Serious game intelligent transportation system based on internet of things

Fresy Nugroho[1,2], I Gusti Putu Asto Buditjahjanto[3], Dwi Pebrianti[4], Jehad A. H. Hammad[5], Moch Fachri[3], Tri Mukti Lestari[1,2], Dian Maharani[6], Alfina Nurrahma'N[2]
[1]Department of Mechanical Engineering, Faculty of Engineering, Universitas Islam Negeri Maulana Malik Ibrahim, Malang, Indonesia
[2]Department of Informatics Engineering, Faculty of Science and Technology, Universitas Islam Negeri Maulana Malik Ibrahim, Malang, Indonesia
[3]Department of Electrical Engineering, Faculty of Engineering, State University of Surabaya, Surabaya, Indonesia
[4]Department of Mechanical Aerospace Engineering, International Islamic University Malaysia, Kuala Lumpur, Malaysia
[5]Department of Computer Information System, Al Quds Open University, Abu Dis, Palestine
[6]Department of Mathematics, Faculty of Science and Technology, Universitas Islam Negeri Maulana Malik Ibrahim, Malang, Indonesia

Article Info

Article history:

Received Nov 7, 2024
Revised Nov 12, 2025
Accepted Jan 10, 2026

Keywords:

Closed-circuit television
Intelligent transportation system
PROMETHEE
Serious game
System usability scale

ABSTRACT

This research examines the implementation of the preference ranking organization method for enrichment evaluation (PROMETHEE) approach for multi-criteria decision-making in a character recommendation system for serious games. The method calculates character skill values across multiple criteria and generates rankings of the best characters according to game environment conditions derived from closed-circuit television (CCTV)-based traffic detection. Image processing algorithms were applied to classify congestion levels into quiet, moderate, and busy categories, which directly influence gameplay modes. Experimental results show that PROMETHEE rankings vary across maps (e.g., A6 ranked highest in quiet mode, while B2 dominated in busy mode), demonstrating the system's contextual adaptability. Usability testing with 50 participants yielded an average system usability scale (SUS) score of 78.9, while expert evaluation using game design factor questionnaire (GDFQ) produced a mean of 4.19/5, both indicating high acceptance and positive user experience. These findings confirm that PROMETHEE is effective in generating context-aware recommendations, providing both strategic depth and engagement. The study concludes that integrating traffic data into serious game design can enrich intelligent transportation systems (ITS) education and awareness, with future improvements possible through real-time player feedback adaptation and machine learning–based traffic prediction.

Corresponding Author:

Fresy Nugroho
Department of Mechanical Engineering, Faculty of Engineering
Universitas Islam Negeri Maulana Malik Ibrahim
Gajayana Street 50, Dinoyo, Malang City, East Java, Indonesia
Email: fresy@ti.uin-malang.ac.id

1. INTRODUCTION

Intelligent transportation systems (ITS) are considered increasingly mature not only in terms of automation [1] but also saving on the basis of ACPs [2] and real-time data processing [3], [4]. Each process presents technologies that improve transportation performance [5], [6] such as geographic information systems (GIS) [7]. Methodologies and tools are very valuable [8]. Technologies such as machine learning and big data help traffic flow [9], while closed-circuit television (CCTV) is now often used to monitor road conditions [10], detect accidents [11], determine incident locations [12], optimize traffic lights [13], and simulate autonomous vehicles [14]. Although many studies have examined CCTV-based control and learning, the application of these ideas to educational or gaming contexts is still rare [15], [16]. There is one metaverse simulation based on ITS [17] but none is based on a serious game yet. While serious games have a significant impact, for example, in preventing cyberbullying [18], fruit education [19], and educational environments [20] that clearly focus on one thing: learning goals and skill improvement [21], it is important to provide elements that are both entertaining and challenging for users, such as endless runners [22]. Endless runners have been applied in previous research, such as studying medical [23] and medical plants [24]. The combination of games and internet of things (IoT) [25] was one of the starting points of research that initially used webcams for emotion recognition [26] and parking detection [27]. This study combines all of the above with the addition of the PROMOTHEE method, following the principles of computerized adaptive practice [28] for player leveling and difficulty. Similar to VR-PEER [29], traffic data is taken from a real-world system and classified congestion levels, then tested on 50 participants.

2. METHOD

Since 2015, there has been an increase in research on the integration of serious games (SG) with the IoT. By 2024, the combination of IoT and ITS will also be very complex and increasingly numerous. A summary of the key findings from these studies is shown in Table 1.

Table 1. Related work

Paper	Serious game	IoT	Intelligent transport system simulation	Simulation	Optimization
Pokrić *et al.* [28]	√	√			
Garcia *et al.* [29]	√	√			
Tangworakitthaworn *et al.* [30]	√	√			
Sumit and Chhillar [31]		√	√		
Cui and Lei [32]		√	√		
Zamani and Kalbasi [33]		√	√		
Gupta *et al.* [34]		√		√	
Alsbou *et al.* [35]		√		√	
Hiroi *et al.* [36]		√		√	
Rajput and Jain [37]			√		√
Proposed	√	√	√	√	√

Multi-criteria decision-making (MCDM) methods are applied in the context of ITS and IoT, but for serious games it is still not massive. For example, there is the potential of preference ranking organization method for enrichment evaluation (PROMETHEE) for ITS optimization compared to analytic hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS). This topic does not yet have quantitative validation [32]. Then there is the IoT-based DEMO EDICT simulation in network evaluation [38]. Urban traffic systems also have not combined the use of MCDM methods, thus limiting their connection to serious games and real-world adaptive gameplay [37].

A comprehensive study also shows that AHP is more widely used in the integration of MCDM methods than PROMETHEE, confirming the scarcity of research exploring the potential of PROMETHEE in game-based adaptive systems [39]. The PROMETHEE method was introduced to assess the level of trust of participants in an urban planning game, demonstrating the potential of PROMETHEE in assessing aspects of player behavior [40]. On the other hand, the comparison of PROMETHEE with AHP and TOPSIS in determining the location of solar PV farms with the highest score in PROMETHEE (0.92 compared to 0.85 in AHP and 0.78 in TOPSIS), confirming the superiority of this method in the ITS context even though it has not been directly applied to serious games [41].

2.1. Serious game

Serious games are mental learning through computers based on certain rules, utilizing entertainment for training [42], simulation [43], teaching [44] and learning process [45], health world simulation [46], policy simulation [47], tourism destinations [48], communication simulation [49], and environment [50], [51]. Serious games has been applied in various fields to facilitate the teaching and learning process and improve learning concentration [52]. The main benefits of serious games include providing learning motivation [53], improve logical reasoning, and enhance the interactive side [54]. Endless runner is recognized as one of the perfect genres in game because this game does not contain violence, racism, or pornography [55]. The game has many obstacles that train the player's concentration [56]. The goal of this player is to get as many scores as possible [57]. The endless runner game can be played by all ages because the concept is easy to understand [58]. This type of game uses 2D or 3D character models that can be played on mobile phones [42] and computers [59].

2.2. PROMETHEE formulation

To rank the alternatives (characters) based on multiple criteria, the PROMETHEE is applied [60].

– Preference function: for each pair of alternatives, a and b with criterion k, the preference function is:

$$P_k(a,b) = F_k(d_k(a,b)), \quad d_k(a,b) = f_k(a) - f_k(b) \tag{1}$$

where $f_k(a)$ is the evaluation of alternative a under criterion k.

– Preference index: the global preference index of alternative a over b is defined as:

$$\pi(a,b) = \sum_{k=1}^{n} w_k \cdot P_k(a,b), \sum_{k=1}^{n} w_k = 1 \tag{2}$$

where w_k is the weight of criterion k.

– Preference function: for each pair of alternatives, a and b with criterion k, the preference function is:

$$\phi^+(a) = \frac{1}{m-1}\sum_{b\in A, b\neq a} \pi\,(a,b), \phi^-(a) = \frac{1}{m-1}\sum_{b\in A, b\neq a} \pi\,(b,a) \tag{3}$$

– Preference function: for each pair of alternatives, a and b with criterion k, the preference function is:

$$\phi(a) = \phi^+(a) - \phi^-(a) \tag{4}$$

The alternatives are then ranked according to π (a), where higher values indicate better ranking.

2.3. Intelligent transportation system

ITS encompass a wide range of applications, journey time planning [61], traffic flow prediction [62], vehicle safety system [63], and route optimization [64]. ITS deployment is expected to solve mobility management challenges [31], traditional and electric vehicles, as well as effective and low-cost [37]. ITS enhancements contribute to improving prediction accuracy, effectively switch lanes, and mitigating the propagation of traffic congestion [65].

2.4. Internet of things

The latest innovation [66] that can be used in research and it connect between sensor-based objects to the Internet, we call as IoT. IoT consists of communication, data, computation, and dynamic sensing of objects because they are sensor-based [67]. Researchers predict that in the future when IoT is deployed in large numbers, it will generate dynamic sensor-based data every second [68]. The information [69] or data obtained is then analyzed and reported in a format that is easy to visualize [70] so that it is easy to understand.

2.5. System design

The design of serious game-Intelligent transportation systems (SG-ITS) consists of five main parts which are CCTV placement, traffic jam, vehicle counting, serious game information and SG-ITS. The connection/hierarchy diagram shown in Figure 1. The finite state machine (FSM) design of SG-ITS, shown in Figure 2, illustrates the game flow and alternative selections determined using the PROMETHEE method, which evaluates six criteria based on player achievements. Players navigate from the main menu to map and character selection, where the system either recommends a character via PROMETHEE or proceeds directly to gameplay based on the player's manual choice. In the development process, data preparation serves as a primary phase in building the alternative selection system of SG-ITS. In this stage, the data required are alternatives and criteria. This data is related to and crucial for determining the final calculation results.

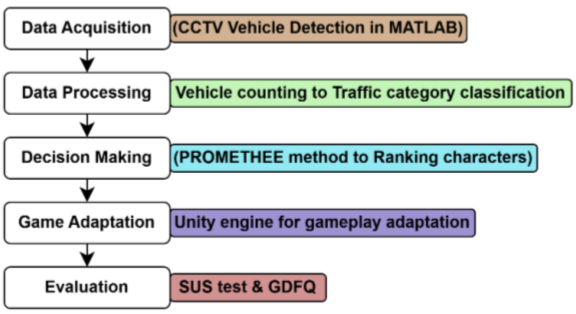

Figure 1. Hierarchy diagram of the analysis

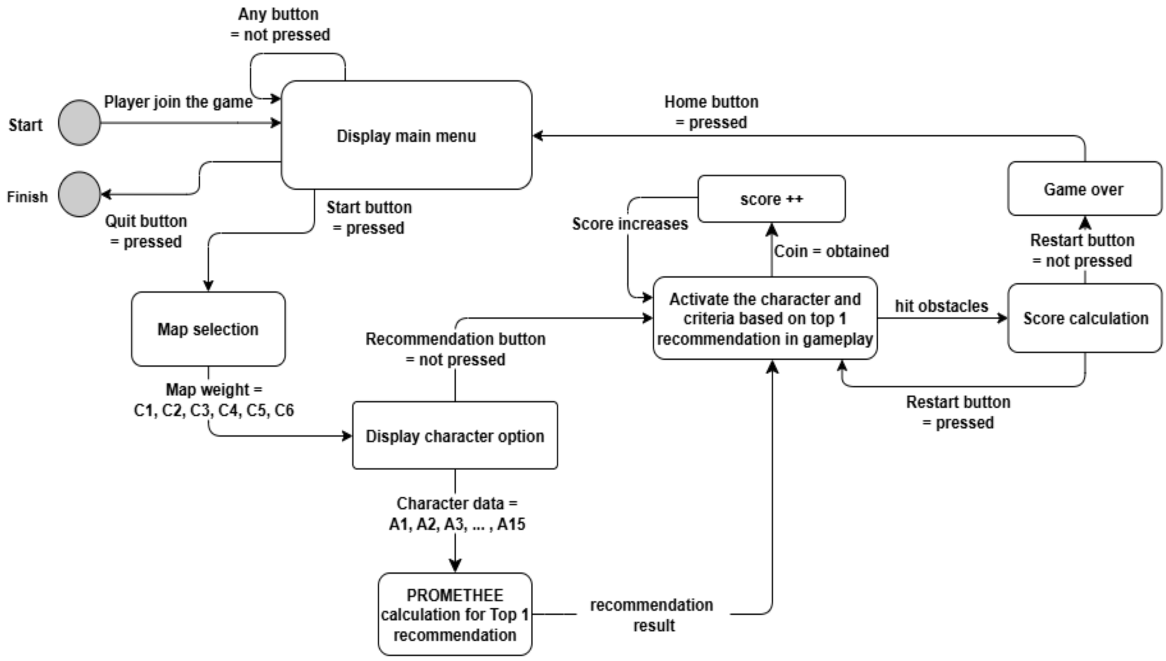

Figure 2. FSM system in unity

2.5.1. Alternative

Alternative data contains the characters players will use in this SG-ITS game. It generally includes several options with a set of values that support players in winning the game. Each character will provide a unique experience and can help players overcome higher difficulty levels. This data contains characters with prices summarized in the Table 2.

Table 2. Alternative

Alternative	Price
A1	50
…	…
A14	700
A15	800

2.5.2. Criteria

The criteria used to evaluate characters in the game are listed in Table 3, with each criterion weighted differently based on traffic conditions. On maps with calm traffic, it's recommended to look for characters with high quickness and coin surge, as this will make collecting coins more efficient. On moderate maps, it's recommended to look for characters with high coin puller, as this will generate more coins but with slightly heavier traffic. On the most difficult maps, namely busy, it's crucial to have barrier protection, as it will protect players from high-impact vehicle impacts.

Table 3. Criteria

Criteria	Means	Map		
		Quiet	Moderate	Busy
C1	Quickness	0.23	0.10	0.12
C2	Coin puller	0.14	0.36	0.12
C3	Jumping	0.14	0.25	0.16
C4	Barrier	0.16	0.08	0.33
C5	Coin surge	0.19	0.10	0.10
C6	Sprint	0.15	0.12	0.18

2.6. Game design
2.6.1. Storyline
The SG-ITS game features a storyline where a character must run endlessly through a congested urban environment. Traffic conditions are crucial because they affect how well the player controls their character and interacts with coins and other items on the road. Initially, CCTV cameras capture images of traffic jams on a particular road, which are then processed using Python. Traffic jams in the game dynamically adapt based on the scans. Players with high scores will increase the intensity of the challenge and the level of traffic jams, and vice versa.

2.6.2. Storyboard
The storyboard provides support to the implementation as it illustrates the concept and storyline of the game from start to finish in Table 4. Table 4 shows that there are six types of scene menus: menu, instruction, map, character, charr recomm, and gameplay. Each menu has its own function. For example, in the map scene, players can choose a map to determine where they will play. In the character scene, this page displays a list of playable characters, and players can choose the role they want to play. The gameplay scene is the main scene to be played.

Table 4. Storyboard

Scene	Explanation
Menu	Upon first entering the game, players are presented with the main menu consists of start, high score, credit and quit.
Instruction	Players can find out how to control the character and use features such as magnets to get more coins in instruction page.
Map	Players can choose map to determine where the player will play.
Character	This page displays list of playable characters.
Char-recomm	This page will allow player to get recommendation character.
Gameplay	This is the main gameplay page.

2.7. Test plan
The SG-ITS system was tested to evaluate the use of the PROMETHEE method for character recommendations based on traffic conditions derived from CCTV image analysis. CCTV functions as a contextual visual element rather than performing real-time recording, while image processing in Python classifies traffic levels into busy, moderate, and quiet categories. Game experts use ratings to determine whether a character meets the criteria for recommended gameplay. Meanwhile, general users provide feedback through a Google Forms-based survey. The combined results from system testing, expert evaluation, and user feedback were analyzed to determine the effectiveness of the PROMETHEE integration and guide further development of SG-ITS.

3. RESULTS AND DISCUSSION
3.1. System testing results
The calculations are taken from CCTV scans and map classification. Then, the PROMETHEE calculation implementation is placed in a recommendation button in the character selection menu. The results are integrated into the unity environment so that they can be played by players.

3.1.1. Image processing algorithm testing
Test data derived from CCTV video using Python will obtain vehicle density classification with light, medium, and busy traffic categories. Detection accuracy is done by comparing the number of detected vehicles with the number of ground truth vehicles, and the results are stored in the database. The number of vehicles can be seen in representing the traffic category (Figure 3). Detection performance is also evaluated using a confusion matrix with TP=3, FP=2, FN=2, and TN=0, resulting in precision=0.60, recall=0.60, and F1-score=0.60. With these results, it can be expected that an algorithm can identify vehicles correctly but there is still a slight overestimation or underestimation that slightly affects the classification accuracy. Even so, the performance is still acceptable.

3.1.2. PROMETHEE method implementation testing
The PROMETHEE method testing is calculated from all characters, with character rankings and net flow values according to traffic conditions. Table 5 specifically presents the character skill value dataset. Table 6 shows the weighted criteria processed through the PROMETHEE formulation.

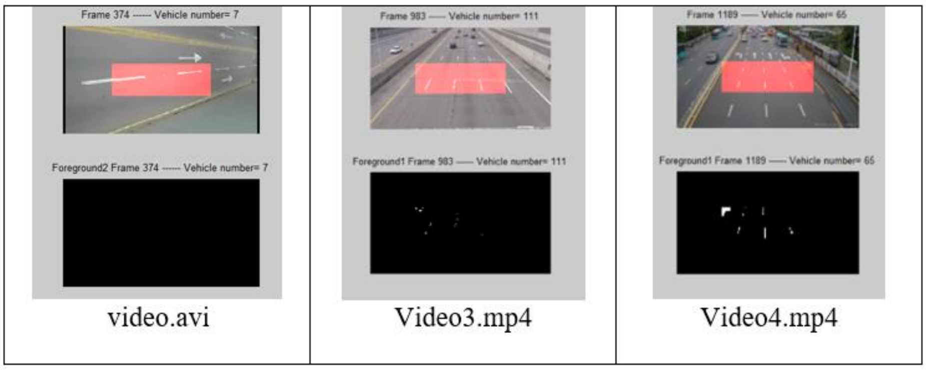

Figure 3. CCTV video

Table 5. Method testing

Criteria	Alternative														
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
C1	2	1.5	2	2	1.5	2	2	3	2	2	2	2	2	2	2
C2	3	1	2	2	3	2	2	2	2.5	2	4	3	3	4	5
C3	1	4	2	3	1	0.5	0.5	2	2.5	3.5	2	3	4	3	5
C4	3	2	1	1	2	0	0	3.5	2	2	4	2	2	2	4
C5	0	1	3	2	1	5	5	1	3.5	3.5	1	4	3	2	3
C6	3	2	2	2	3	1.5	1.5	3.5	2	2	4	3	3	3.5	5

Table 6 presents the resulting rankings, where higher net flow values indicate superior characters. In the 90-coin scenario, the process limits the choices to six feasible characters (A1–A6), which are then ranked using PROMETHEE to identify the best choice for each traffic condition. The results indicate that each alternative exhibits distinct strengths under different traffic conditions: A2 performs best in busy scenarios, while A4 maintains consistent stability across all conditions. In contrast, A1 and A5 perform weaker under quiet and moderate traffic, and A6 excels only in low-traffic situations. Overall, A4 and A2 are the most adaptive options, effectively matching varying congestion levels. The ranking distribution clearly separates high and low performing alternatives, providing useful insight for recommending characters based on available resources (player coins) and simulated traffic conditions.

Table 6. PROMETHEE net flow ranking results for character under different traffic conditions

Alternative	Result		
	Quiet	Moderate	Busy
A1	-0.38	-0.32	0.31
A2	0.06	0.16	0.53
A3	0.22	0.12	-0.13
A4	0.26	0.67	0.15
A5	-0.51	-0.38	-0.25
A6	0.35	-0.25	-0.61

Table 7 shows a significant difference in scores between players who followed the recommendations and those who didn't after two minutes of gameplay. In this case, player 1 chose alternative 1 on a quiet map, even though the system had recommended alternative 6. The result was poor character performance and a lower score. This gap is due to A6 offering a value of 5 and A1 lacking a coin boost.

Table 7. Comparison of player scores with and without PROMETHEE

Map	Recommended character	Player	Score with PROMETHEE	Score without PROMETHEE
Quiet	A6	P1	120	75
		P2	115	80
		P3	118	70
Moderate	A4	P1	140	95
		P2	138	100
		P3	142	90
Busy	A2	P1	160	110
		P2	155	105
		P3	158	100

3.2. Expert testing results

System testing involved expert respondents with professional backgrounds in game development and design. Evaluation was conducted using the game design factor questionnaire (GDFQ) (Table 8), which assesses eight key dimensions: game goals, game mechanism, interaction, freedom, sensation, game value, challenge, and flow. Each factor comprises one to four specific assessment items [71]. The answer frequency of eight key dimensions shown in Figure 4, as an example, for freedom, all of the respondent agrees, for interaction, about 45% respondents agree and about 65% disagree. Expert evaluations yielded an overall average score of 4.23/5. The game's mechanics received the highest rating (4.5) for its consistency with the chosen genre. The sensation aspect achieved a rating of 4.4 for its engaging visual interface. However, options for improving player control are still provided. These results indicate that SG-ITS meets the main standards in game structure and requires slight improvements in flexible player control.

Table 8. Game design factor questionnaire

No.	Question
1	Game goals
	– This game features well-defined tasks and stages
	– I know my objective in the game
	– I prefer to achieve and get best result in game
2	Game mechanism
	– The gameplay is accordance with the genre carried
	– The rules of the game are easy to understand
	– I like the gameplay in the game
3	Interaction
	– Interaction in playing the game is fun. Game play and controls are clear and easy to understand
	– In-game help and advice features are clear and easy to understand
	– Interaction in game play is fun
4	Freedom
	– Game characters can be easily controlled by players
5	Sensation
	– The colors and layout of the interface caught my eye
	– The icons and functions are clear and intuitive
	– The graphics and sound in the game are abundant
6	Game value
	– I want to get the highest score
	– SG-ITS content becomes interesting when added to the game.
7	Challenge
	– I feel challenged to complete the game
	– I can win the game easily
	– I want to play the advanced version of the game

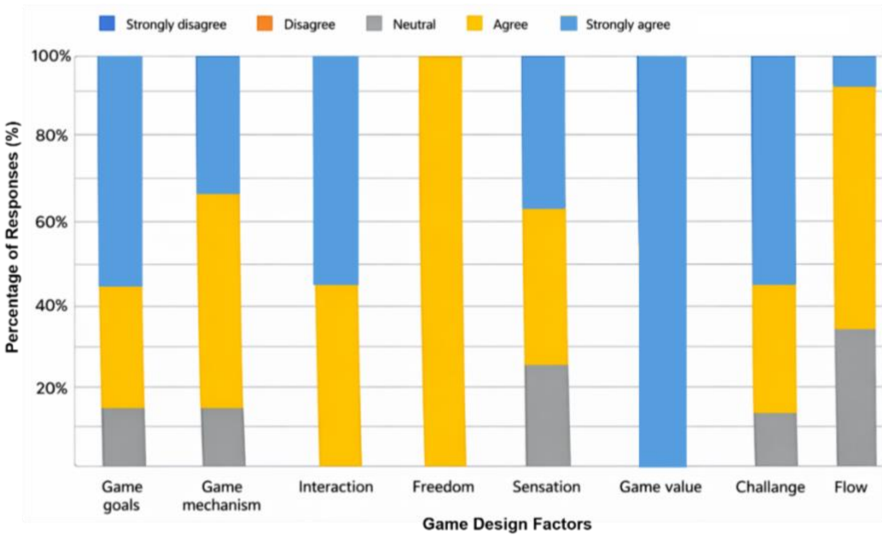

Figure 4. Test results by game experts

For the GDFQ, all expert observations (10 experts×22 items=220 ratings) as the sample. An alternative would be to test the average per expert (n =10). However, treating each item rating as an observation is often applied when the goal is to test whether the overall mean rating is significantly higher than the neutral value, shown in Table 9. Compare $t_{calculated} = 29.99$ with $t_{critical} \approx 1.645$. Since $t_{calculated} \gg t_{critical}$, we reject H_0 at $\alpha = 0.05$. The mean GDFQ rating (4.19) is statistically far higher than neutral benchmark of 3 (p ≪0.001). This indicates that experts evaluated game design factors very positively.

3.3. Usability testing

Usability testing was conducted with 50 players to measure ease of use, player satisfaction, and overall usability of the SG-ITS prototype. The system usability scale (SUS) was employed with a 1–5 Likert scale. Each of the ten questions listed in Table 10. Based on Table 10, the SG-ITS prototype achieved an average SUS score of 78.95, which is categorized as good usability (70–80) and approaching very good (>80). This indicates that most players found the game easy to operate and enjoyable. Positive items scored above 4.5, reflecting strong user engagement, while negative items scored below 2.0, indicating minimal operational difficulty as illustrated in Figure 5.

Table 9. One-sample t-test GDFQ

Item	Value
Data	
Number of respondents: n	220
Sample mean: $\bar{X}$	4.1909
Sample standard deviation: s	0.5890
Benchmark (null hypothesis): μ_0	3
Significance level: α	0.05
Hypotheses	
$H_0: \mu$	3
$H_A: \mu >$	3
Degrees of freedom	$df = n - 1 = 220 - 1 = 219$
Critical value	$t_{0.05,219} \approx 1.645$
Computation	$t = \frac{\bar{X} - \mu_0}{s/\sqrt{n}} = \frac{4.1909 - 3}{0.5890/\sqrt{220}} = \frac{1.1909}{0.0397} \approx 29.99$

Table 10. SUS questions

No	Question
1	I am interested in playing game again
2	I found it is quite complicated to use the game
3	The game feels user-friendly and easy to operate
4	I needed help from another person or technician while playing
5	The features in the game work as expected
6	I found some aspects of the game inconsistent
7	I believe others can easily figure out how to play the game
8	The game felt confusing to me
9	I had no difficulty using the game
10	It took me some time to adapt before I fully understood how to use the game.

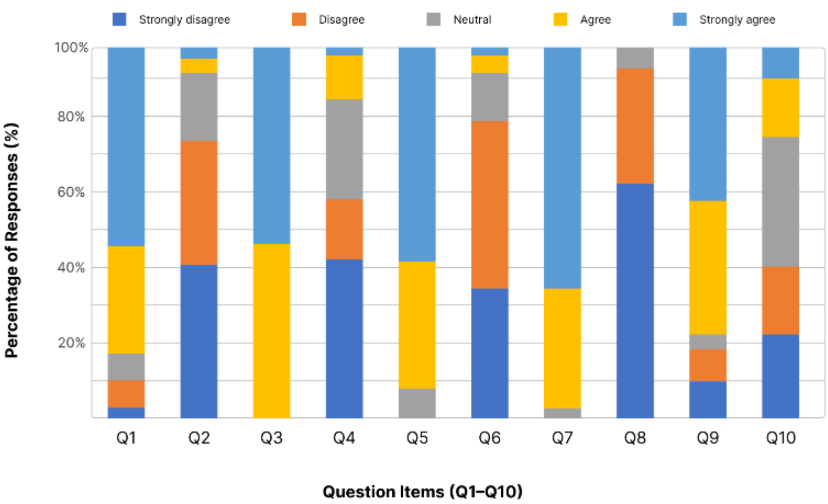

Figure 5. Usability testing results

To validate the SUS statistically, a one-sided (right-tailed) test was conducted. The hypothesis under examination was whether the sample mean score is greater than the benchmark. Based on the test data in Table 11. Decision rule compares: $t_{\text{calculated}} = 6.52$ with $t_{\text{critical}} = 1.677$. Since $t_{\text{calculated}} > t_{\text{critical}}$, we reject H_0 pada $\alpha = 0.05$. Conclusion: there is strong statistical evidence that the mean SUS score is greater than 68 ($p < 0.05$). In other words, the system's usability is significantly above the "acceptable" benchmark.

Table 11. One-sample t-test SUS

Item	Value
Data	
Number of respondents: n	50
Sample mean: $\bar{X}$	78.95
Sample standard deviation: s	11.8783
Benchmark (null hypothesis): μ_0	68
Significance level: α	0.05
Hypotheses	
$H_0: \mu$	68
$H_A: \mu >$	68
Degrees of freedom	$df = n - 1 = 50 - 1 = 49$
Critical value	$t_{0.05,49} \approx 1.677$
Computation	$t = \frac{\bar{X} - \mu_0}{s/\sqrt{n}} = \frac{78.95 - 68}{11.8783/\sqrt{50}} = \frac{10.95}{1.679} \approx 6.52$

3.4. Comparison with existing works

In python-based vehicle detection, the detected accuracy is 84.5% across three traffic density levels, with an average processing time of about one second per frame. However, this result is still lower than the YOLOv4–DeepSORT model with 87.98% which detects 13 types of vehicles [72]. Prioritizing processing speed and smooth game integration are the main objectives in this study. Meanwhile, the YOLO–OpenCV real-time detection model approach can support dynamic game difficulty adaptation [73]. The adaptation responds in about one second and is comparable to flow-state-based [74] and fuzzy logic–based [75] difficulty adjustment approaches. Its main strength lies in leveraging real-world traffic data, making in-game challenges contextually relevant. However, system performance depends on CCTV quality and may experience latency due to network disruptions or detection degradation.

3.5. Discussion

The results of image processing show that the system is able to detect vehicles and classify traffic with fairly good accuracy. with a low number of false positives and false negatives, this shows that the algorithm also remains stable in various conditions. The PROMETHEE-based character recommendation system produces a balanced ranking and is consistent with the game's objectives. Based on expert feedback assessments of 4.23 out of 5, and the SUS test, the system obtained an average score of 78.96. These results indicate that the SG-ITS game has good usability, effective functions, and is positively received by users.

4. CONCLUSION AND FUTURE WORK

This study has successfully integrated an MCDM-based recommendation system, combined with CCTV image detection algorithms, and transformed real-world traffic data into an open-world game mechanic. The PROMETHEE integration method for character recommendation based on traffic conditions demonstrates a strong alignment between gameplay and adaptive strategies. Expert and user evaluations through SUS testing also confirm that the system is well-designed and engaging. Therefore, further innovations to the system could be made to enhance the realism and adaptability of the environment. Machine learning-based traffic predictions can also be added, adjusting the difficulty based on player feedback from biometric data. This is optimized for real-time performance through edge and parallel computing. Further developments could include the introduction of transformer-based multiclass vehicles and predictive modeling to anticipate traffic trends, enabling a more intelligent and immersive serious game experience.

FUNDING INFORMATION

This study was funded by the Penelitian Pengembangan Kolaborasi Internasional, Studi Bisnis Manajemen 2024 grant from DIPA Universitas Islam Negeri Maulana Malik Ibrahim with number DIPA-025.04.2.423812/2024.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Fresy Nugroho	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓
I Gusti Putu Asto Buditjahjanto		✓				✓		✓	✓	✓	✓	✓		
Dwi Pebrianti	✓		✓	✓			✓			✓	✓	✓		✓
Jehad A. H. Hammad	✓	✓	✓	✓	✓		✓		✓	✓		✓		
Moch Fachri	✓		✓	✓	✓			✓	✓	✓	✓			
Tri Mukti Lestari	✓	✓			✓		✓		✓	✓			✓	✓
Dian Maharani				✓		✓	✓	✓	✓	✓			✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

This study does not involve individual personal data or identifiable human subjects. Therefore, informed consent was not required.

DATA AVAILABILITY

The data that support the findings of this study were obtained from the first author. These data were used with permission and are not publicly available due to licensing restrictions. Requests for access may be directed to the corresponding author, [FN], subject to approval from the original authors.

REFERENCES

[1] H. Li, Y. Chen, K. Li, C. Wang, and B. Chen, "Transportation internet: a sustainable solution for intelligent transportation systems," *IEEE Transactions on Intelligent Transportation Systems*, vol. 24, no. 12, pp. 15818–15829, 2023, doi: 10.1109/TITS.2023.3270749.

[2] Y. Ren, H. Jiang, X. Feng, Y. Zhao, R. Liu, and H. Yu, "ACP-based modeling of the parallel vehicular crowd sensing system: framework, components and an application example," *EEE Transactions on Intelligent Vehicles,* vol. 8, no. 2, pp. 1536-1548, Feb. 2023, doi: 10.1109/TIV.2022.3221927.

[3] Z. Xiao *et al*., "Tensor and confident information coverage based reliability evaluation for large-scale intelligent transportation wireless sensor networks," *IEEE Transactions on Vehicular Technology*, vol. 72, no. 10, pp. 13461–13473, 2023, doi: 10.1109/TVT.2023.3275579.

[4] Z. Cai, Z. Chen, Z. Liu, Q. Xie, R. Ma, and H. Guan, "RIDIC: real-time intelligent transportation system with dispersed computing," *IEEE Transactions on Intelligent Transportation Systems*, vol. 25, no. 1, pp. 1013–1022, 2024, doi: 10.1109/TITS.2023.3303877.

[5] Z. Lv, Y. Li, H. Feng, and H. Lv, "Deep learning for security in digital twins of cooperative intelligent transportation systems," *IEEE Transactions on Intelligent Transportation Systems*, vol. 23, no. 9, pp. 16666–16675, 2022, doi: 10.1109/TITS.2021.3113779.

[6] N. Kumar, S. S. Rahman, and N. Dhakad, "Fuzzy inference enabled deep reinforcement learning-based traffic light control for intelligent transportation system," *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 8, pp. 4919–4928, 2021, doi: 10.1109/TITS.2020.2984033.

[7] M. Wei, T. Liu, and B. Sun, "Optimal routing design of feeder transit with stop selection using aggregated cell phone data and open source GIS tool," *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 4, pp. 2452–2463, 2021, doi: 10.1109/TITS.2020.3042014.

[8] G. Fortino, C. Savaglio, G. Spezzano, and M. Zhou, "Internet of things as system of systems: A review of methodologies, frameworks, platforms, and tools," *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. 51, no. 1, pp. 223–236, 2021, doi: 10.1109/TSMC.2020.3042898.

[9] T. Yuan, W. D. R. Neto, C. E. Rothenberg, K. Obraczka, C. Barakat, and T. Turletti, "Machine learning for next-generation intelligent transportation systems: A survey," *Transactions on Emerging Telecommunications Technologies*, vol. 33, no. 4, 2022, doi: 10.1002/ett.4427.

[10] T. K. Vijay, D. P. Dogra, H. Choi, G. Nam, and I. J. Kim, "Detection of road accidents using synthetically generated multi-perspective accident videos," *IEEE Transactions on Intelligent Transportation Systems*, vol. 24, no. 2, pp. 1926–1935, 2023, doi: 10.1109/TITS.2022.3222769.

[11] A. K. Tyagi and N. Sreenath, "Intelligent transportation system: need, working, and tools," in *Intelligent Transportation Systems: Theory and Practice*, Springer, 2023, pp. 201–228, doi: 10.1007/978-981-19-7622-3_9.
[12] M. Tahir, Y. Qiao, N. Kanwal, B. Lee, and M. N. Asghar, "Real-time event-driven road traffic monitoring system using CCTV video analytics," *IEEE Access*, vol. 11, pp. 139097–139111, 2023, doi: 10.1109/ACCESS.2023.3340144.
[13] K. V Thakare, D. P. Dogra, H. Choi, H. Kim, and I. J. Kim, "Object interaction-based localization and description of road accident events using deep learning," *IEEE Transactions on Intelligent Transportation Systems*, vol. 23, no. 11, pp. 20601–20613, 2022, doi: 10.1109/TITS.2022.3170648.
[14] A. Abdelraouf, M. A. Aty, and Y. Wu, "Using vision transformers for spatial-context-aware rain and road surface condition detection on freeways," *IEEE Transactions on Intelligent Transportation Systems*, vol. 23, no. 10, pp. 18546–18556, 2022, doi: 10.1109/TITS.2022.3150715.
[15] K. Masykuroh, H. Hendrawan, and E. Mulyana, "Accuracy–latency trade-offs and computational complexity of ultralytics YOLOv11 for real-time video object detection," *2025 19th International Conference on Telecommunication Systems, Services, and Applications (TSSA),* Yogyakarta, Indonesia, 2025, pp. 1-6, doi: 10.1109/TSSA68467.2025.11303782.
[16] G. Chance, A. Ghobrial, K. McAreavey, S. Lemaignan, T. Pipe, and K. Eder, "On determinism of game engines used for simulation-based autonomous vehicle verification," *IEEE Transactions on Intelligent Transportation Systems*, vol. 23, no. 11, pp. 20538–20552, Nov. 2022, doi: 10.1109/TITS.2022.3177887.
[17] J. N. Njoku, C. I. Nwakanma, G. C. Amaizu, and D. Kim, "Prospects and challenges of metaverse application in data-driven intelligent transportation systems," *IET Intelligent Transport Systems*, vol. 17, no. 1, pp. 1–21, Jan. 2023, doi: 10.1049/itr2.12252.
[18] A. C. Morata, C. A. Fernández, M. Freire, I. M. Ortiz, and B. F. Manjón, "Serious games to prevent and detect bullying and cyberbullying: a systematic serious games and literature review," *Computers & Education*, vol. 157, 2020, doi: 10.1016/j.compedu.2020.103958.
[19] C. Y. Chow, R. R. Riantiningtyas, M. B. Kanstrup, M. Papavasileiou, G. D. Liem, and A. Olsen, "Can games change children's eating behaviour? a review of gamification and serious games," *Food Quality and Preference*, vol. 80, Mar. 2020, doi: 10.1016/j.foodqual.2019.103823.
[20] C. Ferguson, E. L. V. D. Broek, and H. V. Oostendorp, "On the role of interaction mode and story structure in virtual reality serious games," *Computers & Education*, vol. 143, Jan. 2020, doi: 10.1016/j.compedu.2019.103671.
[21] T. Susi, M. Johannesson, and P. Backlund, "Serious games: an overview," *Technical Report HS-IKI-TR-07-001*, School of Humanities and Informatics, University of Skövde, Skövde, Sweden, 2007.
[22] Apptica, "Mobile games: state of the market H1," *apptica.com*, 2023. [Online]. Available: https://apptica.com/report-gaming-h1-2023
[23] P. Arpaia, A. Esposito, E. Galasso, F. Galdieri, and A. Natalizio, "A wearable brain-computer interface to play an endless runner game by self-paced motor imagery," *Journal of Neural Engineering,* vol. 22, no. 2, Mar. 2025, doi: 10.1088/1741-2552/adc205.
[24] M. S. Yazir, E. T. Tosida, and L. Karlitasari, "Endless run based medicinal plant educational game development," *International Journal of Global Operations Research*, vol. 3, no. 2, pp. 64–73, May 2022, doi: 10.47194/ijgor.v3i2.138.
[25] Y.-C. Kuo, C.-L. Li, W.-C. Yin, and C.-Y. Lin, "Red light, green light game system based on IoT devices," in *2023 International Conference on Consumer Electronics - Taiwan (ICCE-Taiwan)*, 2023, pp. 767–768, doi: 10.1109/ICCE-Taiwan58799.2023.10226841.
[26] A. T. Sanli and M. Saran, "Application of a voting-based ensemble method for recognizing seven basic emotions in real-time webcam video images," in *2024 IEEE 9th International Conference for Convergence in Technology (I2CT)*, Apr. 2024, pp. 1–5, doi: 10.1109/I2CT61223.2024.10543506.
[27] T. Fukusaki, H. Tsutsui, T. Ohgane, "An evaluation of a CNN-based parking detection system with webcams," in *Proceedings of the 2020 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA ASC)*, 2020, pp. 100–103.
[28] B. Pokric, S. Krco, M. Pokric, P. Knezevic, and D. Jovanovic, "Engaging citizen communities in smart cities using IoT, serious gaming and fast markerless Augmented Reality," in *2015 International Conference on Recent Advances in Internet of Things (RIoT)*, Apr. 2015, pp. 1–6, doi: 10.1109/RIOT.2015.7104905.
[29] C. G. Garcia, F. T. Saenz, F. G. Burgos, and A. F. Skarmeta, "Integration of serious games and IoT data management platforms to motivate behavioural change for energy efficient lifestyles," in *2017 Global Internet of Things Summit (GIoTS)*, Jun. 2017, pp. 1–6, doi: 10.1109/GIOTS.2017.8016255.
[30] P. Tangworakitthaworn, V. Tengchaisri, and P. Sudjaidee, "Serious game enhanced learning for agricultural engineering education: two games development based on IoT technology," in *2020 - 5th International Conference on Information Technology (InCIT)*, Oct. 2020, pp. 82–86, doi: 10.1109/InCIT50588.2020.9310786.
[31] Sumit and R. S. Chhillar, "IoT enabled security management approach for intelligent transportation system in smart cities," in *2022 IEEE 6th Conference on Information and Communication Technology (CICT)*, Nov. 2022, pp. 1–5, doi: 10.1109/CICT56698.2022.9997813.
[32] Y. Cui and D. Lei, "Design of highway intelligent transportation system based on the internet of things and artificial intelligence," *IEEE Access*, vol. 11, pp. 46653–46664, 2023, doi: 10.1109/ACCESS.2023.3275559.
[33] M. Zamani and A. Kalbasi, "IoT-based intelligent transportation system for passenger-shuttle taxi matchmaking," in *2024 Third International Conference on Distributed Computing and High Performance Computing (DCHPC)*, May 2024, pp. 1–8, doi: 10.1109/DCHPC60845.2024.10454086.
[34] D. Gupta, S. P. Koiry, P. Veerender, P. Jha, C. Sridevi, and A. K. Chauhan, "Modeling and simulation of photovoltaic cell and module for IoT applications," in *2023 International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT)*, Jan. 2023, pp. 728–734, doi: 10.1109/IDCIoT56793.2023.10053556.
[35] N. Alsbou, R. Lane, L. Gurung, and I. Ali, "Simulation and implementation of an IoT-based secure smart biology laboratory for smart cities," in *2023 IEEE 17th International Symposium on Medical Information and Communication Technology (ISMICT)*, May 2023, pp. 1–6, doi: 10.1109/ISMICT58261.2023.10152089.
[36] K. Hiroi, A. Kohiga, S. Fukaya, and Y. Shinoda, "An orchestrator framework for iot-based disaster prevention simulation," in *2023 IEEE SENSORS*, Oct. 2023, pp. 1–4, doi: 10.1109/SENSORS56945.2023.10325055.
[37] A. Rajput and M. Jain, "System dynamics simulation model to reduce the traffic congestion of metropolitan cities of India by implementing intelligent transportation system," in *Proceedings of the International Conference on Mathematical Sciences and Statistics 2022 (ICMSS 2022)*, Dordrecht: Atlantis Press International BV, 2023, pp. 440–455, doi: 10.2991/978-94-6463-014-5_38.
[38] H. H. Hassan *et al.*, "(DEMO) EDICT: a simulation tool for performance metrics datasets in iot environments," in *2023 19th International Conference on Distributed Computing in Smart Systems and the Internet of Things (DCOSS-IoT)*, Jun. 2023, pp. 71–73, doi: 10.1109/DCOSS-IoT58021.2023.00020.
[39] S. Cebi, S. C. Onar, B. Oztaysi, and C. Kahraman, "Integration of analytic hierarchy process with other mcdm methods: a literature review," International Symposium of the Analytic Hierarchy Process 2022, Dec. 2022, doi: 10.13033/isahp.y2022.046.

[40] R. Baušys, I. Leščauskienė, and R. Semėnas, “Participant trustworthiness analysis in the game-based urban planning processes by promethee-mgqnn approach,” *Journal of Civil Engineering And Management*, vol. 27, no. 6, pp. 427–440, Jul. 2021, doi: 10.3846/jcem.2021.15263.
[41] D. G. Vagiona, “Comparative multicriteria analysis methods for ranking sites for solar farm deployment: a case study in greece,” *Energies*, vol. 14, no. 24, Dec. 2021, doi: 10.3390/en14248371.
[42] M. Misra, E. Á. Segura, and A. S. Arif, “Exploring the pace of an endless runner game in stationary and mobile settings,” in *Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts*, Oct. 2019, pp. 543–550, doi: 10.1145/3341215.3356256.
[43] G. Karadeniz, A. Ozcan, M. Bayram, and G. Ince, “Simulation of counter-UAV tactics against drone swarms: a serious game approach,” in *2023 10th International Conference on Recent Advances in Air and Space Technologies (RAST)*, Jun. 2023, pp. 1–6, doi: 10.1109/RAST57548.2023.10197945.
[44] M. Karthan, D. Hieber, A. Kreuder, U. Frick, R. Pryss, and J. Schobel, “Concept and requirements for an educational serious game teaching pandemic management,” in *2023 IEEE 36th International Symposium on Computer-Based Medical Systems (CBMS)*, Jun. 2023, pp. 153–156, doi: 10.1109/CBMS58004.2023.00208.
[45] K. H. A. Tan, Y. Cai, B. T. Lokesh, Y. Zhu, C. Su, and Q. Cao, “VR serious game for learning the computer organisation and architecture course,” in *2023 3rd International Conference on Educational Technology (ICET)*, Sep. 2023, pp. 1–6, doi: 10.1109/ICET59358.2023.10424233.
[46] M. Sosa, J. M. Fontana, R. O’Brien, E. Laciar, and L. Molisani, “A serious game controlled by myoelectric signals for prosthetic use training,” in *2022 IEEE Biennial Congress of Argentina (ARGENCON)*, Sep. 2022, pp. 1–4, doi: 10.1109/ARGENCON55245.2022.9940103.
[47] S. Kurahashi, “An infectious disease medical policy simulation and gaming,” in *2019 International Research Conference on Smart Computing and Systems Engineering (SCSE)*, Mar. 2019, pp. 1–8, doi: 10.23919/SCSE.2019.8842733.
[48] Y. M. Arif, S. Harini, S. M. S. Nugroho, and M. Hariadi, “An automatic scenario control in serious game to visualize tourism destinations recommendation,” *IEEE Access*, vol. 9, pp. 89941–89957, 2021, doi: 10.1109/ACCESS.2021.3091425.
[49] C. Marx, L. and Bichlmeier, “Development and evaluation of a serious game for training patient-physician communication,” in *Proceedings of the 2023 IEEE Conference on Games (CoG)*, 2023, pp. 1–4.
[50] F. Nugroho, P. M. N. S. A. Basid, F. S. Bahtiar, and I. G. P. A. Buditjahjanto, “Dynamic difficulty adjustment of serious-game based on synthetic fog using activity theory model,” *International Journal of Advanced Computer Science and Applications*, vol. 14, no. 6, pp. 564–573, 2023, doi: 10.14569/IJACSA.2023.0140660.
[51] F. Nugroho *et al.*, “Adaptive maze-based islamic educational games using MOORA method,” *Jurnal Nasional Pendidikan Teknik Informatika*, vol. 14, no. 2, pp. 471–486, 2025, doi: 10.23887/janapati.v14i2.100064.
[52] R. M. Rahimabad and M. H. Rezvani, “Identifying factors affecting the empathy of players in serious games,” in *2021 International Serious Games Symposium (ISGS)*, Nov. 2021, pp. 27–34, doi: 10.1109/ISGS54702.2021.9685014.
[53] M. Moradi and N. F. B. M. Noor, “The Impact of problem-based serious games on learning motivation,” *IEEE Access*, vol. 10, pp. 8339–8349, 2022, doi: 10.1109/ACCESS.2022.3140434.
[54] B. D. S. Goncalves, O. Postolache, and J. M. D. Pereira, “Gait rehabilitation in virtual reality serious game interactive scenarios,” in *2022 International Conference and Exposition on Electrical And Power Engineering (EPE)*, Oct. 2022, pp. 672–676, doi: 10.1109/EPE56121.2022.9959874.
[55] H. A. Rosyid, H. Hasanah, M. I. Fathurrozi, and M. I. Akbar, “Block-based approach to observe game content space in endless-runner game,” in *2019 International Conference on Electrical, Electronics and Information Engineering (ICEEIE)*, Oct. 2019, pp. 273–278, doi: 10.1109/ICEEIE47180.2019.8981422.
[56] A. Jamil, Z. Murtza, M. K. Nazir, M. Waseem, Z. Ghulam, and R. U. Farooq, “A generic formal specification of an infinite runner games for handheld devices using Z-notation,” in *2019 IEEE 4th International Conference on Computer and Communication Systems (ICCCS)*, Feb. 2019, pp. 409–413, doi: 10.1109/CCOMS.2019.8821750.
[57] S. Sae-Lao, T. Jumneanbun, P. Paliyawan, and R. Thawonmas, “Encourage players to smile while playing games bring more enjoyment,” in *2020 IEEE Conference on Games (CoG)*, Aug. 2020, pp. 690–693, doi: 10.1109/CoG47356.2020.9231694.
[58] B. Michaud, Y. Cherni, M. Begon, G. Girardin-Vignola, and P. Roussel, “A serious game for gait rehabilitation with the Lokomat,” in *2017 International Conference on Virtual Rehabilitation (ICVR)*, 2017, pp. 1–2, doi: 10.1109/ICVR.2017.8007482.
[59] A. Nurrahma *et al.*, “Application of multi-criteria promethee method to assist character selection in the endless runner game,” *Jurnal Teknik Informatika*, vol. 5, no. 4, pp. 1181–1189, Jul. 2024, doi: 10.52436/1.jutif.2024.5.4.2183.
[60] A. Alinezhad and J. Khalili, “ANP method,” in *New Methods and Applications in Multiple Attribute Decision Making (MADM)*, Cham, Switzerland: Springer, 2019, pp. 115–125, doi: 10.1007/978-3-030-15009-9_17.
[61] U. Kaytaz, S. Ahmadian, F. Hofmann, F. Sivrikaya, and S. Albayrak, “Online monte carlo planning with QoS subgoals for data caching in ITS MEC networks,” in *2023 IEEE International Conference on Omni-layer Intelligent Systems (COINS)*, Jul. 2023, pp. 1–6, doi: 10.1109/COINS57856.2023.10189272.
[62] X. Chen and R. Chen, “A review on traffic prediction methods for intelligent transportation system in smart cities,” in *2019 12th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI)*, Oct. 2019, pp. 1–5, doi: 10.1109/CISP-BMEI48845.2019.8965742.
[63] A. Sharma and R. B. Battula, “FOOTREST: Safety on roads through intelligent transportation system,” in *2020 International Conference on Information Networking (ICOIN)*, Jan. 2020, pp. 818–820, doi: 10.1109/ICOIN48656.2020.9016473.
[64] B. Yasay, K. Francisco, N. O. Velasco, M. Guillermo, and A. Bandala, “Fuzzy logic adaptive bus route determination for intelligent transportation system of buses along epifanio delos santos avenue (EDSA),” in *2023 8th International Conference on Business and Industrial Research (ICBIR)*, May 2023, pp. 1014–1019, doi: 10.1109/ICBIR57571.2023.10147519.
[65] Y.-T. Tseng and H.-W. Ferng, “Enhanced rerouting mechanism with machine learning for travel time and congestion reduction,” in *2022 IEEE 95th Vehicular Technology Conference: (VTC2022-Spring)*, Jun. 2022, pp. 1–5, doi: 10.1109/VTC2022-Spring54318.2022.9860918.
[66] E. Pagliari, L. Davoli, and G. Ferrari, “Harnessing communication heterogeneity: architectural design, analytical modeling, and performance evaluation of an IoT multi-interface gateway,” *IEEE Internet of Things Journal*, vol. 11, no. 5, pp. 8030–8051, 2024, doi: 10.1109/JIOT.2023.3317672.
[67] X. Xie, H. Wang, and X. Liu, “Scheduling for minimizing the age of information in multisensor multiserver industrial internet of things systems,” *IEEE Transactions on Industrial Informatics*, vol. 20, no. 1, pp. 573–582, Jan. 2024, doi: 10.1109/TII.2023.3268749.
[68] A. Hazra, A. Kalita, and M. Gurusamy, “Meeting the requirements of internet of things: the promise of edge computing,” *IEEE Internet of Things Journal*, vol. 11, no. 5, pp. 7474–7498, Mar. 2024, doi: 10.1109/JIOT.2023.3339492.

[69] İ. Kahraman, A. Köse, M. Koca, and E. Anarim, "Age of information in internet of things: a survey," *IEEE Internet of Things Journal*, vol. 11, no. 6, pp. 9896–9914, Mar. 2024, doi: 10.1109/JIOT.2023.3324879.

[70] D. H. Hussein and M. Ibnkahla, "A novel mathematical framework for modeling application-specific IoT traffic," *IEEE Internet of Things Journal*, vol. 11, no. 2, pp. 2364–2381, Jan. 2024, doi: 10.1109/JIOT.2023.3293028.

[71] Y.-R. Shi and J.-L. Shih, "Game factors and game-based learning design model," *International Journal of Computer Games Technology*, vol. 2015, pp. 1–11, 2015, doi: 10.1155/2015/549684.

[72] N. N. Hasibuan, M. Zarlis, and S. Efendi, "Detection and tracking different type of cars with YOLO model combination and deep sort algorithm based on computer vision of traffic controlling," *Sinkron*, vol. 5, no. 2B, pp. 210–221, Dec. 2021, doi: 10.33395/sinkron.v6i1.11231.

[73] P. D. Manikkannan, "Vehicle tracking and counting through image processing," *Interantional Journal of Scientific Research in Engineering and Management*, vol. 7, no. 12, pp. 1–11, Dec. 2023, doi: 10.55041/IJSREM27599.

[74] R. Tadayon, A. Amresh, T. McDaniel, and S. Panchanathan, "Real-time stealth intervention for motor learning using player flow-state," in *2018 IEEE 6th International Conference on Serious Games and Applications for Health (SeGAH)*, May 2018, pp. 1–8, doi: 10.1109/SeGAH.2018.8401360.

[75] K. Chrysafiadi, M. Kamitsios, and M. Virvou, "Fuzzy-based dynamic difficulty adjustment of an educational 3D-game," *Multimedia Tools and Applications*, vol. 82, no. 18, pp. 27525–27549, Jul. 2023, doi: 10.1007/s11042-023-14515-w.

BIOGRAPHIES OF AUTHORS

Fresy Nugroho is a lecturer in Informatics at the UIN Maulana Malik Ibrahim, Malang. He received his S.T. in Electrical Engineering of Universitas Brawijaya, Malang, in 1997. He received M.T. and Dr. degrees in Electrical Engineering, Institut Teknologi Sepuluh Nopember (ITS), Surabaya in 2010 and 2022, respectively. His research interest is serious game, IoT, AI, ML, and intelligence systems. He can be contacted at email: fresy@ti.uin-malang.ac.id.

I Gusti Putu Asto Buditjahjanto is a lecturer at the State University of Surabaya, Indonesia. He received his S.T. in Electrical Engineering of ITS, Surabaya, Indonesia, in 1998. He received M.T. and Dr. degrees in Electrical Engineering, ITS, Surabaya, Indonesia in 2003 and 2011, respectively. He is a professor in State University of Surabaya, Surabaya, Indonesia. His research fuzzy multi-attribute group DM, learning media, DSS, and intelligence systems. He can be contacted at email: asto@unesa.ac.id.

Dwi Pebrianti is a lecturer in Mechanical Aerospace Engineering at the International Islamic University Malaysia (IIUM). She received her S.T. in Electrical and Electronic Engineering, Universitas Indonesia, Indonesia, in 2001. She received M.Tech. in Engineering Synthesis at The University of Tokyo, in 2006, and Ph.D. degrees in Artificial Systems Science, Chiba University, Chiba, in 2011. She is an assistant professor in IIUM. Her research interest is nonlinear control and robotics, unmanned aerial vehicle, vision-based robot navigation, and motion and dynamics control. She can be contacted at email: dwipebrianti@iium.edu.my.

Jehad A. H. Hammad is a computer scientist with a master's degree from the School of Computer Sciences at the University Sains Malaysia that he received in 2009. He pursued his academic journey further and earned a Dr. in Electrical Engineering ITS in Surabaya, Indonesia in 2018. His research: e-learning, adaptive e-learning, and virtual classes. Currently, he is a faculty member of Technology and Applied Sciences at Al-Quds Open University, Palestine. He can be contacted at email: jhammad@qou.edu.

Moch Fachri is a lecturer in Faculty Engineering at the State University of Surabaya, Indonesia. He received his S.T. (2016), M.T. (2018) and Dr. (2025) degrees in Electrical Engineering, ITS, Surabaya, Indonesia in 2018 and, Indonesia, since 2025. His research game technology, crowd simulation, RVO, multiagent navigation, and collision avoidance. He can be contacted at email: moch.fachri1992@gmail.com.

Tri Mukti Lestari is a lecturer in Informatical Engineering at the UIN Maulana Malik Ibrahim, Malang, Indonesia. She received her S.Kom. in Informatic Engineering of Universitas Widyagama, Malang, Indonesia, in 2015. She received M.T. degrees in Universitas Islam Indonesia Yogyakarta in 2019. Her research interest is dashboard visualization, BI, and surveillance. She can be contacted at email: trimuktilestari@ti.uin-malang.ac.id.

Dian Maharani is a lecturer in Mathematic at the UIN Maulana Malik Ibrahim, Malang, Indonesia. She received her S.Pd. in Universitas Negeri Malang, Indonesia, in 2016. She received her M.Si. degrees in Institut Teknologi Bandung in 2018. Her research interest is PCA, mikhlin operator, and morrey space. She can be contacted at email: dian.maharani@mat.uin-malang.ac.id.

Alfina Nurrahma’N received her S.Kom. and M.Kom. in Informatic Engineering of UIN Maulana Malik Ibrahim, Malang, Indonesia, in 2020 and 2024. Her research interest is game, internet of thing, machines learning, and intelligence systems. She can be contacted at email: alfinanurrahman15@gmail.com.