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Development of a VR Metaverse System for Campus Navigation Using the Dijkstra Algorithm

Mochammad Nur Fikri Denintyo*[1], Tito Sugiharto[2], Yulyanto[3]
[1,2,3]Universitas Kuningan, Indonesia
E-mail: *[1]20210810144@uniku.ac.id, [2]tito@uniku.ac.id, [3]yulyanto@uniku.ac.id

Abstract

Advancements in Virtual Reality (VR) and Metaverse technologies have created new opportunities to enhance user experiences, particularly in education. This study presents the design and development of a VR-based Metaverse application for the Faculty of Computer Science at Universitas Kuningan. The application functions as an interactive promotional tool and campus navigation aid, utilizing the Dijkstra algorithm to compute the shortest routes within the virtual environment. Key features include realistic 3D campus visualizations, integrated information on essential locations, and route optimization from the main gate to user-selected destinations. Testing was conducted through black-box, white-box, and User Acceptance Testing (UAT) methods. User feedback indicated that navigation was effective, with directional clarity and usability scored at 3.59 and 3.18, respectively, while the 3D visualization received scores above 3.4 for realism. Interactivity and immersion achieved a score of 3.35, and the interface was deemed intuitive and accessible across devices (3.38 and 3.82). Despite minor issues with system responsiveness (averaging 2.65), users expressed high overall satisfaction and a strong intention to reuse and recommend the application, with a recommendation score of 3.76. This implementation highlights the potential of Metaverse technology in education and serves as a foundation for its wider adoption in Indonesian higher education.

Keywords— *Virtual Reality, Metaverse, Campus Navigation, Dijkstra Algorithm, Educational Technology.*

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1. INTRODUCTION

The digital era has significantly transformed various aspects of life, including education. The rapid development of information and communication technology has enabled the emergence of innovative learning methods and new forms of interaction. Among these, Virtual Reality (VR) and the Metaverse have emerged as cutting-edge technologies offering immersive and interactive experiences in digital environments[1], [2][3].

Metaverse, as a shared virtual space, has drawn increasing attention across different sectors, including higher education[4]. It presents a promising research direction due to its potential to create more engaging and collaborative learning environments. In the context of education, Metaverse can overcome traditional learning limitations by providing enriched and interactive experiences[5].

As an institution focused on information technology, the Faculty of Computer Science at Universitas Kuningan has a unique opportunity to adopt VR and Metaverse technologies to enhance educational quality and the student experience. Integrating VR in learning environments can also attract prospective students by offering innovative ways to explore the campus[6]. Despite the availability of supporting hardware such as Oculus VR devices, the use of these technologies remains limited and underexplored, especially in the context of promotional media.

Currently, the promotional strategies employed for campus introduction rely primarily on social media and printed brochures. These media lack interactivity and immersive qualities, preventing prospective students from experiencing the campus environment directly. The information provided is typically static and constrained by 2D formats, with limited capacity for real-time updates. Additionally, printed brochures require physical distribution, which limits their outreach.

Particularly in Campus 2 of the Faculty of Computer Science, there has been no application of Virtual Reality for promotional purposes, even though technology offers the potential to deliver a more engaging and realistic campus tour. This research aims to address this gap by developing a Metaverse-based virtual

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campus environment to introduce the faculty's facilities interactively.

To support effective exploration within the virtual environment, this study integrates the Dijkstra algorithm, which is known for its efficiency in determining the shortest path between two points[7]. This implementation will facilitate navigation within virtual space, helping users to move from the main gate to various destinations within the campus.

Therefore, this study focuses on the design and development of a Metaverse VR application for the Faculty of Computer Science, implementing the Dijkstra algorithm to enable efficient navigation within the virtual campus environment. The final prototype aims to provide a virtual space that accurately represents the faculty's facilities while offering a functional, immersive, and educationally valuable user experience.

The objective of this research is to develop an interactive and immersive VR-based Metaverse prototype that not only serves as an innovative promotional tool but also enables accurate campus navigation using the Dijkstra algorithm. Through this system, prospective students can explore the faculty environment virtually, gain spatial awareness of important locations, and experience a realistic campus atmosphere without needing to be physically present. It is expected that this research will contribute to the advancement of VR and Metaverse-based educational technologies and serve as a foundation for further exploration and adoption within higher education in Indonesia, particularly in computer science faculties.

2. RESEARCH METHODS

The research method outlines the systematic steps undertaken in this study, presented in the form of a flowchart. This flowchart illustrates the overall research process, starting from problem identification, requirement analysis, system design and development to system testing and evaluation of the research outcomes. Each stage is structured to ensure a clear and logical progression toward achieving the research objectives.

The research process shows in Figure 1, beginning with system requirement identification through problem analysis and literature review. Relevant references from books, journals, and existing Metaverse implementations in higher education were examined. Data collection was conducted via observations and interviews with faculty leaders, lecturers, and students to identify user needs.

The next phase involved system and interface design, including use case diagrams, navigation flowcharts, 3D object models, and Metaverse website layout. A prototype was then developed based on the initial design and evaluated by selected faculty and students to gather feedback on usability, feature completeness, and system effectiveness.

Based on user input, the system design and prototype were reviewed and refined before entering the final development stage, where all features were fully implemented and integrated. The system was subsequently tested to ensure its functionality and interactive experience. The final stage is system maintenance, aimed at ensuring long-term functionality and adaptability to future changes.

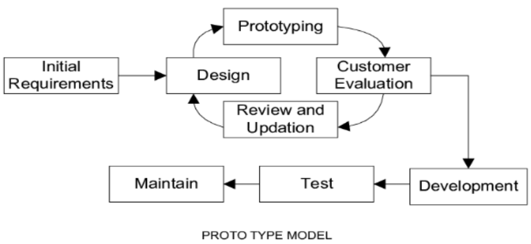

Fig 1. Research Process

2.1. Prototype System

This study adopts the Prototype System Development Model, which emphasizes iterative development, early user involvement, and continuous refinement of the system. The research began with the identification of problems related to the limited use of interactive media for campus promotion. This was followed by a literature review involving books, scientific journals, and prior studies related to Virtual Reality (VR) and Metaverse technologies in the context of higher education. To further understand user expectations, data were collected through direct observation and interviews with the dean, lecturers, and students of the Faculty of Computer Science at Universitas Kuningan. Comparative studies of existing Metaverse platforms were also conducted to gather references on design features and implementation strategies.

After identifying the problem and analyzing the context, a requirement analysis was carried out to determine the system's functional and non-functional needs. These included features such as 3D visualization of the campus, shortest-path navigation using the Dijkstra algorithm, integration of location-based

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information, user-friendly interface design, and cross-device accessibility. The system design stage involved creating case diagrams, navigation flowcharts, and user interface mockups. Additionally, 3D models representing the campus environment were developed using Blender, and the virtual campus was built using the Spatial.io platform.

Following the design phase, a prototype was developed to simulate the main features of the system, such as interactive 3D exploration and campus navigation[3]. The prototype was then evaluated by a group of representative users, including faculty members and students, to gather feedback on usability, visual quality, interactivity, and system performance. The feedback obtained was analyzed and used to revise and improve the prototype, particularly in areas such as navigation flow, user interface clarity, and system responsiveness.

The improved version of the application was then finalized by integrating all refined features into a complete VR Metaverse system for Campus 2 of the Faculty of Computer Science. The Dijkstra algorithm was fully implemented to allow accurate and efficient navigation within the virtual environment. After development, the final system underwent a comprehensive testing phase, including black-box testing, white-box testing, and User Acceptance Testing (UAT), to ensure that all functionalities operated correctly and met user expectations. Finally, the system entered the maintenance phase, which focuses on ensuring long-term operability, providing technical support, and preparing the system for future enhancements or adjustments in line with evolving user needs.

2.2. Djisktra Algorithm

The Dijkstra algorithm is a classic graph-based search algorithm developed by Edsger W. Dijkstra in 1959, designed to find the shortest path between nodes in a graph, which may represent, for example, road networks, computer networks, or virtual environments[8]. It is widely used in various fields, including routes, network optimization, and more recently, virtual navigation systems in immersive environments such as Virtual Reality (VR) and Metaverse applications.

In this study, the Dijkstra algorithm is implemented to calculate the shortest and most efficient navigation path between points of interest within the virtual campus environment. Each location on the virtual map is represented as a node, while the possible routes between them are represented as edges with associated weights or distances. When a user selects a starting point and a destination, the algorithm calculates the optimal path by iteratively selecting the nearest unvisited node, updating the shortest distances, and marking nodes as visited until the destination node is reached. The result is a list of nodes representing the most efficient path, which is then visualized within the Metaverse environment as a guiding route.

The main advantages of the Dijkstra algorithm are its simplicity, accuracy, and reliability, particularly when all edge weights are non-negative. These characteristics make it a suitable choice for pathfinding in virtual spaces where quick and reliable navigation is essential to improve user experience. In the context of this research, the Dijkstra algorithm supports real-time navigation assistance within the virtual Faculty of Computer Science campus, allowing users to explore facilities such as classrooms, laboratories, and administrative offices effectively [9].

This implementation not only enhances orientation within the digital space but also adds functional value to the VR Metaverse system, making it not just a visual representation but also an interactive and informative platform. By integrating Dijkstra's algorithm, the system provides a personalized and efficient campus tour, which is particularly beneficial for prospective students unfamiliar with the real-world layout of the institution

Each location within the virtual campus is modeled as a node, and the possible paths between them are treated as edges with associated weights or distances. When a user selects a starting point and destination, the algorithm performs a systematic traversal of the graph, updating the shortest known distances to each node and determining the optimal path based on the lowest cumulative cost. This calculated path is then visually rendered within the VR environment to guide the user.

In determining the shortest route using Dijkstra's Algorithm, there are several steps that must be taken so that the desired shortest route can be achieved properly in the campus Metaverse implementation, including:

1. Determine the starting point or node and the end node of the campus room location,
2. Determine the weight value or distance between each existing room location,
3. Next, set all nodes as 'untranslated nodes and the start node as the 'departure start node',
4. Path value = 0, find the initial shortest route using Dijkstra's Algorithm by comparing the

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weight value (distance) connected to the initial node,

5. If successful, the shortest path has been found, while if unsuccessful, the steps will be repeated to find the route,
6. Nodes that have been travelled are designated as 'touched nodes' and become 'departure nodes' for the next stage, with the path distance value equal to the total path distance that has been travelled,
7. Find the next route until it reaches the last node at the location of the campus room. If successful, then the shortest path to the final node has been reached, and the route-finding process is declared complete.

2.3. Research Data

In this research, the data used are the names of rooms and facilities in Campus 2 of the Faculty of Computer Science. In addition, information about the rooms and facilities, as well as information about the navigation route starting from the main gate, were used as reference points to various rooms on campus to manually draw the Graph. The distance between room locations was also obtained to process the data in manually finding the shortest route, and the coordinates of the room locations were used to create location point markers in the campus Metaverse system. Table 1 shows Location Coordinates.

No.	*Node*	Latitude	Longtitude
1	A	-6.97569	108.47727
2	B	-6.97580	108.47789
3	C	-6.97584	108.47785
4	D	-6.97592	108.47780
5	E	-6.97595	108.47778
6	F	-6.97599	108.47771
7	G	-6.97606	108.47768
8	H	-6.97609	108.47761
9	I	-6.97604	108.47767
10	J	-6.97600	108.47770
11	K	-6.97591	108.47780
12	L	-6.97583	108.47783
13	M	-6.97580	108.47788
14	N	-6.97575	108.47776
15	O		
16	P	-6.97621	108.47746
17	Q	-6.97614	108.47737
18	R	-6.97610	108.47731
19	S	-6.97606	108.47726
20	T	-6.97601	108.47720
21	U	-6.97569	108.47761
22	V	-6.97572	108.47756
23	W	-6.97573	108.47771
24	X	-6.97588	108.47749
25	Y	-6.97594	108.47742
26	Z	-6.97605	108.47747
27	AA	-6.97609	108.47753
28	AB	-6.97578	108.47751
29	AC	-6.97560	108.47768
30	AD	-6.97580	108.47744
31	AE	-6.97574	108.47752
32	AF	-6.97570	108.47755
33	AG	-6.97567	108.47760
34	AH	-6.97590	108.47740
35	AI	-6.97596	108.47736
36	AJ	-6.97599	108.47732
37	AK	-6.97565	108.47785
38	AL	-6.97567	108.47745
39	AM	-6.97547	108.47747
40	AN	-6.97592	108.47756
41	AO	-6.97604	108.47725
42	AP	-6.97601	108.47722
43	AQ	-6.97602	108.47774
44	AR	-6.97615	108.47761
45	AS	-6.97617	108.47758
46	AT	-6.97616	108.47760
47	AU	-6.97622	108.47749
48	AV	-6.97609	108.47764
49	AW	-6.97597	108.47720

Table I : Location Coordinates Table

Below is the pseudocode for Dijkstra's Algorithm.

Pseudocode : Djikstra Algorithm

```
Input:
  A weighted graph G(V, E),
  where V is the set of vertices and E is the
set of edges
  A starting vertex source
Output:
  Shortest distance from source to all other
vertices
1. Initialize:
    For each vertex v in V:
      distance[v] ← ∞          // Unknown
distance from source to v
      previous[v] ← null    // Previous node
in optimal path
    distance[source] ← 0      // Distance from
source to itself is 0
    Q ← V                    // Set of all vertices
in the graph (unvisited set)
2. While Q is not empty:
    u ← vertex in Q with smallest distance[u]
    Remove u from Q
    For each neighbor v of u:
      alt ← distance[u] + weight(u, v)
      If alt < distance[v]:
        distance[v] ← alt
```

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previous[v] ← u
3. Return:
distance[]: shortest distance from source to each vertex
previous[]: optimal path tree to reconstruct paths

3. RESEARCH RESULTS

3.1 Proposed System

Analysis of the proposed system describes the stages of how the proposed system will function. The goal is to provide a detailed description of how the Faculty of Computer Science Metaverse VR Application works. This proposed system can be seen in Figure 2.

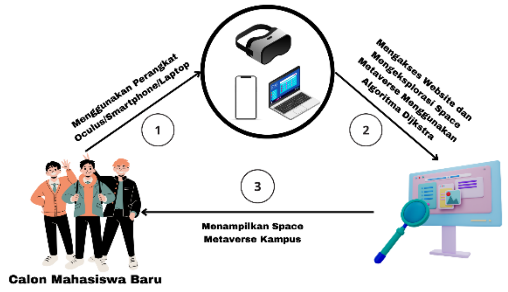

Figure 2. Proposed System

Based on Figure 2, the system from Spatial.io will display the pre-built Metaverse where users will access the Metaverse through various devices. Access can be done through mobile phones with a responsive interface, laptops/PCs for a more detailed experience, and also using Oculus devices for Virtual Reality mode that provides a higher level of immersion. When users have accessed the Spatial.io website and searched for the Metaverse of the Faculty of Computer Science Campus, the system will direct users to a specially designed virtual environment.

After successfully entering the Campus Metaverse, users can use their avatars to interact with the virtual environment and explore the entire modelled campus area. Users can explore various rooms such as Classrooms, Dean's Room, Computer Laboratory, Library, and other facilities that have been implemented in the virtual environment. The implementation of Dijkstra's Algorithm in the system will help users find the shortest route from one location to another, so that navigation in the Campus Metaverse becomes more efficient and intuitive for users, especially for new students or visitors who are not familiar with the campus layout.

3.2 Use Case Diagram

Use case diagram shows how the system interacts with the surrounding environment. In this use case diagram, users (Prospective New Students) can communicate with the system through various methods.

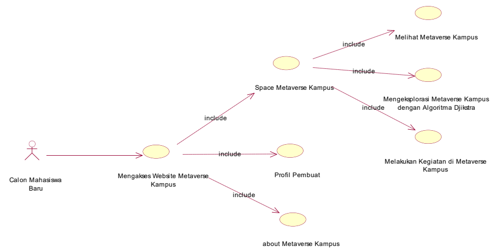

Figure 3. Use Case Diagram

Based on Figure 3, the system design involves a primary actor—prospective students—who interact directly with the Campus Metaverse system through several key use cases. The main use case is "Access Campus Metaverse Website", which includes additional features via the «include» relationship, such as "Creator Profile", "About Campus Metaverse", and "Campus Metaverse Space."

The "Campus Metaverse Space" serves as the core feature of the system, comprising three main activities: "View Campus Metaverse," "Explore Campus Metaverse," and "Engage in Activities within the Metaverse." These activities are directly linked to the main use case and guide users to access a 3D virtual environment hosted on the Spatial.io platform. Within this space, users can visualize the campus buildings in three dimensions.

Furthermore, the system offers an exploration feature powered by the Dijkstra algorithm, which helps users identify the shortest path for navigation within the virtual campus. This enhances the efficiency and clarity of movement through the Metaverse. Users can also engage in interactive activities, such as simulations or object-based interactions within the virtual environment.

4. DISCUSSION

The development and implementation of a VR-based Metaverse system for campus navigation have shown significant potential in enhancing user interaction and improving the promotional strategy of higher education institutions. The system was specifically designed for the Faculty of Computer Science at Universitas Kuningan and aimed to offer a virtual campus tour experience using 3D modeling and the Dijkstra algorithm for shortest-path navigation.

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4.1 System Design and User Experience

The integration of Metaverse technology via the Spatial.io platform allowed for a realistic and immersive virtual representation of Campus 2. Based on the system evaluation, users responded positively to the 3D visualization aspect, with buildings and spatial layouts resembling the physical campus. This confirms that the design approach successfully met the goal of creating an interactive promotional media that goes beyond static content such as brochures and social media posts.

User feedback also indicated that the experience was engaging and intuitive, particularly in aspects of virtual exploration and navigation. Although some technical limitations were reported, such as slow loading times and occasional lag, the core functionalities were generally well-received.

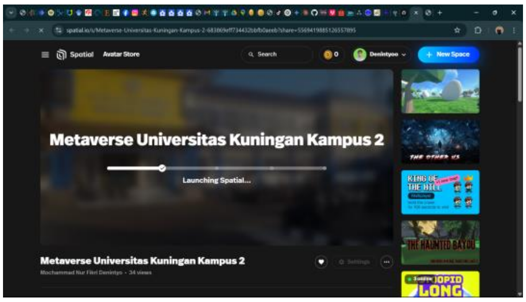

Figure 4. Metaverse

Figure 4 shows the display of the Metaverse Campus space when the user selects the Enter Metaverse menu, it will go directly to the space on the Spatial.io web page.

Figure 5. Metaverse View

This view displays the Campus Metaverse by displaying the 3D building of Campus 2 of Kuningan University with spaces and also the interior and exterior of the campus.

4.2 Navigation Efficiency with Dijkstra Algorithm

The application of the Dijkstra algorithm proved to be effective in enhancing the navigation system within the virtual environment. By calculating the shortest path from the main gate to various destinations (e.g., classrooms, labs, administrative buildings), the algorithm provided structured guidance that helped reduce disorientation among users. The implementation aligned well with previous research, which supports the use of Dijkstra in spatial search problems within simulation and VR settings (Harahap & Khairina, 2017; Indriana et al., 2023).

Users rated navigation clarity and usability at 3.59 and 3.18, respectively, suggesting that the algorithmic support was beneficial in achieving efficient movement across the virtual space. This also indicates that algorithm-driven navigation can serve as an important feature for enhancing virtual campus systems, especially for prospective students unfamiliar with the environment.

User feedback indicated that navigation was effective, with directional clarity and usability scored at 3.59 ± 0.42 and 3.18 ± 0.38, respectively ($n=30$ respondents). The distribution analysis showed that 73% of users rated navigation clarity above 3.0, with 23% providing excellent ratings (≥ 4.0).

4.3 Comparison with Previous Studies

To contextualize the contribution of this research, a systematic comparison with previous metaverse implementations in educational settings is necessary. This section specifically examines the work of Duan et al. (2021), which represents one of the most comprehensive campus metaverse prototypes documented in recent literature.

4.3.1 Overview of Compared Studies

Duan et al.'s CUHKSZ Metaverse (2021): Duan et al. developed a blockchain-driven metaverse prototype for The Chinese University of Hong Kong, Shenzhen. Their system was built on Unity game engine integrated with FISCO-BCOS consortium blockchain technology. The primary objectives centered on creating a virtual social ecosystem where students could interact, create user-generated content, and participate in a token-based economy. The system featured location-based services using GPS tracking, allowing students' physical presence on campus to influence their virtual experience—for example, earning tokens at higher rates when studying in the university library.

This Study - Faculty of Computer Science VR Metaverse (2025): This research developed a VR-based metaverse application for the Faculty of Computer Science at Universitas Kuningan using the Spatial.io platform. The system serves dual purposes: as an interactive promotional tool for prospective students and as a campus navigation aid. The core distinguishing feature is the integration of Dijkstra's algorithm to compute optimal routes within the virtual environment.

4.3.2 Key Differences in System Design and Focus

Platform and Technology Architecture: Duan et al. utilized Unity as their development engine, which required custom programming and substantial technical infrastructure. Their blockchain implementation through FISCO-BCOS demanded server setup, smart contract deployment using Solidity, and ongoing blockchain maintenance. This approach provided deep customization capabilities but required significant technical expertise and computational resources.

In contrast, this research employs Spatial.io, a ready-made metaverse platform that operates through web browsers and supports multiple devices without requiring extensive backend infrastructure. The 3D campus models were created using Blender and imported into Spatial.io, while the Dijkstra algorithm was implemented as a separate computational module that interfaces with the platform. This approach reduces technical complexity while maintaining functional effectiveness.

Navigation Capabilities - The Critical Distinction:

The most significant difference between the two systems lies in their approach to user navigation within the virtual environment:

Duan et al.'s Approach: Their system employed location-based GPS tracking that synchronized users' physical location with their virtual avatar position. When students physically moved around campus, their avatar would correspondingly move in the metaverse. This created an interesting connection between physical and virtual worlds. However, this approach has inherent limitations:

- It only functions when users are physically present on campus
- It does not provide directional guidance or route suggestions
- New visitors or prospective students unfamiliar with campus layout receive no navigational assistance
- Users must explore manually or rely on prior knowledge of campus geography
- The system visualizes the campus but does not compute or recommend paths

This Study's Approach: This research implements Dijkstra's algorithm for intelligent pathfinding, which fundamentally changes the navigation paradigm:

- The algorithm actively computes the shortest path between any two points in the virtual campus
- Users can select a destination (e.g., Computer Laboratory, Dean's Office, Classroom) and receive automated route guidance
- The system calculates optimal paths from the main gate to all major campus facilities
- Each location is represented as a node with coordinate data, and paths between locations have weighted distances
- The algorithm processes this graph structure to determine minimum-distance routes
- Visual indicators guide users along the computed path, reducing disorientation

Practical Example of the Difference: Consider a prospective student who wants to visit the Computer Laboratory:

- In Duan et al.'s system: The student would see the 3D campus and must explore by moving their avatar around, potentially getting lost or taking inefficient routes
- In this system: The student selects "Computer Laboratory" from a destination menu, and the Dijkstra algorithm immediately computes and displays the shortest path from the main gate, showing turn-by-turn guidance through the virtual space

4.3.3 Functional Purpose and Target Users

Duan et al.'s System:

- Primary Purpose: Social ecosystem for current students
- Target Users: Enrolled students already familiar with campus
- Core Features: Social interaction, token economy, user-generated content, blockchain-based governance
- Use Case: Daily student engagement, virtual events, campus community building

This Study's System:

- Primary Purpose: Promotional tool and navigation aid
- Target Users: Prospective students, new students, visitors unfamiliar with campus
- Core Features: Campus visualization, algorithmic navigation, facility information, VR immersion

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- Use Case: Campus tours, promotional activities, orientation for new students

4.3.4 Navigation System Implementation Details

To further clarify the technical distinction, the navigation implementations differ as follows:

Duan et al.'s Location-Based System:

- Uses smartphone GPS sensors to detect physical location
- Maps real-world coordinates to virtual world coordinates
- Avatar position updates automatically based on GPS data
- No pathfinding computation or route recommendation
- Navigation is passive (follows user movement) rather than active (guides user movement)

This Study's Dijkstra Algorithm Implementation:

- Pre-defines 49 nodes representing key campus locations (see Table I with coordinates)
- Calculates distances between connected nodes as edge weights
- When user selects destination, algorithm computes shortest path using iterative distance minimization
- Result is a sequence of nodes representing optimal route
- System visualizes this path with directional indicators in the 3D environment
- Navigation is active (system guides user) rather than passive

4.3.5 Complementary Strengths

It is important to note that both systems possess complementary strengths:

Strengths of Duan et al.'s approach:

- Rich social interaction features
- Blockchain-based economy and governance
- Strong community engagement mechanisms
- Seamless physical-virtual world connection for enrolled students

Strengths of this study's approach:

- Efficient navigation for unfamiliar users
- Lower technical barrier for implementation
- Clear promotional and informational value
- Algorithmic route optimization with measurable efficiency

4.3.6 Research Contribution Positioning

This comparative analysis reveals that while Duan et al. advanced the state of campus metaverse development by demonstrating comprehensive social ecosystem creation, their work did not address the specific challenge of navigation assistance for users unfamiliar with campus layout. This research fills that gap by proving that metaverse applications can integrate intelligent pathfinding algorithms to serve practical navigational and promotional purposes.

The contribution of this study is not merely the creation of another campus metaverse, but specifically the integration of algorithmic navigation (Dijkstra) into a VR metaverse environment to solve the real-world problem of campus orientation for prospective and new students. This represents a functional advancement beyond pure visualization or social interaction, demonstrating that metaverse technology can serve practical, goal-oriented purposes in educational promotion and student services.

Future research could combine both approaches: building socially-rich campus metaverse environments (as demonstrated by Duan et al.) enhanced with intelligent navigation systems (as demonstrated in this study) to create comprehensive virtual campus platforms that are simultaneously engaging, functional, and accessible.

4.4 Educational and Promotional Impact

The system not only achieved technical feasibility but also showed promise in terms of its educational and promotional objectives. Many users expressed interest in reusing the system and even recommended it to others, with an average satisfaction score of 3.76. This implies that immersive virtual experiences have the potential to increase user engagement and institutional appeal.

Furthermore, the system could serve as a foundation for future learning tools or virtual campus events, especially in hybrid or distance learning contexts. By integrating interactive simulations, informational content, and real-time navigation, the Metaverse system expands the possibilities for how educational institutions communicate their identity and values

5. CONCLUSION

Based on the results and implementation of this research, several key conclusions can be drawn:

1. This study successfully designed and developed a Virtual Reality (VR)-based Metaverse application that represents the environment of the Faculty of Computer Science at Universitas Kuningan. The application functions as both an interactive

promotional tool and a digital campus navigation system.
2. The integration of the Dijkstra algorithm effectively supports the navigation feature, enabling users to identify the shortest path from the main gate to various campus locations. This contributes to an intuitive and informative virtual exploration experience.
3. Testing using the black-box method confirmed that the core functionalities including navigation, object interaction, 3D visualization, and system performance across devices (PC and VR headsets) operated as expected.
4. The immersive campus visualization and guided navigation features enhanced the application's promotional appeal, increasing prospective students' interest and offering a clearer understanding of the campus layout.
5. This implementation demonstrates the potential of combining VR and Metaverse technologies with intelligent path-finding algorithms to improve both educational and promotional engagement in higher education environments.

6. SUGGESTIONS

Based on the results of this research, the following suggestions are proposed for future development and improvement of the system:

1. The application can be further enhanced by integrating social interaction features among users within the Metaverse environment. This would enrich the user experience and align more closely with the true concept of a fully immersive Metaverse.
2. Integration with the university's academic information system is recommended so that the application serves not only as a promotional tool, but also as a functional platform for academic purposes such as new student orientation, classroom mapping, and lecture scheduling.
3. System performance still requires improvement, particularly for mass-scale usage. Therefore, future testing with a larger number of simultaneous users is essential to evaluate the system's overall stability and responsiveness.

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