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Development of an Augmented Reality (AR)-Based Indoor Navigation Application for Evacuation and Emergency Handling in UIN Sunan Ampel Surabaya Building

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Abstract— *The management of emergency situations in buildings is a crucial aspect of occupational health and safety (OHS). Fast and efficient evacuation is essential to ensure the safety and well-being of all individuals within the building. To address this need, this research developed a marker-based augmented reality (AR) application to support evacuation and emergency handling. The application was built using the Unity game engine, the A* algorithm for navigation, and Unity Navmesh for environment modeling. The development process followed systematic research methods, including needs analysis, design, development, testing, and system evaluation. Implemented in C# programming language, the application integrates ARCore for AR features and ZXing for QR code decoding. Testing results demonstrated that the application provides accurate and efficient evacuation guidance, with a navigation accuracy averaging a margin of error of 1.12 meters. Additionally, the Image Tracking feature enables recognition of emergency equipment, further supporting emergency response. The application functions reliably under various lighting conditions, ranging from 878 lux to 1 lux. By integrating these capabilities, this system is anticipated to enhance the efficiency and effectiveness of evacuation and emergency handling processes in multi-story buildings.*

Keywords : Augmented Reality, Indoor navigation, A Algorithm, Unity, Navmesh.*

I. INTRODUCTION

It is of paramount importance to consider Occupational Safety and Health (OHS) in the context of building management. An emergency is defined as an undesirable situation that has the potential to cause harm to humans, property, the environment, or the production process. Examples of emergencies that can occur in buildings include fires, explosions, gas leaks, earthquakes, landslides, floods, riots, and terrorist attacks [1]. One of the important components in OHS is the ability to handle emergency situations, especially fast and efficient evacuation. In this context, technology plays an important role in assisting the evacuation and emergency handling process [2]. UIN Sunan Ampel Surabaya Gunung Anyar Campus has a building with a multi-storey building structure and various facilities in it. When an emergency occurs, building occupants must also be able to evacuate safely and efficiently. To solve this problem, the development of a navigation system is considered an effective solution.

To navigate indoors, the use of GPS (Global Positioning System) based navigation techniques has limitations both in terms of accuracy and the ability to map multi-storey buildings [3]. Therefore, a technique is needed that can handle navigation while in the building, or commonly called indoor navigation [4] To create an indoor navigation application, an algorithm that can find the shortest route is needed, namely pathfinding. One of the most popular pathfinding algorithms is the A* algorithm, which has proven to be effective and optimal in finding the shortest route. The A* algorithm works by combining information from the path that has been explored with an estimate of the distance to the destination, so that it can find the most efficient route [5]

Reviewing previous research on indoor navigation systems conducted by Alifa, Ginardi, and Arunanto entitled "Indoor Navigation System Using Wi-fi Signal and Digital Compass Based on Integration with Smartphone for Case Study in High Rise Building", several weaknesses were found. One of them is that user interaction with the application is only a 2-dimensional map of the room arrangement [6]. Therefore, this research utilises augmented reality technology to improve the user interaction experience. Augmented reality technology is adopted because it can present a new experience for users by projecting system-generated information directly into the user's view through a smartphone device. Thus, augmented reality is considered an effective tool to enhance interaction and real perception of virtual objects. Furthermore, features supporting the emergency handling process are added, such as navigation with audio output and recognition of emergency equipment using image tracking.

The main advantage of the developed application is its ability to operate offline without the need for a network. This is especially important in emergency situations that may cause power outages or loss of signal. By utilising the Unity game engine and A* Algorithm for navigation, as well as Navmesh for environment modelling, the app is designed to be able to provide a more interactive experience to the user. In addition, it also offers sufficient accuracy and speed in the process of evacuation and emergency handling in high-rise buildings.

This research aims to develop an application that combines Augmented Reality (AR), the A* Pathfinding algorithm, and Unity Navmesh to provide accurate and fast navigation assistance in emergency situations. By leveraging these technologies, the application offers a more interactive and informative evacuation guide, enabling users to efficiently navigate emergency routes. This system is specifically designed to improve safety and preparedness in the buildings of UIN Sunan Ampel Surabaya, addressing challenges in indoor navigation with high accuracy and adaptability. Furthermore, this research contributes to the field of AR and emergency response technology by enhancing existing methods and providing a practical tool that reduces risks and improves the readiness of building occupants. The outcomes are expected to provide a scalable and innovative solution for evacuation and emergency handling, especially in academic environments, while also laying the groundwork for future advancements in safety technologies.

II. RESEARCH METHODS

In developing this application, the method used is ADDIE. The ADDIE method is a framework used to develop and design programs or applications systematically and effectively [7]. This method is often used in the field of education and training, but can also be applied in software development and other projects. ADDIE is an acronym for the five main stages that must be passed, namely Analysis, Design, Development, Implementation, and Evaluation [8]. In this study, the implementation stage only reached testing and then continued to the evaluation stage.

To explain the details in its detailed stages, it has been presented in the flowchart illustrated in Figure 2.1.

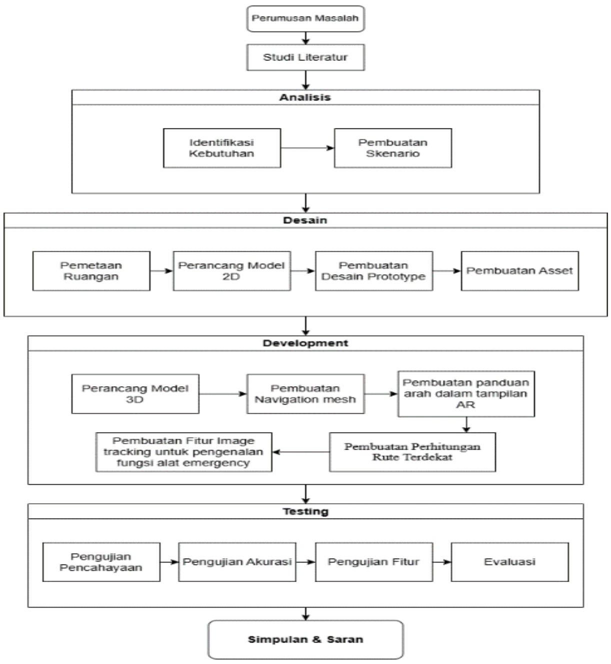

Figure 1. System Development Flow

The following is an explanation of the stages in application development shown in Figure 1.

2.1 Problem Formulation

Problem formulation involves the identification and selection of problems to be addressed within the framework of this research. The selected problem is explained in detail in the background section of the writing, namely regarding the handling of evacuation in emergency conditions where this research utilizes virtual media, namely AR, to direct building occupants to evacuate themselves safely.

2.2 Requirements Analysis

The app uses several Augmented reality (AR) techniques in its development, including Marker-Based AR to trigger the display of digital content using visual patterns such as QR Codes, and Spatial Awareness to understand and track the position and orientation of the device in three-dimensional space using sensors such as cameras, accelerometers, gyroscopes, and magnetometers. The app also integrates Navigation and Pathfinding using Navmesh in Unity, allowing the virtual agent to calculate the optimal route using the A* Algorithm to find th e shortest path at the lowest cost. In addition, the app incorporates User Interface (UI) elements such as buttons, text, and sliders with AR displays to enhance user interaction. For route visualization, the app uses Unity's Line Renderer to draw clear and effective paths in 3D space, providing the necessary visual guidance for users in navigating the building environment. The functional requirements of this project include: 1. Route Search: Users can search for optimal evacuation routes within the building. 2. Direction Display Change: Users can change the display of directions in the application as needed. 3. Audio Feature Enabling: The app provides audio features to give evacuation instructions. 4. Image Tracking: The application can recognize emergency equipment using the Image Tracking feature.

2.3 Prototype Design

Preparation of assets needed to develop AR Indoor navigation applications, such as 2D map designs, images, sounds, texts and videos. The preparation stage is carried out by searching, creating, or designing assets that match the theme and function of the AR Indoor navigation application.

2.4 Development

The development stage involves the creation and integration of the designed elements. It includes coding, creating 3D models, and implementing the necessary features according to the design specifications. In the system development process, 3D model design and navigation mesh (navmesh) generation are performed using 2D designs as reference, which are designed directly in Unity. The navmesh models the area that the agent can traverse in a 3D environment. The closest route calculation feature was developed with marker-based AR for repositioning and spatial awareness to track the movement of the device, using the A* algorithm to determine the optimal route. Directional guidance in the AR view is displayed with Unity's Line Renderer, following the navmesh path to aid navigation. In addition, the image tracking feature is used to recognize and track the emergency device by displaying useful information when the target image is detected.

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2.5 Testing dan Evaluation

This section describes the various tests conducted to evaluate the performance and quality of the developed AR application. Tests include lighting tests, accuracy tests, and feature tests, as well as evaluation of test results to ensure the application functions properly and meets the set standards.

III. RESULT AND ANALYSIS

The UML Use Case Diagram illustrates the functional interactions between the user and the system, outlining the key features and capabilities of the AR-based navigation application. This section details the primary functions of the application, such as route navigation, audio instructions, and emergency equipment recognition, which together enable efficient and safe evacuation guidance in emergency situations.

3.1 UML Use Case Diagram

Use Case Diagram is a diagram that describes the interaction between actors (users) and the system in the form of functionality provided by the system. This diagram focuses on what is done by the user and the system, and defines the relationship between actors and use cases (use cases) [9]. Use Case Diagrams are very useful in describing how users can interact with the system, helping to understand user needs and functions that must be provided by the system.

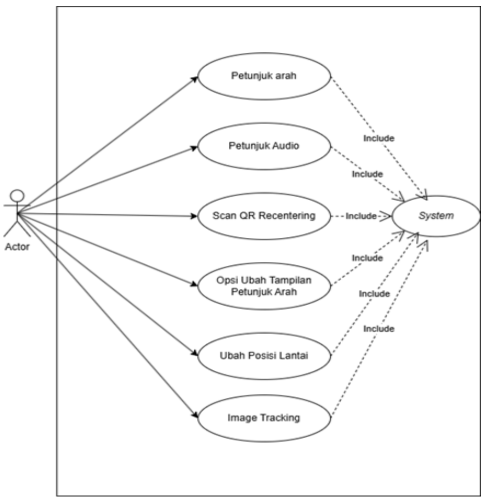

Figure 2. Use Case Diagram

From Figure 3.1 Use Case Diagram above, it can be explained that this application has interaction between one user and the system. In this application there are 6 main functions, namely Directions, Audio Instructions, Scan QR Recentering, Change Direction Display Options, Change Floor Position, and Image Tracking. For the procedure of use, this application starts with the user matching the location of the current position, location matching can be done by scanning the nearest QR Code, so that the application can find out the current location of the user. After the location is found, the user can then choose the evacuation point, after the destination is determined the application will display navigation in the form of lines or arrows. In the middle of navigation the user can also find out how to use emergency equipment such as Apar or Hydrant by facing the camera towards these tools, then the application will display a video on how to use the tool.

3.2 Activity Diagram

Activity Diagram is a type of diagram in the Unified Modeling Language (UML) that describes the flow of activities in a system, from start to finish. This diagram is very useful for visualizing how activities in the system are interconnected and how the system moves from one state to another [10]. This application involves four main activities in the development process, namely: Route Search, Changing the display of directions, Enabling audio features, and Image Tracking. The Activity Diagram of the system development can be seen in Figure 3 up to 5.

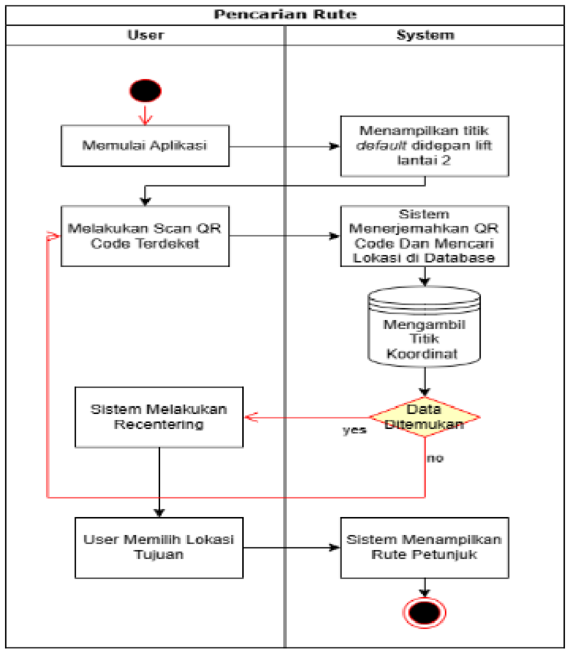

Figure 3. Route Search Activity

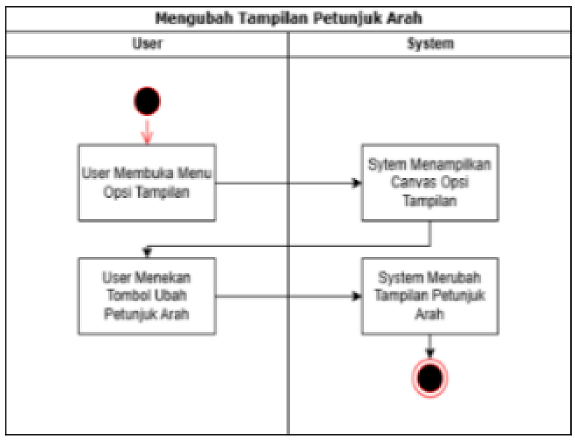

Figure 4. Change Direction Activity

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Options menu UI view The view in Figure 3.6 is the default menu when the application is first run. It contains several buttons such as a button to change directions, a button to activate the Audio feature, and a dropdown button to select the destination location. The technique used to switch the display is UI Object Swapping, which is a method that allows transition between menus by activating and deactivating UI objects in one scene without the need to reload or change scenes.

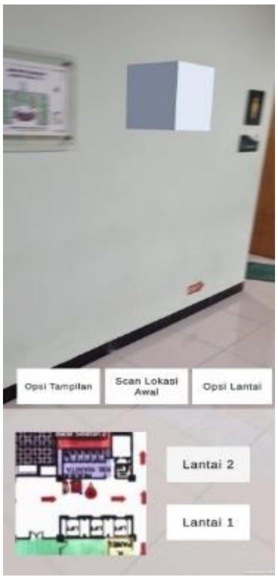

Figure 5. QR Code Recentering

The Initial Location Scan Menu in Figure 5 has several UI elements such as panels, buttons, and sliders. The square panel in the camera frame is used as a mark for the Scan QRCode Recentering area. The Scan QRCode button is used to show and hide the panel, which should be disabled when not in use so that the feature does not continuously fetch frame data which can slow down the application performance. When navigation starts, the user can choose between two visualization options.

Figure 6. Line Visualization

Figure 6 is a preview of the line visualization, while in Figure 7 it is an arrow. Both visualizations can be adjusted in height using the slider in the display options menu

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Gambar 7. Floor Options

Figure 7 is a view of the floor options menu. The cube object in the camera frame is the default point when the user uses the floor change feature. On each floor, the default cube point is located in front of the floor plan image in the real environment. But if the user is not at this default point, the user can use the Scan QRCode feature to match where the location is. In this version of the application, the developer only takes samples from the 1st and 2nd floors so that in this menu display there are only 2 floor button options.

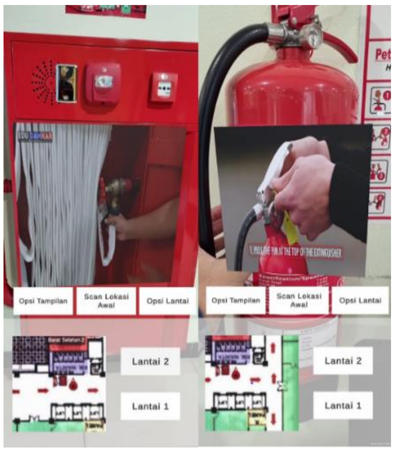

Figure 8. Image Tracking

In Figure 8, the left side shows an example of an image tracking experiment on a Hydrant. From the results of the experiment, the system displays media in the form of a video containing information on how to operate the

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Hydrant. The right shows an experiment on the Apar, where the system successfully displays media in the form of a video on how to use the Apar. Image tracking can detect objects without special markers (Markless) if the object has a specific and uniform appearance/pattern.

3.4 Exposure and Accuracy Testing

Lighting testing is an important step in ensuring that AR apps work well in various light conditions. In this test, the developer has tested the app using a lux meter to measure the light intensity in various situations. Tests were conducted in two different lighting conditions to assess the app's performance in navigation.

Accuracy testing was conducted to evaluate how precisely the navigation features in the app can determine the route and reach the specified destination. This test involves several scenarios with multiple starting location points and end location points, and measures the margin of navigation error in meters using a laser distance meter. In addition, this test was conducted on several Android versions to ensure the consistency of application performance on various devices. The test results are attached in table 1 below.

Table 1 Accuracy Test

No	Titik Awal	Titik Tujuan	Margin Kesalahan Navigasi (meter)	Versi *Android*	Kondisi Pencahayaan
1	*Start lantai 1*	*Timur - Utara*	1.24	13	*Normal*
2		*Timur - Selatan*	1.31	13	*Normal*
3		*Barat - Utara*	0.87	13	*Normal*
4		*Barat - Selatan*	0.64	13	*Normal*
5	*Start lantai 2*	*Timur - Utara*	1.37	13	*Normal*
6		*Timur - Selatan*	0.94	13	*Normal*
7		*Barat - Utara*	0.70	13	*Normal*
8		*Barat - Selatan*	0.80	13	*Normal*
9	*Start lantai 1*	*Timur - Utara*	1.75	13	*Minim*
10		*Timur - Selatan*	1.74	13	*Minim*
11		*Barat - Utara*	1.45	13	*Minim*
12		*Barat - Selatan*	0.74	13	*Minim*
13	*Start lantai 2*	*Timur - Utara*	1.27	13	*Minim*
14		*Timur - Selatan*	1.22	13	*Minim*
15		*Barat - Utara*	1.93	13	*Minim*
16		*Barat - Selatan*	0.67	13	*Minim*
17	*Start lantai 1*	*Timur - Utara*	0.96	14	*Normal*
18		*Timur - Selatan*	1.05	14	*Normal*
19		*Barat - Utara*	1.21	14	*Normal*
20		*Barat - Selatan*	0.86	14	*Normal*
21	*Start lantai 2*	*Timur - Utara*	1.20	14	*Normal*
22		*Timur - Selatan*	1.12	14	*Normal*
23		*Barat - Utara*	0.83	14	*Normal*
24		*Barat - Selatan*	0.72	14	*Normal*
25	*Start lantai 1*	*Timur - Utara*	1.60	14	*Minim*
26		*Timur - Selatan*	1.01	14	*Minim*
27		*Barat - Utara*	0.69	14	*Minim*
28		*Barat - Selatan*	0.73	14	*Minim*
29	*Start lantai 2*	*Timur - Utara*	1.58	14	*Minim*
30		*Timur - Selatan*	1.53	14	*Minim*
31		*Barat - Utara*	1.36	14	*Minim*
32		*Barat - Selatan*	0.66	14	*Minim*

From the results of the accuracy testing conducted and attached in Table 4.1, it can be seen that the navigation error margin varies between 0.64 meters to 1.93 meters with an average of 1.12 meters. This margin of error indicates how far the position generated by the application deviates from the expected position. Tests were conducted on 2 versions of Android, namely version 13 and version 14, the results showed that the application was able to provide consistent and accurate results across devices. This shows that the navigation feature in the application works well and can be relied upon to provide proper guidance to the user For lighting testing, under normal lighting conditions, as shown in Figure 3.11, namely with light intensity ranging from 276 lux to 873 lux, the application runs well. The test results in Table 1 show that the application is able to maintain accuracy with an average error (miss) of about 1.05 meters. This shows that under adequate lighting conditions, the application can recognize and track the position quite accurately

The second test was conducted in minimal lighting conditions, as shown in Figure 3.12 with light intensity between 1 lux to 12 lux. The results of this test show that the application can still function normally, even in very minimal light conditions. The average error under these conditions was 1.37 meters. Although there is a slight increase in the measurement error, the app's performance in navigating remains quite good.

From the test results, it can be concluded that the app's performance in navigation is strongly influenced by ambient light conditions and the camera's ability to capture light. In low light conditions, the app can still function, but with a slight decrease in accuracy. Therefore, a device camera that has good sensitivity to light will be able to support the app's performance in various lighting conditions.

3.5 Features Testing

The second test was conducted in minimal lighting conditions, as shown in Figure 8 with light intensity between 1 lux to 12 lux. The results of this test show that the application can still function normally, even in very minimal light conditions. The average error under these conditions was 1.37 meters. Although there is a slight increase in the measurement error, the app's performance in navigating remains quite good

Table 1. Features Test

Feature	Scenario	Expected results	Test Results
Navigation	The user opens the Scan QRcode panel	The system will activate the gameobject from the Scan panel and the Scan feature is ready to use	OK
	User scans QRcode	The system will translate the QRcode and look for the coordinates in the database. When data is found, the text in the panel will display the name of the location point, and the application screen will flash to indicate that the session has been reset and the location has been successfully repositioned.	OK
	User selects destination	An automatic route is created to the destination point	OK
	Routes are visualized using lines	Route lines appear according to navigation	OK
	The user presses a button to change the visualization	The appearance of the route visualization will change	OK
	Routes are visualized using arrows	Arrows appear and face in the navigation direction	OK
	Set the height of the visualization using the slider	The directions will shift horizontally according to the height set on the slider	OK
	Turning on the Audio Feature	The system will play audio to provide direction guidance according to the navigation path	OK
Image Tracking	Point the camera at the APAR	A video guide to using the APAR will appear	OK
	Point the camera at the HYDRANT	A video guide to using HYDRANT will appear	OK
	Point the camera at 2 Emergency tool objects	The system will display videos from each of these tools simultaneously	OK

After testing various application features, all test cases were successfully executed with the expected results. This test shows that each main feature in the application works well and meets the predetermined specifications.

VI. CONCLUSION

This study successfully developed an AR-based evacuation and emergency handling application integrating the A* Pathfinding algorithm and Navmesh using the Unity game engine and C#. ARCore enabled real-time mapping, while ZXing decoded QR codes as navigation reference points. Testing showed reliable navigation accuracy with an average error margin of 1.12 meters, sufficient for effective evacuation guidance in emergencies. The application functioned well across various lighting conditions (1–878 lux), with features like QR code navigation, image tracking, and audio instructions meeting expectations. Despite minor challenges with reflective surfaces, the system provided reliable guidance, enhancing safety and response efficiency in multi-story buildings. This research highlights the potential of AR technology to improve evacuation processes and lays a foundation for future advancements, such as integrating more precise tracking systems and additional hardware for enhanced accuracy.

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