AR-NAVIS: Mobility Application for Blind and Deaf Students Based on Augmented Reality

1st Joko Slamet Saputro
Department of Electrical Engineering
Universitas Sebelas Maret
Surakarta, Indonesia
jssaputro89@staff.uns.ac.id

2nd Gunardi
Department of Special Education
Universitas Sebelas Maret
Surakarta, Indonesia
gunarhadi@ staff.uns.ac.id

3rd Fadjri Kirana Anggarani
Department of Psycological
Universitas Sebelas Maret
Surakarta, Indonesia
fadjrikiranaa@staff.uns.ac.id

4th Najya Anastasya
Department of Electrical Engineering
Universitas Sebelas Maret
Surakarta, Indonesia
najyaanastasya@student.uns.ac.id

5th Reva Setiabudi
Department of Electrical Engineering
Universitas Sebelas Maret
Surakarta, Indonesia
revasetiabudi13@student.uns.ac.id

6st Sutrisno Ibrahim
Department of Electrical Engineering
Universitas Sebelas Maret
Surakarta, Indonesia
sutrisno@staff.uns.ac.id

*Corresponding author: jssaputro89@staff.uns.ac.id

Received: March 20, 2024; **Accepted:** May 23, 2024

***Abstract*—Students with disabilities, especially those with visual and hearing impairments, face challenges in navigating through the campus environment. Hence, the development of AR-NAVIS as an Augmented Reality (AR)-based mobility orientation application stands as a significant innovation in providing services for them. This application aims to assist disabled students in moving within the campus environment, both indoors and outdoors. AR-NAVIS identifies the safest and most efficient routes, enabling disabled students to engage in independent activities and enhancing both their academic and non-academic performance. The application development process involves analyzing students' needs, prototype design, model validation, trials, and dissemination. Its features include AR-based 3D guidance, directional text, voice, vibration mode, and hazard information. The app is expected to provide accurate information about buildings or locations that are the destination for disabilities students. The result show that application development can guide disabilities user move between buildings smoothly. The experiment found that there was an increase in student activity after having this application.**

Keywords*—*augmented reality, unity, visual and hearing barriers, mobility orientation

I. INTRODUCTION

Universities in Indonesia have provided access for people with disabilities to receive better education. This is to carry out its obligations as an inclusive campus by realizing equal rights to education. For disabled students who are blind and deaf, mobilization in a new environment is a challenge in itself. Ease of mobility is important to make it easier for students to move easily around the campus environment. Limitations in mobility will result in hampered daily life activities for students with disabilities in obtaining information [1]. This is due to problems with visual abilities and understanding of students' signs of poor vision and hearing impairment [1]. Students with visual impairments tend to fail to understand body image accurately, as a result of limited exploration, limited movement, and overprotectiveness towards the environment which will have an impact on delayed motor development [2]. For students, hearing impairments in mobility orientation problems are difficulties in understanding signs and communication to understand new places on campus.

The mobility limitations faced by students with disabilities pose significant challenges in their daily campus life. These limitations not only hinder their ability to navigate the campus independently but also affect their overall academic and social experiences. For visually impaired students, navigating unfamiliar environments without visual cues can be daunting, leading to a reliance on others for assistance and reducing their sense of independence. Similarly, hearing-impaired students may struggle with communication barriers, making it difficult to understand auditory instructions or warnings in their surroundings. These mobility challenges can result in increased anxiety, reduced participation in campus activities, and ultimately, a less inclusive educational experience. Addressing these issues through innovative solutions like AR-based assistive technology is crucial in promoting equal access and enhancing the quality of life for disabled students [3].

Universitas Sebelas Maret (UNS) is an inclusive campus that currently accepts students with disabilities. There are currently 47 students with disabilities, with 37 students having visual and hearing impairments. The problem of new students with disabilities getting to know their new campus environment. The campus has the responsibility to overcome this problem, one of which is by using assistive technology to provide mobility orientation services for new students. Mobile applications on smartphones and tablets have become part of our daily lives [4]. The use of Augmented Reality (AR)-based assistive technology connected to smartphones and tablets is also increasing. AR has been proven to be effective in various areas of human life, ranging from education, marketing, and mobility orientation training [4]. The use of AR-based assistive technology is very accessible for people with visual and hearing disabilities. AR can be used to show a place easily with pointing images that are easy to understand with 3D models [5].

AR-based navigation applications are functionally the most effective technology in supporting people with disabilities in mobility orientation skills in the campus environment [6]. Navigation skills include using an AR-based smartphone application to make decisions in determining the correct direction when traveling on foot in the campus environment according to the direction of the destination [7]. One of the new AR features implemented includes the ability to identify the best route that is free from potential hazards such as obstacles and inclines [8][10]. The results show that the proposed solution supports mobility orientation for people with visual and hearing impairments using AR can improve mobility orientation capabilities indoors and outdoors easily and safely. Based on existing problems, the basis for this research is the development of AR-NAVIS: Augmented Reality (AR) Based Mobility Orientation Application for Students with visual and hearing impairments in the Campus Environment.

The structure of the paper is presented as follows. The background and application development methods described in section II. The application testing and implementation of the AR-NAVIS in both environments discussed and explained in section III. Finally, the conclusion and future development of this research is given in section IV.

II. Methods

A. *Need Analysis*

As an inclusive campus, UNS has 47 students with disabilities, of which 37 students who have visual and hearing impairments are classified as new students. The primary need for new students is an introduction to the campus environment for students with visual and hearing impairments. The results of a survey via Google Form regarding the need for assistive technology that can help students carry out indoor and outdoor mobility orientation in the campus environment, are as follows:

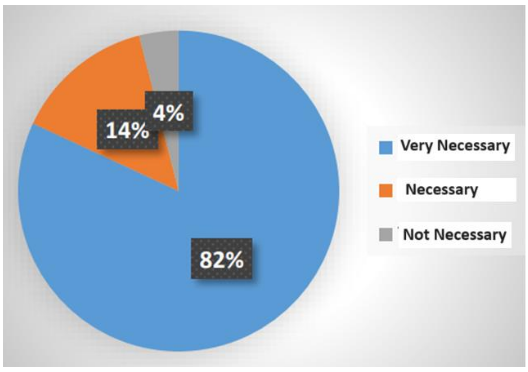

Fig. 1. Result of needs survey

Based on Figure 1 above, it shows that the survey results of 82% or 29 students stated that it is very necessary to develop assistive technology that can help students carry out indoor and outdoor mobility orientation to make activities easier in the campus environment.

This implies that out of the 37 new students with visual and hearing impairments, 29 responded to the survey, emphasizing the importance of developing such technology.

B. *Application Development*

Research begins by collecting and studying references, starting from examining references related to navigation applications, Unity software, and augmented reality. These references were obtained from several sources, including research results, theses, journals and other media. After technical data and references have been collected, the next step is to execute the application creation using Unity software.

The design stage in this research can be seen in figure 2.

Fig. 2. Research diagram

In Figure 2, After an in-depth analysis of related literature, the next step in this research involved the development of a software application. The method applied is making an application prototype to detect weak points that may exist in the implementation. In addition, the focus of application development is not only limited to its functionality, but also on the user interface (UI) aspect with the aim of increasing ease of use and interaction between users.

System testing is a stage that needs to be carried out by a developer when system development has been completed to test and ensure that each program that has been created meets the client's request which was previously approved during the system design stage. There are 2 testing methods that can be carried out, namely alpha testing and beta testing. Alpha testing is an internal process conducted by developers and QA teams in a controlled environment to identify bugs and verify that the software meets functional requirements. This phase involves both white-box and black-box testing, focusing on detecting major issues. Beta testing follows, involving external users who test the software in real-world conditions. The primary goal is to gather feedback on performance, usability, and any remaining bugs.

In developing this application, the author has designed an application using Unity software. The design process involves integrating several previously created assets, such as arrows, user interfaces, and map mapping data. First, the author uses Unity software as the main platform for building applications[11]. Unity is known as a powerful development environment for application creation, especially in the context of game and simulation development. One of the key elements integrated in this application are arrows. These arrows may be used to indicate directions or provide important instructions to the user. The arrow design can involve aspects such as size, color, and animation to effectively guide the user.

III. Results and Discussion

The results and discussion of this research will discuss the design application testing and the implementation of the AR-NAVIS both in indoor and outdoor navigation.

A. *Design Interface Application*

The application interface was created using Unity *software* by combining *User Interface* (UI) design and *Assets* such as animation.

1) *Homepage*

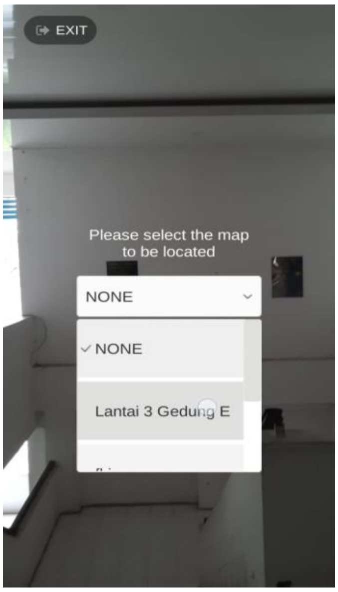

Fig. 3. Applfication start page

In the initial display of the application (Figure 3), a dropdown menu is displayed containing a list of building maps and available road routes. There is also an "Exit" button to exit the application.

2) After Selecting Map

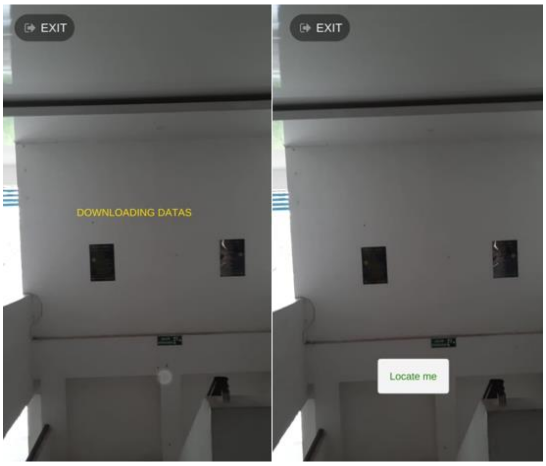

Fig. 4. Data download display and " *Locate me* " feature

After selecting a map, the process of downloading data from that map will be carried out as seen on Figure 4. Next, the " *Locate me* " process can be carried out by pressing the appropriate button. The " *Locate me* " process functions to detect the user's position through camera scanning. If the " *Locate me* " process fails, the application will process the position match again. If successful, the words " *Located Successfully* " will appear as shown in Figure 5.

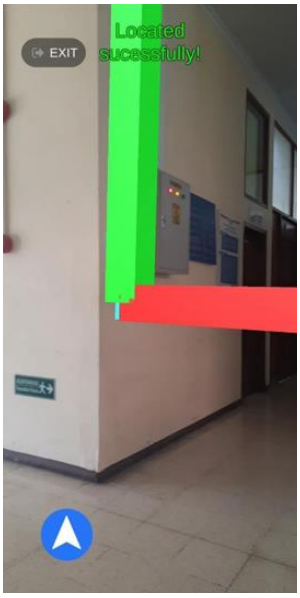

Fig. 5. Display when the application successfully detects the user's position

The arrow-shaped guidance button at the bottom left of the screen functions to bring up the guiding robot, as shown in Figure 6.

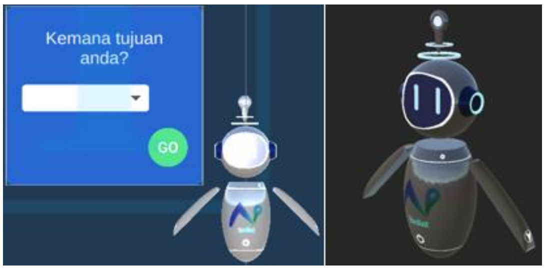

Fig. 6. Application guiding robot

3) Navigation View

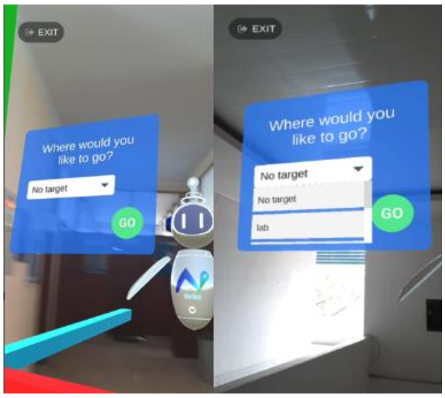

Fig. 7. Start navigation display

As shown in Figure 7, to start the journey, the application will display a guiding robot and a menu of the room/building you want to go to. Once the destination has been selected, pressing the "Go" button will prompt the application to show the directions with a guiding robot and animated moving arrows as shown in Figure 8.

Fig. 8. Navigation display

4) Arrive at Destination

Fig. 9. Display when reaching the destination

When you arrive at the destination room, the application will display a *dropdown menu* for the next room (if any) as shown in Figure 9. When the trip is finished, press the " *Exit* " button to exit the application.

B. *Application Testing*

The application testing was conducted using alpha and beta testing methods, which refer to the research conducted by Chaulina Alfianti, Oktavia, Rosandi Fila Setiawan, and Andrew Christianto. These methods ensure that the software performs well in both controlled environments and real-world conditions by gathering feedback from both internal teams and external users[12].

At the application testing stage, the author uses the alpha testing method to test whether the application can function as the author expects or not. Alpha testing is software quality testing that focuses on software functionality. Alpha testing aims to find incorrect functions, interface errors, data structure errors, performance errors, initialization and termination errors [9]. This test was conducted by five individuals, consisting of three developers and two members of the UNS Disability Study Center. Table 1 shows the testing process for each item to function.

TABLE I. ALPHA TESTING

No	Function	Result
1	Successfully accessed the initial application display and displayed the latest map menu	Succeed
2	Successfully downloads the selected map data and displays the " *Locate Me* " button	Succeed
3	Successfully scanned the user's location/position	Succeed
4	Successfully displays the guiding robot and room data on the selected map	Succeed
5	Successfully shows navigation with animation	Succeed
6	Successfully detects the achieved destination as well as room data on the selected map if you want to navigate again	Succeed

After the alpha testing phase, beta testing was conducted to gather feedback from actual users regarding the performance, functionality, and usability of the software in real-world conditions. Beta testing is an advanced testing phase that involves external users outside the development organization, commonly referred to as "beta users." In this case, the beta testing was conducted with deaf students.

TABLE II. BETA TESTING

No	Function	Tester Feedback	Result
1	Successfully accessed the initial application display and displayed the latest map menu	Application started correctly, but the font size was a bit small	Succeed (font size adjustment needed)
2	Successfully downloads the selected map data and displays the "*Locate Me*" button	Map data downloaded, but it took longer than expected	Succeed (optimize download speed)
3	Successfully scanned the user's location/position	Location detected correctly, but positioning was slightly off in crowded areas	Succeed (improve positioning accuracy in crowded areas)

4	Successfully displays the guiding robot and room data on the selected map	Guiding robot displayed correctly, room data was clear and helpful	Succeed
5	Successfully shows navigation with animation	Animations were smooth, but sometimes lagged in low-signal areas	Succeed (optimize performance in low-signal areas)
6	Successfully detects the achieved destination as well as room data on the selected map if you want to navigate again	Detected destination correctly, but the repeat navigation option was confusing	Succeed (improve repeat navigation clarity)

The AR-NAVIS application, which has gone through alpha and beta testing, is then tested in a live environment to determine the application's performance. At this stage, the navigation system was tested in conditions outside the building (*outdoor*) and conditions inside the building (*indoor*). Testing the AR-NAVIS navigation system to evaluate the accuracy of the starting point, destination point, route that was successfully generated.

Outdoor Navigation

Fig. 10. Location of the starting point for *outdoor navigation* with placement x:-0.007 y= 0.001 z =0

In figure 10, the initial stages of creating outdoor mapping are given. The author conducted an experiment with scanning by determining the starting point for navigation and scanning to the end point. The first step in the mapping process is to establish a starting point for navigation. This is a critical stage because the accuracy of the entire mapping process hinges on the precision of the initial coordinates.

Fig. 11. Location of *outdoor navigation End point* with placement x:-24,629 y= -4,611 z =112,837

In Figure 11, we present the culmination of our mapping process: the final route point. This critical waypoint signifies the culmination of meticulous data collection, analysis, and synthesis. As our mapping endeavors draw to a close, the visual representation of our efforts, encapsulated in the mapping results or image generation, emerges with clarity and precision. The journey to this final route point is marked by a series of intricate steps, each contributing to the comprehensive understanding of the terrain we traverse.

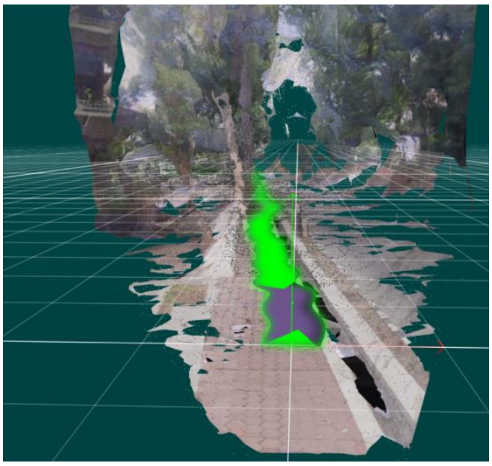

Fig. 12. *Map results* for road direction formation

Figure 12 displays the scanning results, with a prominent green line delineating the route created and traversed. This line serves as a visual guide, showcasing the path forged through our scanning efforts. It symbolizes progress, overcoming obstacles, and the culmination of meticulous exploration.

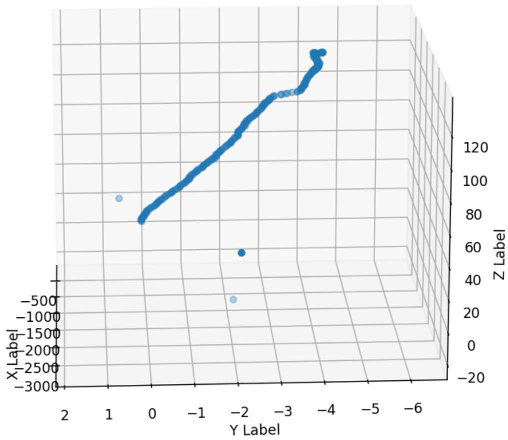

Fig. 13. XYZ graph resulting from *outdoor mapping*

Figure 13 presents a graph illustrating mapping location results, highlighting the unique points generated by each mapping scan. These points collectively inform the direction of the road, showcasing the dynamic nature of our mapping process and the diverse insights it yields.

Indoor Navigation

Fig. 14. Location of the starting point for *indoor navigation* with placement x:0.167 y= -0.069 z =0.66

In Figure 14, similar to Figure 10, we establish the starting point of the route for navigation purposes. This pivotal point serves as the foundation for our journey, guiding us towards our destination. Continuing through Figure 15, we reach the ultimate navigation placement: the stairs to the 2nd floor. This final location point marks the culmination of our navigation path, signaling the completion of our spatial exploration.

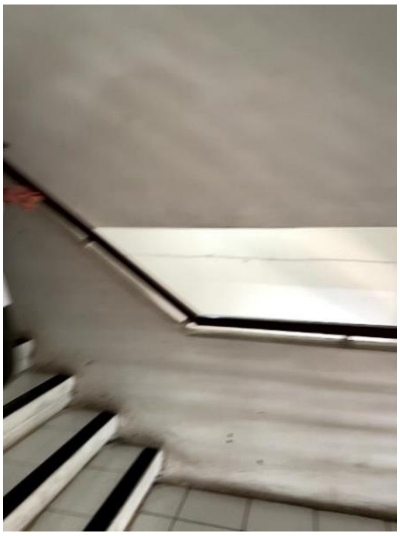

Fig. 15. *indoor* navigation endpoint with placement x:-0.619 y= 1.497 z =15.299

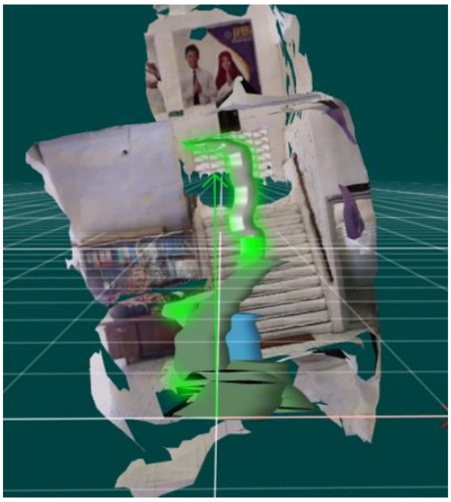

Fig. 16. Image of trajectory reconstruction results

After completing the mapping processing, Figure 16 unveils the navigation reconstruction, depicting the route direction illustrated in the accompanying diagram. From this reconstruction, we pinpointed location point XYZ, serving as a crucial reference for our navigational endeavors. Subsequently, Figure 17 showcases a path derived from this location data, offering further insights into our spatial analysis and navigation strategies.

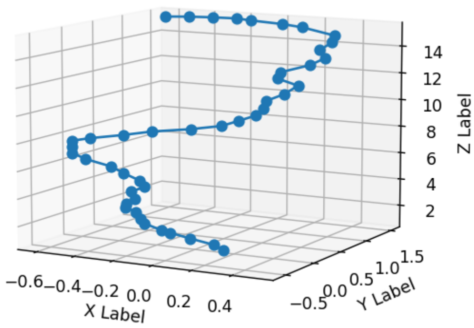

Fig. 17. Path graph

It is important to mention that AR-NAVIS can only be used in the pre-mapped or trained tracks. It cannot be used effectively in new or untrained environments. However, a new environment can be added to the application only by developer. This limitation means that the application requires prior environmental mapping to function accurately, which restricts its usability to areas that have already been mapped and stored in the application.

IV. Conclusion

This research has succeeded in developing a mobile application to help the mobility of deaf and blind students in an Augmented Reality-based campus environment. AR-NAVIS is one of the innovations in providing services for students with disabilities to support activities on campus both indoors and outdoors. AR-NAVIS can guide the mobility of students with disabilities in the campus environment via smartphone devices. Navigation or directions are generated based on a known environmental mapping process. From the experiment, it was found that there was an increase in student activity after having this application. AR-NAVIS increase mobility and participation of disability student in campus.

The path route was generated by the XYZ pinpoint representing the route that has been created by users. However, the accuracy position it may concern to be improved in future development of application, especially in indoor environment.

Acknowledgment

The authors would like to thank BELMAWA KEMENDIKBUDRISTEK for providing facilities and support for this research under scheme of Learning Innovation and Assistive Technology Assistance Program for Higher Education in 2023. The authors are grateful for the opportunity and resources which have contributed to the successful completion of this research.

References

[1] Malik, S., Abd Manaf, U. K., Ahmad, N. A., & Ismail, M., 2018. Orientation and mobility training in special education curriculum for social adjustment problems of visually impaired children in Pakistan. International Journal of Instruction, 11(2), pp. 185-202.

[2] Zusfindhana, I., Megaswarie,, R., Ariyanto,, D., & Prystiananta, N., 2019. Early intervention for children with visual impairment. Journal of ICSAR, 3(2), pp. 64-69.

[3] A. M. Ridha and W. Shehieb. Assistive Technology for Hearing-Impaired and Deaf Students Utilizing Augmented Reality. 2021 IEEE Canadian Conference on Electrical and Computer Engineering (CCECE), ON, Canada, 2021, pp. 1-5, doi: 10.1109/CCECE53047.2021.9569193.

[4] Žilak M., Car Ž., & Čuljak I. A., 2022. Systematic literature review of handheld augmented reality solutions for people with disabilities. Sensors, 22(20), pp. 7719.

[5] Putra, H. R. R., Fauzan, M. A. & Prawita, F. N., 2021. Geo navigasi: augmented reality based direction and information in geology museum (case study of geology museum building). e-Proceeding of Applied Science, 7(5), pp. 2027-2032.

[6] McMahon, D. D., Smith, C. C., Cihak, D. F., Wright, R., & Gibbons, M. M., 2015. Effects of digital navigation aids on adults with intellectual disabilities: Comparison of paper map, google maps, and augmented reality. Journal of Special Education Technology, 30(3), pp.157–165.

[7] Asraf, S.M.H., Hashim, Ameer, F.M., & Idrus, S.Z.S., 2020. Mobile application outdoor navigation using location-based augmented reality (AR). Journal of Physics: Conference Series, 152.

[8] Oliveira, L.C., Andrade, A.D., Oliveira, E.C., Soares, A.B., Cardoso, A., & Lamounier, E.A., 2017. Indoor navigation with mobile augmented reality and beacon technology for wheelchair users. IEEE EMBS International Conference on Biomedical & Health Informatics (BHI), pp. 37-40.

[9] F. C. Ningrum, D. Suherman, S. Aryanti, H. A. Prasetya, dan A. Saifudin, 2019. Pengujian Black Box pada Aplikasi Sistem Seleksi Sales Terbaik Menggunakan Teknik Equivalence Partitions," Jurnal Informasi Universitas Pamulang, 4(4), pp. 125–130.

[10] Lu, F. et al., 2021. An ARCore-Based Augmented Reality Campus Navigation System. *Applied Sciences,* Agustus, 11(7515), pp. 1-16.

[11] Hidayat, M. I. & Qoiriah, A., 2022. Implementasi Pathfinding dengan Algoritma A* pada Aplikasi Indoor NavigationMenggunakan Unity Navmesh. *Journal of Informatics and Computer Science (JINACS),* Januari.pp. 1-9.

[12] C. A. Oktavia, R. F. Setiawan dan A. Christianto, "Perancangan Aplikasi Augmented Reality Untuk Pengenalan Ruangan Menggunakan Marker 3D Objects Tracking," *Jurnal Ilmiah Teknologi Informasi Asia*, vol. 13, no. 1, pp. 53-60, 2019.