstract*— The market value of the gaming industry in 2021 is said to be more than 198.40 billion USD. Market value is also supported by the number of gamers, with 4.75 billion in January 2022. In today's In-App Purchase (IAP) income method has become a big trend in today's modern era models of free-to-play games, where gamers can choose or buy many items during the game to speed up the progress of the game or enjoy the full content of the game. However, sometimes players are overwhelmed with the number of items on offer, making it difficult for players to choose because the game content is too diverse. In addition, players are also worried about the security of their digital assets because, in 2021, there will be 7.5 million digital assets lost due to hacking. We propose a recommendation system to make it easier for players to choose items that suit their playstyle to solve this problem. We use the multi-criteria recommender system (MCRS) method because this method can improve the accuracy of recommendations compared to conventional recommendations that only use one criterion. In this study, we used eight criteria to calculate the recommendations. The results of our recommendation test show the accuracy value = 0.71, precision = 0.76, recall = 0.71 and F1 score = 0.66. To address security issues, we propose the implementation of a Non-Fungible Token (NFT) for each item. NFT can increase security because it uses a decentralized blockchain architecture in which every transaction is encrypted. The system guarantees that the assets will remain online so that users do not risk losing ownership of their assets when the developer changes game data, or the game server closes.**

Keywords—Game Industry, In-App Purchase, Multi-Criteria Recommender System, Non-Fungible Token, Blockchain.

I. INTRODUCTION (*HEADING 1*)

Game Development is one of the most important businesses in the Entertainment Industry, with more than 198.40 billion USD in 2021 [1]. This revenue is also supported by a growing audience, with more than 4.75 billion gamers worldwide in January 2022 [2]. The growth results from various marketing strategies of developers to increase their income. These strategies are, for example, prepayment games that get full game content on an initial payment and Free games that have a whole range, but players need to make in-app purchases if they have advanced needs [3]. The eMarketer survey [4] shows that in-App purchases (IAP) will become a big trend. IAP is also supported by statistics on the increasing number of in-app purchase revenues every year [5]. However, sometimes, players are overwhelmed with the number of items on offer and the variety of playstyles. This leads players to find it challenging to improve their game progress because the game content is too difficult.

One way to help make it easier for players to choose appropriate content is to use a recommendation system [6]. The recommendation system can help prevent this problem by offering items that match the player's preferences and play style, improving the purchase and in-game experience [7]. The system can ultimately increase revenue by increasing player retention and conversion from user free to play to pay to play [8]. However, in implementing In-App-Purchase sales, a large amount of money is lost from downloading or duplicating assets illegally [9]. Based on Apsalar research, 7.5 million virtual assets are lost due to fraud and hacking [10]. In addition, players are also worried about losing ownership of their assets when developers change game data or close game servers [11].

There is a solution to improve system security described in the research of Chia-Hung et al. [12] by using blockchain architecture. The study explains the decentralized blockchain architecture, where every transaction made is encrypted, and every transaction data nature cannot be changed and deleted, allowing for better data security. Christos et al. [11] explained that the reward mechanism in most games, including eSports, is usually controlled by game developers, and these prizes have no exchange value in the real world. The use of NTF can allow changes in the ownership mechanism of digital assets that players entirely hold, and each asset has an exchange value in the real world. This system guarantees that the asset will stay online, so users do not risk losing control of the digital asset or its value, even if the game company loses interest or goes bankrupt.

In this study, the MCRS recommendation system (Multi-Criteria-Recommender-System) will be used, which will perform calculations on player data with previous player data that has been recorded in the database. This method will generate item recommendations according to the data of players who have similar playstyles. Furthermore, for NFT-based In-App-Purchase implementation, we propose blockchain with the Ethereum platform. This research is expected to make it easier for players to choose the appropriate game items. The NFT method is also expected to create a complete digital asset ownership mechanism and have a sound security system.

II. RELATED WORK

Using the in-app purchase model is a more effective method of converting casual players (without buying items) into players who buy items. The concept is different from traditional payment methods or prepayments, where the user pays for the game and then plays it [13, 14]. In-app purchases provide a recurring revenue stream for game developers. Therefore, it is essential to analyze in-app purchase patterns and determine how to increase monetization [15].

A recommendation system is an essential method for increasing income [17]. In the research conducted by Arif et al. [19], a multi-criteria recommender system (MCRS) method was used to generate recommendation ratings as a reference for players to choose tourist destinations in halal tourism games. This method Improves the capabilities of conventional tourism recommendation systems, which are generally based on a single criterion. In this study, the authors use eight destination ranking criteria as a reference for calculating the recommendation system in the halal tourism game. Each of these criteria becomes a reference for tourists' assessment of halal tourist destinations in Indonesia. However, centralized data architecture is prone to data theft, hacking, and data loss when the server is turned off [20].

In Christos Karapapas' research, Non-Fungible Tokens (NFT) were used to build a flexible, decentralized, and fair base system for trading games. The author created a fully decentralized system, where the player entirely holds the digital asset ownership model. The concept allows game assets owned to be resold and priced depending on their rarity and utility. It also provides an advantage for gamers without needing a trusted party. The system guarantees that the asset will remain online, so players do not risk losing control of the digital asset or its value, even if the game company loses interest or goes bankrupt [11, 21].

III. METHODOLOGY

This study has several objectives, including making an In-App Purchase item recommendation system to make it easier for prospective buyers to determine the items to be purchased. The goal is to affect the number of item sales because players' ease in choosing things to buy also increases the possibility of selling items. In addition, this research also aims to improve transaction security by using a decentralized blockchain network. Items purchased by players will be mined into NFT format and broadcast to a blockchain network encrypted in each block. The NTF format also gives players full ownership of the purchased items. Items also have real-world exchange rates that can be exchanged for other currencies.

The game platform that we made is based on personal computers (PC). We chose that platform because most MMORPG games are on the PC platform, including the games we use as the reference for this research. The game engine we use for the development process is Unity, Visual Studio as a script editor, Blender 3D as a 3D modeler, and metamask for crypto wallet management. The blockchain network platform used in this research is Ethereum, the network that will accommodate the NFT data needed for this game. The following subsection will explain the program flow, NFT implementation, and MCRS performance.

A. Game Scenario and Game Flow

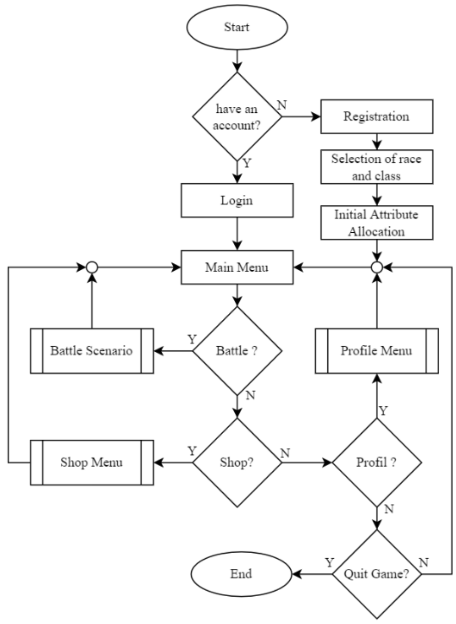

Figure 1 Game Flow Flowchart

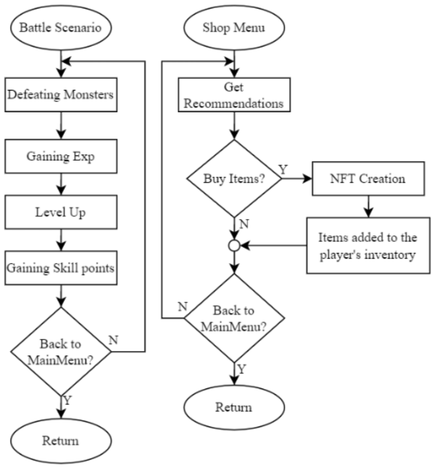

Figure 2 Battle and Shop Flow

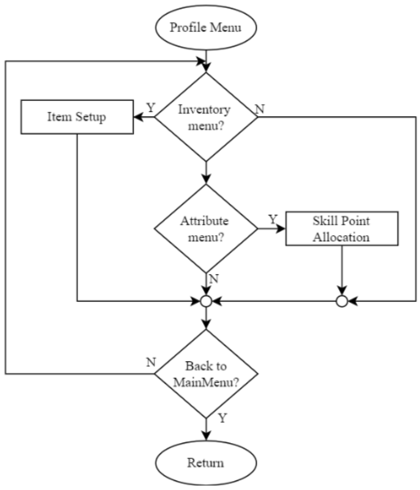

Figure 3 Profile Scenario

As seen in Figure 1 of the game scenario design flowchart, the process starts with logging in for players who already have an account. Registering is for players who do not have an account. After the process is complete, the player will be directed to the main menu page. This game has three game menu options, Battle mode, Profile, and Shop.

- Battle Scenario is a game mode where players must defeat enemies to gain experience, which is used to level up. By leveling up, players will get skill points which are used to increase stats.
- The Shop menu is a page where players can buy the items they want. A recommendation system will help players determine which item best suits the character's current condition.
- The profile menu is a page that displays information on characters such as statistical parameters, list items, and levels. Players can allocate skill points to increase statistical parameters and equip their items on this page.

1) Multi-criteria recommender system

In this study, we propose using MCRS as a method for generating item recommendations that are visualized through a list of items on the Shop page in the game. In this study, the parameters that affect the results of the recommendations are character statistics and item ratings. Figure 4 below shows two parts that affect the MCRS process. The character progression part is the process of players increasing levels by defeating enemies and will get skill points when leveling up. These skill points can be used to increase the character's stats. When the stats change, the recommendation calculation will also change. In the recommender system section, an MCRS calculation works based on item usage data based on statistics and item ratings from previous players in the game.

In MMORPG games, the player's playstyle is strongly influenced by the statistics they have because every playstyle played must be supported by the appropriate statistics. Therefore, two criteria will be used to calculate recommendations in this study.

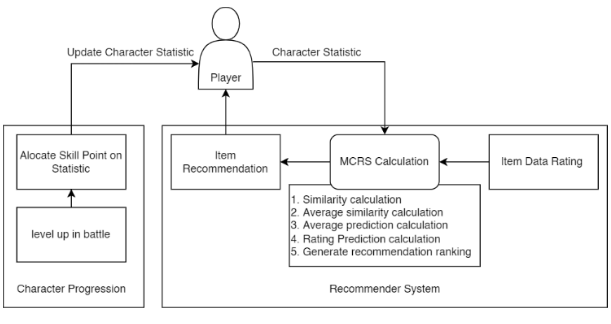

Figure 4 flow Multi-criteria recommender system

The first step in calculating the MCRS is to calculate the similarity value of player μ with all previous player μ'. To find the similarity results sim(μ,μ') we use a cosine-based similarity calculation with the formula for Eq. (1). Where I(μ,μ') is the item rated by player μ and μ', and R(μ,i) is the rating from user μ for item i.

$$sim(\mu,\mu') = \frac{\sum_{i \in I(\mu,\mu')} R(u,i) R(\mu',i)}{\sqrt{\sum_{i \in I(\mu,\mu')} R(u,i)^2} \sqrt{\sum_{i \in I(\mu,\mu')} R(u,i)^2}} \quad (1)$$

Table 1 Criteria Table

Criteria	Description
P1	Strength
P2	Dexterity
P3	Vitality
P4	Agility
P5	Intelligence
P6	Wisdom
P7	Level
P0	Overall

Criteria	Description
R1	Damage
R2	Attack Speed
R3	Combo
R4	Weapon Skill
R5	Match Playstyle
R6	Match With Stats
R7	Cooldown Skill
R0	Overall

The next step is to calculate the average equation $_{avg}(\mu,\mu')$ each rating obtained from the previous calculation between the player μ and the previous player μ' as in Eq. (2). In the similarity calculation$sim_c(\mu,\mu')$, the similarity value of each criterion c is obtained between the player μ and the previous player μ'. Using average similarity, the similarity value of the player with the previous player has a higher result. The value of n is the number of criteria that get a rating from the user.

$$sim_{avg}(\mu,\mu') = \frac{1}{n+1} \sum_{c=0}^{n} sim_c(\mu,\mu') \quad (2)$$

After the system gets the similarity value of player μ with each previous player μ', the next step is to rank all similarity values to get the highest value. The system assumes that the player μ' with the highest score is the closest to the player μ. Then the following process is rating prediction, which takes the overall rating value of R0 for each item that is the most similar, then that value is filled into the data item player μ, which is still empty. The last step is to generate Top-N recommendations. The system sorts R0 values for player μ, and produces a sequence of R0 values for all items from the highest to the lowest.

B. NFT Implementation

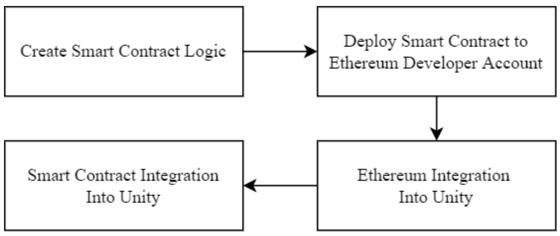

Figure 5 Flow Creation NFT

This section discusses the implementation of NFT smart contracts on the In-App Purchase mechanism. The blockchain platform used is ethereum. To make an NFT contract, a standard token protocol that Ethereum has approved is required. In this study, the ERC-1155 standard token will be used. ERC-1155 is the newest token standard on the Ethereum Blockchain. It is a universal standard supporting both ERC-20 (Fungible) and ERC-721 (Non-Fungible) features.

NFT also supports transparency and long-term data storage, which means the history of the data will be visible and accessible to everyone on the network. Data security is also maintained because there is an encryption process in every transaction made. In contrast to the centralized network that can only be accessed as long as the service is running, the decentralized NFT network allows data to remain active. Even if the game developer closes the game service, it will not be lost. The following is the process of applying NFT in this research.

- The first is Smart Contract Logic Script Writing. The logic used includes NFT creation functions, NFT transfers, NFT stock additions, and several other functions.
- The following process is deploying the smart contract into the Ethereum developer account. The process so that the developer owns the smart contract.
- Next is the process of integrating Ethereum into the Unity engine.
- The following process is the integration of Smart Contracts into unity. This integration process is carried out by converting smart contracts into a format that can be read in C#. After the conversion process is complete, the functions in the smart contract can be run on the Unity engine.

IV. Result And Discussion

This chapter will discuss the testing of the IAP recommendation system using the Multi-criteria recommender system. There are tests for accuracy, precision, recall, and F1 values. This chapter will also discuss the implementation of NFT in this game. There is a test of gas price, time process, and results of NFT transactions.

A. *Gameplay Visualization*

This section aims to show the results of implementing and visualizing an NFT-based recommendation system in an Action-RPG game. Figure 6 shows the main menu display, which is the main navigation for players to play this game. Figure 7 is a display of recommended items from the MCRS calculation results. Figure 8 is a display of rating data input. Figure 9 is a battle gameplay view where the player must defeat the opponent to level up.

B. *MCRS result*

This test is carried out to analyze the level of accuracy and precision of the resulting recommendation system. This test uses a matrix configuration to generate accuracy, precision, recall, and F1 scores based on the following equation.

$$accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (3)$$

$$precision = \frac{TP}{TP + FN} \quad (4)$$

$$recall = \frac{TP}{TP + FN} \quad (5)$$

$$F1\ Score = 2 \times \frac{P \times R}{P + R} \quad (6)$$

Based on the formula above, it is known that TP (True Positive) is the number of items recommended by the system and also recommended by players. At the same time, TN (True negative) is the number of items not recommended by the system and players. Furthermore, FP(False Positive) is the number of items recommended by the system but not in the set recommended by the player. At the same time, FN(False Negative) describes the number of items recommended by players but not included in the system's recommendation rating.

Figure 6 Main Menu

Figure 7 Shop

Figure 8 item rating input

Figure 9 battle scene

In this test, we use two test scenarios. The first is based on the items number that the player has rated. The second is based on the different input ratings of the player. Figure 10 shows the comparison of precision, recall, accuracy, and F1 based on the first scenario, while Figure 11 shows the second scenario results.

C. NFT Implementation

This test is carried out to test whether the NFT system is running according to its functionality. The test carried out is to transfer the NFT to other accounts 20 times. In addition, gas price efficiency tests will also be carried out to minimize the costs that must be paid for each transaction.

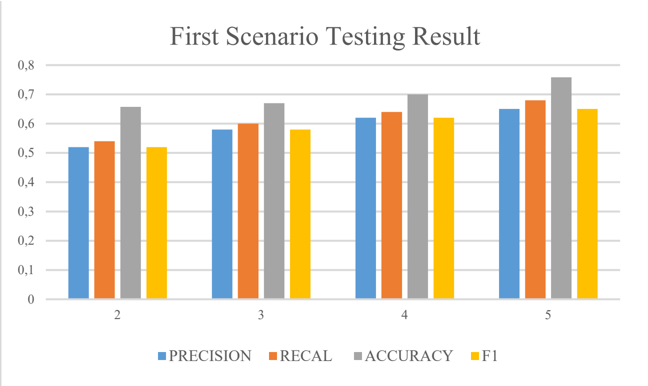

Figure 10 First Scenario Testing Result

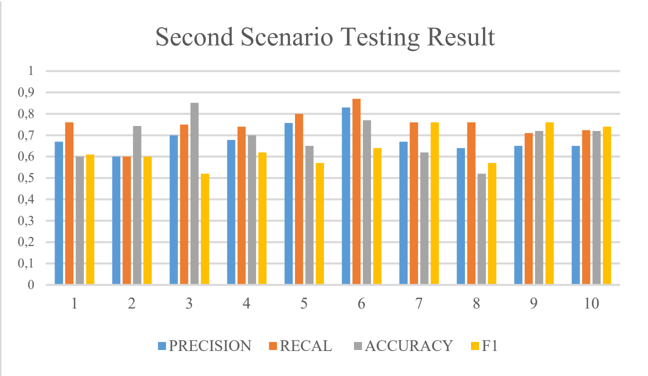

Figure 11 Second Scenario Testing Result

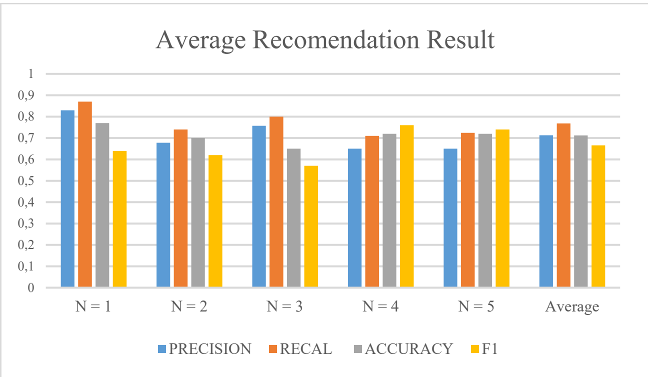

Figure 12 Average accuracy, precision, recall and F1 scores.

- Gas Price Test

Gas Price is the rate that must be paid by the person who makes the transaction to the person who has succeeded in mining. Gas price is the amount of gas fee multiplied by the gas used, and the gas is the computational process carried out. The following are the results of transaction testing based on several gas prices.

- Gas Limit Test

Gas limit testing is carried out to determine the minimum gas limit used in sending score data as a transaction in this case. Determination of the suitable gas is also a factor in the success of transactions on the Ethereum blockchain network. Figure 13 shows the results of the gas limit test used in the study. The minimum gas limit can be used in in-game transactions with a maximum success rate of 400,000 gas.

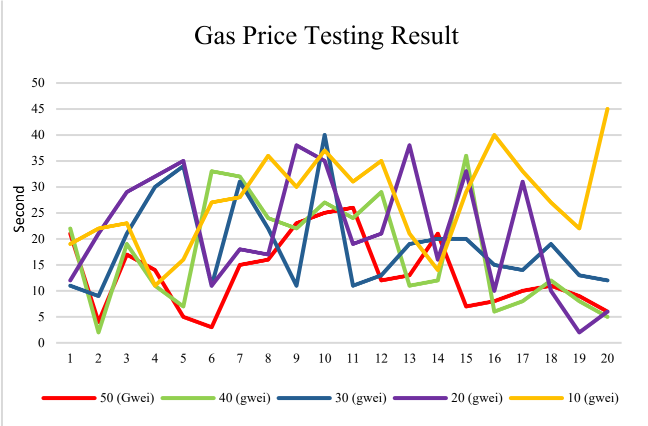

Figure 13 Gas Price Testing Result

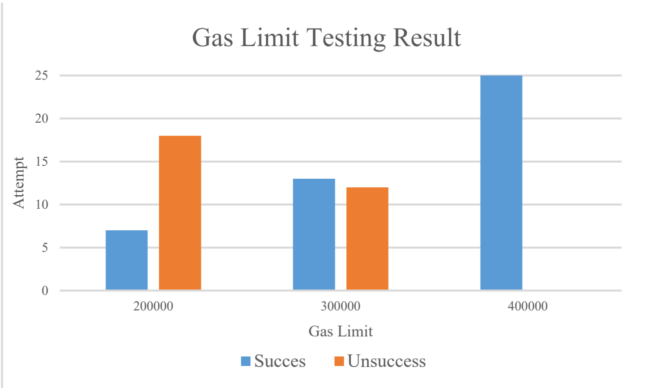

Figure 14 Gas Limit Testing Result

By testing the gas price and gas limit, the optimal arrangement of NFT transactions is obtained. The percentage of successful transactions will be even more significant with these settings. Figure 15 is the result of the NFT transaction accessed via the Opensea website.

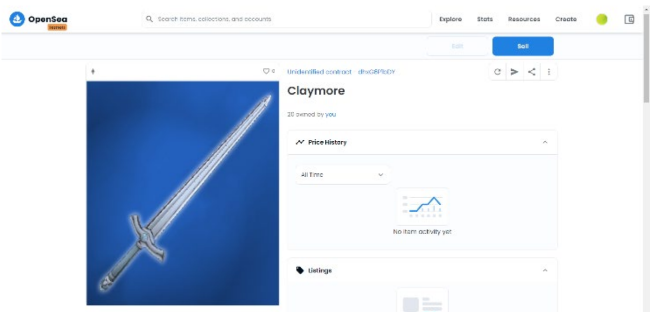

Figure 15 NFT Visualization on OpenSea

V. CONCLUSION

In this study, we developed a recommendation system to assist players in selecting items that suit their playstyle. We use the MCRS method by using a dataset from the previous player rating input. The MCRS in this study uses two criteria types. The first is based on the results of the input rating $R_0, R_1, R_2, R_3, R_4, R_5, R_6, and\ R_7$. Furthermore, the second criterion comes from the player's statistical values $P_0, P_1, P_2, P_3, P_4, P_5, P_6, and\ P_7$. The dataset will be the reference data for the item recommendation results.

We developed an Action RPG game using the Unity Engine in the implementation process. We make adventure games that aim to defeat enemies to earn money and level up. Testing the recommendation system shows that the number of input ratings and the composition of the input ratings affects the results obtained. The test results show that MCRS has an average value of accuracy = 0.71, precision = 0.72, recall = 0.71 and F1 score = 0.66. While the results of the highest recommendation value are accuracy = 0.83, precision = 0.77, recall = 0.76 and F1 score = 0.71. In the NFT test, it can be seen that the difference in gas price affects the transaction speed. The more expensive the transaction fee will also increase the transaction speed. Meanwhile, in the gas limit test, the optimal value was obtained at 400,000.

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REFERENCES

[1] K. Anderton, "The business of video games: Market share for gaming platforms in 2019 [infographic]," Jun 2019. [Online]. Available: https://www.forbes.com/sites/kevinanderton/2019/06/26/thebusiness-of-video-games-market-share-for-gaming-platforms-in-2019-infographic/6f39edfe7b25

[2] C. Gough, "Number of gamers worldwide 2021," Aug 2019. [Online]. Available: https://www.statista.com/statistics/748044/numbervideo-gamers-world/

[3] C.-L. Hsu, and J. C.-C. Lin, "What Drives Purchase Intention for Paid Mobile Apps?--An Expectation Confirmation Model with Perceived Value," Electronic Commerce Research and Applications, vol. 14, no. 1, pp. 46–57, 2015.

[4] eMarketer. (2017). from: http://www.emarketer.com/Article/In-App-

[5] Alliedmarketresearch https://www.alliedmarketresearch.com/in-app-purchase-market-A07186.

[6] Koushik Bhargav Muthe, Khushboo Sharma, Karthik Epperla Nagendra Sri," A Blockchain Based Decentralized Computing And NFT Infrastructure For Game Networks" Second International Conference on Blockchain Computing and Applications (BCCA), 10.1109/BCCA50787.2020.9274085, 2020.

[7] J. S. Breese, D. Heckerman, and C. Kadie. Empirical analysis of predictive algorithms for collaborative filtering. In Proceedings of the Fourteenth Conference on Uncertainty in Artificial Intelligence, pages 43–52, San Francisco, 1998. Morgan Kaufman.

[8] Paul Bertens, Anna Guitart, Pei Pei Chen and A´ frica Peria´n˜ez: A Machine-Learning Item Recommendation System for Video Games. IEEE Conference on Computational Intelligence and Games (CIG), 10.1109/CIG.2018.8490456, 2018.

[9] B. Ward, Y. Khmelevsky, G. Hains, R. Bartlett, A. Needham, and T. Sutherland, "Gaming network delays investigation and collection of very large-scale data sets," 2017 Annual IEEE International Systems Conference (SysCon), 2017.

[10] Apsalar, LATEST APSALAR DATA ON IN-APP CLICK AND IAP FRAUD, https://apsalar.com/2015/07/latest-apsalar-data-on-in-app-click-and-iap-fraud/

[11] Christos Karapapas, Iakovos Pittaras, George C. Polyzos, "Fully Decentralized Trading Games with Evolvable Characters using NFTs and IPFS" IFIP Networking Conference (IFIP Networking), 10.23919/IFIPNetworking52078.2021.9472196, 2021.

[12] C. -H. Liao, H. -E. Lin and S. -M. Yuan, "Blockchain-Enabled Integrated Market Platform for Contract Production," in IEEE Access, vol. 8, pp. 211007-211027, 2020, doi: 10.1109/ACCESS.2020.3039620

[13] Viennot, N., Garcia, E., Nieh J., "A Measurement Study of Google Play." The 2014 ACM international conference on Measurement and modeling of computer systems., 2014.

[14] Lettner, F., Clemens, H., "Automated and unsupervised user interaction logging as basis for usability evaluation of mobile applications." Proceedings of the 10th International Conference on Advances in Mobile Computing & Multimedia., 2015.

[15] Wohn, D. Y., Na, E., "Virtual item purchasing patterns in a social game: differences between high and low spenders." Proceedings of the 2014 iConference., 2014.

[16] Dutting, P., Henzinger, M., Weber, I., "Maximizing revenue from strategic

[17] recommendations under decaying trust." Proceedings of the 21st ACM International Conference on Information and Knowledge Management. 2015.

[18] Leroux, B. Dhoedt, B., Demeester, P., "Performance characterization of game recommendation algorithms on online social network sites." Journal of Computer Science and Techonology, 2015.

[19] Y. M. Arif, R. Nurhayati, S. M. S. Nugroho and M. Hariadi, "Destinations ratings based multi-criteria recommender system for Indonesian halal tourism game" Intelligent Networks and Systems Society, 2022.

[20] S. Chevet, "Blockchain technology and non-fungible tokens: Reshaping value chains in creative industries," SSRN Electronic Journal,

[21] Y. M. Arif, R. P. Pradana, H. Nurhayati, S. M. S. Nugroho and M. Hariadi, "A Blockchain-Based Multiplayer Transaction For Tourism Serious Game," 2020 International Conference on Computer Engineering, Network, and Intelligent Multimedia (CENIM), 2020, pp. 138-143, doi: 10.1109/CENIM51130.2020.9297837.