Journal of Artificial Intelligence and Engineering Applications

Website: https://ioinformatic.org/

15th February 2025. Vol. 4. No. 2; e-ISSN: 2808-4519

Earthquake Simulation Design Using Virtual Reality at the East Java Province Environmental Agency Building

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Abstract

This study presents the development of a virtual reality-based simulation aimed at improving earthquake disaster preparedness at the East Java Provincial Environmental Service Building. The simulation introduces proper emergency response procedures, realistic earthquake scenarios, and comprehensive knowledge of building layouts, evacuation route signs, and designated assembly points. The research methodology involved direct observations and interviews with employees to gather detailed information about existing preparedness measures. The simulation was developed through stages of problem identification, data collection, object modeling using Blender 3D, and integration into a cohesive system via Unity. The final implementation resulted in a dynamic, interactive, and educational simulation that closely mirrors real-life emergency situations. Testing results indicate that the simulation operates effectively, providing immersive experiences and facilitating user interaction. This tool is expected to enhance the understanding of emergency procedures for employees, particularly new staff and visitors, while fostering a safer, disaster-prepared work environment. The study underscores the potential of virtual reality technology as a strategic approach to disaster risk reduction and education.

Keywords: *Earthquake Simulation, Disaster Preparedness, Virtual Reality, Emergency Response, Emergency Evacuation*

1. Introduction

Indonesia is recognized as one of the countries with the highest risk of natural disasters in the world, particularly earthquakes. This is due to its location in the Pacific Ring of Fire, an area of high tectonic activity. Earthquakes, characterized by their sudden and unpredictable nature, pose serious threats to human safety, infrastructure, the environment, and the economy [1]. Given the destructive impact they can cause, community preparedness becomes a crucial element in minimizing risks. This preparedness includes understanding mitigation measures, evacuation procedures, and the ability to act quickly in emergency situations [2].

In the context of governmental preparedness, the building of the Environmental Agency of East Java Province (Dinas Lingkungan Hidup Provinsi Jawa Timur) is a strategic facility that requires special attention [3]. As a government institution responsible for monitoring and managing the environment in East Java, this building not only houses vital state documents but also serves as the operational hub for addressing environmental issues. Given its critical role, the level of preparedness among staff in this building needs to be enhanced, particularly in facing potential earthquake disasters that could threaten both individual safety and state assets [4].

The Environmental Agency of East Java Province has already utilized modern technologies, such as the Integrated Environmental Reporting and Monitoring Information System (SIPELITA), in conducting its environmental monitoring and management duties. However, disaster preparedness training, particularly for earthquakes, has not yet been incorporated into the agency's regular programs. The introduction of VR-based simulations is expected to bridge this gap. VR simulations are not only relevant for educating staff on evacuation procedures but also support a more systematic implementation of disaster mitigation within the government environment [5].
In line with technological advancements, the application of Virtual Reality has emerged as an innovative solution for disaster preparedness simulations. VR offers the capability to create virtual environments that closely resemble real-world situations, allowing users to practice emergency scenarios without physical risk. This technology provides an immersive experience by engaging multiple senses, such as sight, hearing, and interaction with virtual objects. With VR-based simulations, staff at the Environmental Agency can learn disaster response steps in a more interactive, effective, and realistic manner. This approach is expected to enhance their response to earthquakes, both in terms of self-rescue and protecting documents and state assets [6].

This study focuses on the development of Virtual Reality based simulations to improve preparedness for earthquake disasters at the Environmental Agency of East Java Province. The implementation of VR technology is expected to provide strategic benefits, including raising staff awareness and knowledge, strengthening disaster response capabilities, and supporting more effective disaster risk reduction efforts in the future. Consequently, the results of this study contribute to creating a safer, more responsive, and disaster-aware work environment.

2. Research Methodology

The data used in this study includes direct observation data collected at the East Java Provincial Environmental Service Building and interview data obtained from employees working in the building. The direct observation data was gathered through systematic observations of the conditions and facilities at the location, while the interview data was collected through in-depth interactions with employees to obtain information regarding procedures, understanding, and preparedness in dealing with potential disasters. These two types of data serve as the basis for developing a virtual reality-based simulation to enhance disaster preparedness at the East Java Provincial Environmental Service Building [7], [8].

The development of this earthquake disaster simulation based on virtual reality follows several structured stages. The first stage is Problem Identification, which serves as the initial step before the simulation creation process. This stage aims to identify the shortcomings of previous training programs. Based on a case study conducted at the East Java Provincial Environmental Service Building, the training was only delivered through video media, which was deemed insufficient in providing a deep understanding of earthquake preparedness. This identification serves as the foundation for designing a more effective and interactive training method. The next stage is Data Collection, which involves a systematic process of gathering information. The author conducted direct observations and interviews with employees of the East Java Provincial Environmental Service to obtain detailed information about the existing training programs and specific details about the building's structure and layout. The information collected during this stage is then used as a reference for developing the virtual reality-based simulation. The following stage is Analysis, where the detailed simulation scenario is designed by defining every object that needs to be created in the VR simulation. The scenario includes essential elements related to evacuation procedures and disaster mitigation for earthquakes. In the Object Modeling Stage, virtual environment assets are created using Blender 3D. This stage involves the development of small elements that construct the entire virtual world, such as evacuation route signs and assembly points, which are essential components of earthquake disaster emergency response. The requirements for several assets are determined based on the analysis results from the previous stage. Various assets created in Blender 3D include graphics and other relevant three-dimensional objects. The final stage is Implementation, where all the designed objects are integrated using the Unity application for deployment into the virtual reality simulation. At this stage, the created elements are combined into a cohesive system to form an interactive simulation that closely resembles real-life scenarios. Through this structured process, the VR simulation aims to deliver a more effective training program to enhance earthquake disaster preparedness at the East Java Provincial Environmental Service Building [9], [10].

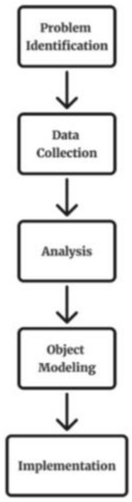

Figure 1: Development Flow

3. Results

The research results are presented in the form of problem-solving analyzed based on the developmental flow approach, which can serve as recommendations for addressing various identified issues. The discussion is accompanied by a detailed explanation of each stage within the developmental flow, providing a clear and systematic overview of the process undertaken. This approach is expected to contribute significantly to formulating solutions that are both applicable and relevant to the problems that are the focus of the research.

3.1. Problem Identification

The first stage is Problem Identification, which serves as the initial step in the development process before the creation of the simulation. This stage aims to explore and thoroughly understand the shortcomings, obstacles, or weaknesses in the previous training program. Problem identification is carried out through data collection, both qualitative, to obtain a comprehensive overview as a reference for improving or enhancing the necessary aspects.

Based on a case study conducted at the East Java Provincial Environmental Service Building, it was found that earthquake preparedness training for new employees and visiting guests was previously delivered only through video media published publicly on YouTube via the official channel of the East Java Provincial Environmental Service. This method was deemed less effective in providing in-depth understanding, especially for new employees and visiting guests, due to its passive nature and lack of direct interaction. Moreover, video-based training did not provide practical experience or real simulations that could help participants understand the steps that need to be taken in emergency situations.

The problem identification process includes an analysis of training needs, evaluation of the effectiveness of previously used methods, and gathering feedback from employees. The results of this stage serve as the main foundation for designing a training method that is more effective, interactive, and tailored to the needs of employees, with the expectation of enhancing preparedness and skills in dealing with emergency situations such as earthquakes.

Figure 2: Video Media publicly published on the YouTube application through the official channel of the East Java Provincial Environmental Service

3.2. Data Collections and Analysis

The next stage is Data Collection, which is a systematic process of gathering relevant and in-depth information. This stage aims to ensure that all necessary data is available and can be used as a basis for developing the virtual reality-based simulation. Following this is the Analysis stage, where the simulation scenario is designed in detail by defining every object that needs to be created in the virtual reality-based simulation. This scenario includes essential elements related to evacuation procedures and earthquake disaster mitigation.

The author applied various data collection methods, including direct observations and in-depth interviews with employees of the East Java Provincial Environmental Service. Direct observations were conducted by examining real conditions in the field, such as available facilities and identifying the locations of evacuation route signs and assembly point signs, which are essential elements in disaster emergency response. Meanwhile, interviews were conducted to gather further information regarding employees' experiences in participating in training previously delivered solely through video media, challenges faced, and suggestions for designing an earthquake preparedness simulation. Additionally, this stage also involved collecting technical data regarding the structure, dimensions, and layout of the East Java Provincial Environmental Service Building. This information is crucial to ensure that the virtual reality-based simulation developed can accurately represent the building's conditions, enabling the simulation to provide a realistic and applicable experience for training participants.

The data collected during this stage is then analyzed comprehensively to identify the needs for simulation development. This analysis aims to produce accurate references, ensuring that the designed simulation can provide solutions aligned with training needs and enhance employees' preparedness in facing emergency situations such as earthquakes.

Figure 3: Direct observation of the East Java Provincial Environmental Service Building and interviews with employees of the East Java Provincial Environmental Service Building

Table 1: General Info East Java Provincial Environmental Service Building

No	General Info East Java Provincial Environmental Service Building		
1	Total Length of the Building	:	±36 meters.
2	The total width of the building	:	±17 meters
3	Building Height.	:	±9 meters
4	Room layout on the first floor.	:	The first floor is divided into four main rooms, consisting of the personnel subdivision room, the head office room, the secretariat room, and the meeting room.

5	Room layout on the second floor.	:	The second floor is divided into five main rooms, consisting of the Division 4 room, the Division 3 room, the Division 3 meeting room, the bathroom, and the server room.

Table 2: The earthquake disaster simulation scenario derived from the analysis is included in the VR Simulation

No	The earthquake disaster simulation scenario derived from the analysis is included in the VR Simulation		
1	When the earthquake occurs	:	The scenario will begin on the second floor, specifically in the Division 4 room. Users will be given the freedom to choose between taking cover under a table or immediately running outside. However, users will also be provided with guidance on the correct steps, which involve taking cover under a table first until the earthquake stops before proceeding with further actions.
2	When the earthquake stops (Evacuation Stage Exiting the Building)	:	The scenario will begin on the second floor. After the user selects the correct option in the initial scenario, they will be given the freedom to explore the surrounding area and immediately follow the evacuation route signs toward the stairs to the first floor. Once the user reaches the first floor, they will be presented with the option to take the back route or the route leading to the assembly point. Users will retain the freedom to make their own choice. However, they will also be guided with the correct steps, which involve selecting the route leading to the assembly point as the most appropriate action.
3	When leaving the building (The Evacuation Stage towards the assembly point)	:	The scenario will begin outside the building. After the user selects the correct option in the previous scenario, they will be given the freedom to explore the surrounding area and proceed to the assembly point.

3.3. Object Modeling

In the Object Modeling Stage, the building layout and virtual environment assets are designed and created using Blender 3D software. This stage is a crucial process that involves developing small elements to form a detailed virtual world. The elements designed include rooms, furniture, objects within the rooms, as well as evacuation route signs and assembly points. All these elements are integral parts of the earthquake emergency response simulation, requiring accurate and realistic designs.

The modeling process begins with the design of the building layout based on technical data and analysis obtained from the previous stage. This information includes building dimensions, structures, and the placement of essential facilities such as evacuation routes and assembly points. Blender 3D serves as the primary tool for creating three-dimensional visual representations of these assets.

Additionally, every object created is carefully detailed, including textures, dimensions, and colors, to align with real-world conditions. For example, evacuation route signs are designed with striking colors and shapes to facilitate easy identification by simulation users. Other objects, such as furniture and items within the rooms, are also created to accurately reflect the actual layout of the East Java Provincial Environmental Service Building.

Figure 4: Layout of the First Floor in the East Java Provincial Environmental Service Building

Figure 5: Layout of the Second Floor in the East Java Provincial Environmental Service Building

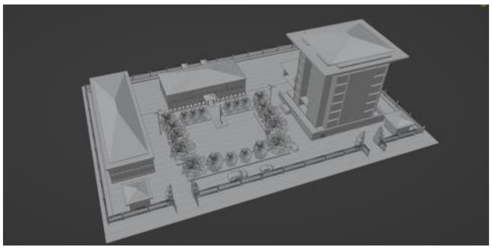

Figure 6: Layout of the Front Yard of the East Java Provincial Environmental Service Building

Figures 4, 5, and 6 showcase the 3D design of the layout and decorative assets located in the rooms on the first floor, second floor, and the front yard of the East Java Provincial Environmental Service Building. The design includes detailed layouts of each room, such as workspaces, meeting rooms, and other supporting facilities, as well as decorative elements that enhance the ambiance of the rooms. Additionally, the front yard of the building is specifically designed to represent the assembly point used in emergency response situations.

3.4. Implementation

The final stage is Implementation, where all previously designed objects are integrated using the Unity application to be implemented into the virtual reality-based simulation. At this stage, all created elements, including layouts, decorative assets, and evacuation scenarios, are combined into a cohesive system. The objective is to create an interactive simulation that not only resembles the analyzed real-world scenarios but also provides an educational and informative experience for users.

This implementation process includes integration testing of the elements to ensure that every component functions properly in the virtual environment. The resulting system is designed to accurately represent emergency situations, including evacuation routes, assembly points, and emergency response steps. Additionally, the simulation is designed to offer high interactivity, allowing users to understand and practice the correct procedures for handling earthquake disasters. The outcome of this implementation stage is a virtual reality simulation that not only mirrors real-life conditions but also delivers significant educational value, making it an effective learning tool to enhance disaster preparedness.

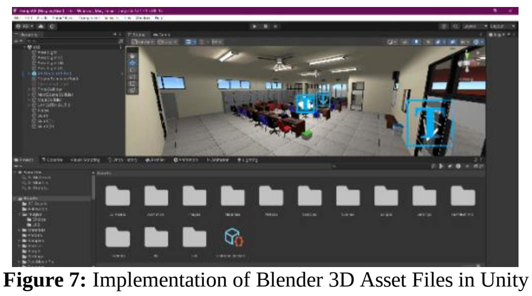

Figure 7: Implementation of Blender 3D Asset Files in Unity

Figure 7 illustrates the process of implementing assets that have been completed using Blender 3D software, which are then integrated into Unity to develop an earthquake disaster simulation based on Virtual Reality. This process includes importing 3D models designed in Blender into Unity, as well as configuring and programming the assets to ensure they function optimally within the simulation environment. This integration is carried out with the aim of creating an interactive and realistic virtual experience, making the resulting simulation an effective learning tool for improving earthquake disaster preparedness. This stage is a crucial step in transforming static 3D assets into a dynamic simulation that supports comprehensive emergency response scenarios.

Figure 8: Start Menu

Figure 8 displays the initial interface of the earthquake disaster simulation. This interface includes two main buttons: the "Play" button and the "Exit" button. The "Play" button provides users with the option to start the simulation and explore the designed disaster scenarios, while the "Exit" button allows users to leave the simulation. This interface is designed to be simple yet functional, enabling users to make decisions easily according to their needs. The initial interface also aims to offer an interactive introductory experience and prepare users before fully entering the simulation.

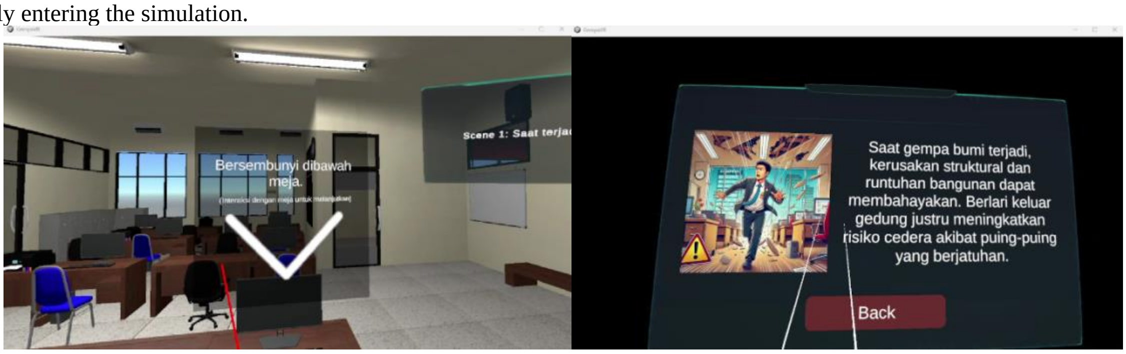

Figure 9: The initial scenario during the occurrence of an earthquake

Figure 9 illustrates the initial scenario during an earthquake. In this scenario, users are presented with several options to determine the actions they will take during the earthquake. If users select an incorrect option, the system provides the correct guidance along with an explanation of why the selected choice is less appropriate. While users are given the freedom to choose, the system ensures that they receive educational information about the proper emergency response steps. This approach is designed to ensure that users not only gain an interactive experience but also develop a deep understanding of the correct procedures to follow during an earthquake. As a result, this simulation is not only informative but also educational, enhancing users' awareness and preparedness in facing emergency situations.

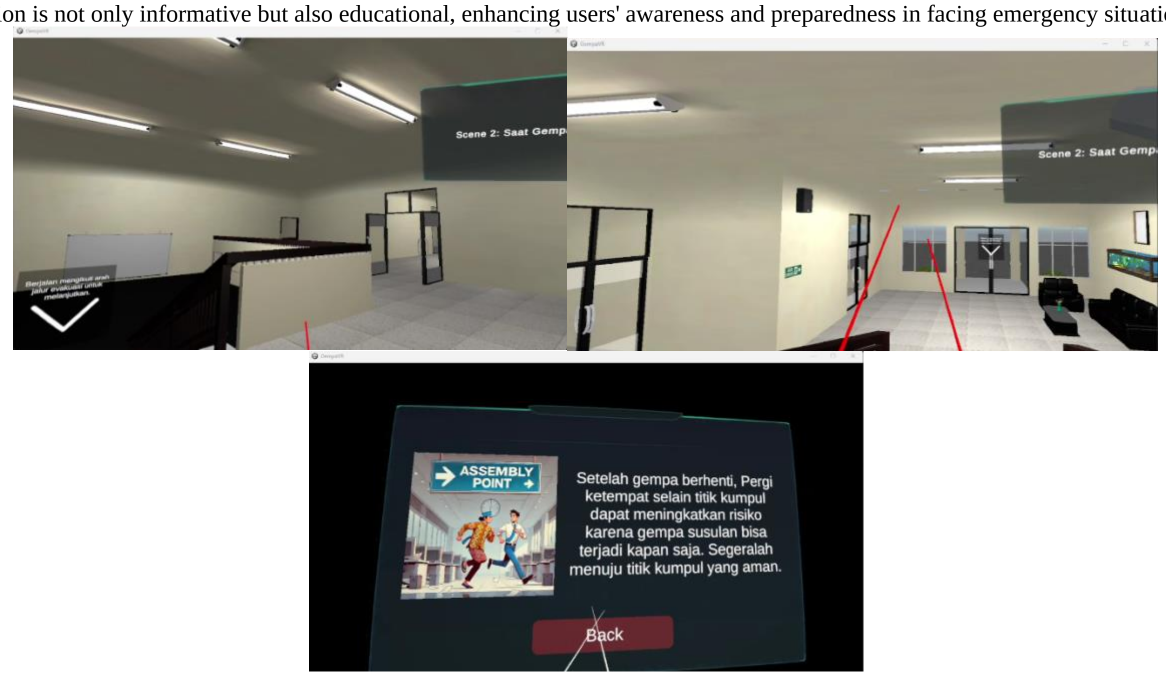

Figure 10: The second scenario takes place after the earthquake has stopped, focusing on the process of exiting the building and proceeding to the designated assembly point

Figure 10 illustrates the second scenario that occurs after the earthquake has stopped. This scenario focuses on the evacuation stage, where users are directed to exit the building and proceed to the designated assembly point. In this scenario, users are presented with various options to simulate realistic decision-making situations. If users choose an incorrect option, the system will provide guidance on the correct choice along with an explanation of why that choice is more appropriate.

Figure 11: The final scenario takes place after the earthquake has stopped, focusing on the stage of proceeding to the designated assembly point

Figure 11 illustrates the final scenario after users have exited the building and gathered at the designated assembly point. In this scenario, users are given the freedom to explore the surrounding area or proceed directly to the marked location indicated by an arrow to assemble at the gathering point. This step is designed as the final stage of the earthquake simulation and serves as a marker that the simulation has concluded.

4. Conclusion

In this study, a virtual reality-based simulation has been successfully designed and developed to introduce earthquake disaster emergency response procedures at the East Java Provincial Environmental Service Building. This virtual reality-based simulation includes an introduction to proper emergency response procedures, the experience of feeling an earthquake resembling real conditions, an understanding of the building layout, evacuation route signs, and the designated assembly points provided at the East Java Provincial Environmental Service Building. The implementation test results show that the virtual reality-based simulation functions well, displays relevant information, and allows effective interaction with users. This simulation is not only designed to provide an interactive experience but also to enhance the understanding of employees, especially new employees and visiting guests, regarding the emergency response steps that must be taken during and after an earthquake.

Acknowledgement

The author would like to express deep gratitude to God Almighty. Thanks to His grace and blessings, the author was able to successfully complete this research. The author also extends heartfelt thanks to all employees of the East Java Provincial Environmental Service for their guidance and support in developing the Virtual Reality-based Earthquake Disaster Simulation. This support has been invaluable in helping the author understand the technical and practical aspects of the simulation. The author also expresses sincere gratitude to the Industrial Systems and Ergonomics Laboratory, the Industrial Engineering Study Program, and Universitas Pembangunan Nasional "Veteran" East Java for their academic guidance, facilities, and resources provided throughout the research process. All the assistance and support provided by various parties have made a significant contribution to the completion of this research. The author hopes that the results of this study can benefit many parties, particularly in enhancing earthquake disaster preparedness through the use of Virtual Reality technology.

References

[1] Fahry, M. R., & Mirwan, M. (2023). Peranan Dinas Lingkungan Hidup Provinsi Jawa Timur dalam Pengawasan Ketaatan Lingkungan Tidak Langsung Industri Transportasi di Kota Madiun Jawa Timur. Jurnal Sains dan Teknologi.

[2] Muttalib, A., & Mashur. (2019). Analisis Dampak Sosial Ekonomi Masyarakat Pasca Bencana Gempa Bumi Di Kabupaten Lombok Utara (KLU). Jurnal Ilmiah Mandala Education.

[3] Wiradhika, N., Sastromiharjo, A., & Mulyati, Y. (2020). PEMANFAATAN TEKNOLOGI VIRTUAL REALITY UNTUK MENINGKATKAN KEMAMPUAN MENULIS SISWA. Jurnal Seminar Internasional Riksa Bahasa XIV.

[4] Editya, A. S. (2022). Pengembangan Simulasi Mitigasi Bencana Banjir Menggunakan Teknologi Virtual Reality. Jurnal Ilmu Komputer dan Desain Komunikasi Visual.

[5] Putra, O. V., Pradhana, F. R., & Shaleha, F. (2022). SIMULASI 3 DIMENSI RUTE EVAKUASI BENCANA DI GONTOR PUTRI KAMPUS 3 BERBASIS VIRTUAL REALITY (VR).

[6] Zhang, F., & Xu, Z. (2021). Virtual reality-based evaluation of indoor earthquake safety actions for occupants. Advanced Engineering Informatics.

[7] Pardede, A. M. H., Novriyenni, N., & Kadim, L. A. N. (2020). Emergency patient health service simulation as a supporter of smart health care. In *IOP Conference Series: Materials Science and Engineering* (Vol. 725, No. 1, p. 012084). IOP Publishing.

[8] Pardede, A. M. H. (2019). *Model Optimisasi dan Simulasi Komputer Pelayanan Perawatan Kesehatan Dalam Lingkup SMART Healthcare* (Doctoral dissertation, Universitas Sumatera Utara).

[9] Pardede, A. M. H. (2016). Advanced Fuzzy Logic Controllers in Smart Buildings for Classrooms Campus Buildings in Tropical Binjai. *Methodika*, *2*(2), 171-174.

[10] Pardede, A. M. H. (2018). Framework for patient service queue system for decision support system on smart health care.