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An Augmented Reality Application for the Community Learning about the Risk of Earthquake in a Multi-storey Building Area

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Abstract

Area surrounding tower is a danger area when earthquake attack. It has an enermous risk. People in this area have to know the risk for their safety. Socialization, simulation, and learning media need to be provided continuously to improve people awareness on the importance of knowledge about the earthquake risks. The media that can reach all society is a mobile application. An application that contains earthquake information in the surrounding area of tower is the solution to this problem. Earthquake learning application that is able to explain level of risk in detail and easy to understand**.** For more immersive interactions, we propose the augmented reality on mobile application to visualize the simulation of earthquake effect on the tower. The augmented reality provides the conditions with 3D modeling. So, users have experience to feel the level of damage and safe distance in the tower area. The evaluation result shows that 84% respondent appreciates this application. First common users do not know the risk of earthquakes on the surrounding area of the tower, and they understand the importance of earthquake risk in buildings after use this application.

Keywords: Augmented reality, earthquake in tower, earthquake learning, mobile application, 3D modeling, and simulation of disaster.

1. INTRODUCTION

Indonesia is in the ring of fire that is potentially affected by earthquakes. On the other hand, there has many tower as city development. The earthquakes in the surrounding tower had a great impact as in the Padang (2009). This earthquake caused a large number of casualties because buried under the ruins of the building. It may occur again in other areas. To reduce this impact, it needs to socialize and simulate special natural disasters in urban area or regional areas that have many towers such as office, school etc.

Figure 1. Padang earthquake 2009 (left) and simulation of earthquake in Ponpes Ashshidiqiyah 2, Batuceper Tangerang (right) [13]

Simulated natural disaster earthquakes need to be done periodically and continuously. BMKG (Meteorology Agency in Indonesia) and BNPB (Disaster Management Agency in Indonesia) has made efforts to socialize and simulate earthquakes to the public. The simulation of the earthquake made as real as the earthquake environment [13], so the students immediately scattered out when the earthquake was simulated. This simulation use the firecracker explosion to capture the atmosphere and have more tense effect to the students. Students tried to gather in the field. Some students and teachers who were simulated became victims also dressed up with the number of injured and artificial blood, while surviving students simulated how to evacuate the wounded and die. The simulation carried out by BMKG has not covered all the elements of society [13].

In the other hands, the uses of technology, especially mobile applications, as media reach the wider range. The use of mobile simulations for natural disasters is an alternative method to provide knowledge about natural disasters themselves, their impact and characteristics. It is a key to select media for learning of disaster impact. This also applies to the simulation of earthquakes in the area surrounding the multi-story building.

Currently, mobile apps provide more interactive features such as augmented reality, virtual reality and kinesthetic sensors. Augmented reality uses camera sensors and combines both the real world and the virtual world. This technology generates 3D objects that interact with the user. Users can see 3D objects and feel as if they appear in the real world. The use of AR technology to simulate the earthquake disaster in the area around the high rise building offers an interactive and immersive learning media. This application not only provides information about earthquakes and their impacts in the area around high rise buildings, but also presents an interactive module that allows users to feel the impact of earthquakes on high rise buildings while looking for a safe place.

2. RELATED WORKS

Johannes Leebmann, *et al* [1] explains to Search and Rescue team about how to perform a rescue action in a building where an earthquake happened. With the help of ARS (augmented reality system), the real object and the virtual is integrated, and the scale of the virtual is adjusted on the same size as the real one. ARS is developed for rescuing individuals who are trapped in the ruin of the building. In this journal the augmented reality concept is used as learning media about the effect of the earthquake on the multi-storey building.

Restu Faizah, *et al* [2] The effect of the earthquake on multi-storey building and with dynamic response analysis. Dynamic response analysis will help planners as consideration inputs. The research is analyzing the gravitation forces mode 1 on the 2D structure.

Rony Ardiansyah, [3] The magnitude of an earthquake on hipocentre is measured by Richter scale will cause the amount of vibration and different effects on the different surface areas on the earth (epicentre). This different interpretation is introduced by an Italian scholar, Guiseppe Mercalli in 1902, known as Modified Mercally Intensity Scale (MMI). The total of effect scale is 12 unit that is adjusted with the effect of the earthquake. The commonly used scale is Richter scale which use the result of seismograph measurement to explain and compare the strength and the wide of the earthquake.

Jusuf J. S. Pah, *et al* [4] this research analyze the structure of high buildings. Every sample is tested on four earthquake accelerogram, those are El-Centro, Kobe, Chi-chi Taiwan, and Japan to identify the shaking mode. To identify the maximum height of the deformed high building in mode 1 while responding to the earthquake. And also to identify the maximum height of the shifted wall ensuring mode 1 deformation of high structured building while responding to the earthquake.

Naosuke Yamashita, et al [5] This research estimates safe zone and danger zone in a room with learning application using augmented reality on android smartphone. Vuforia [6] is a tutorial book to make augmented reality applications on android smartphone using Vuforia and Unity 3D. This book is very useful for the production of this application. Yi-Shiuan, et al [7] this research is educative advanture game which the player encouraged to run away from earthquakes. This game can be used to enhance the user's knowledge on escaping from earthquakes and looking for safe shelters.

Autodeks [8] is tutorial book about 3ds Max 2011 that is useful to make building model and building animation when strucked by earthquakes. W. Kim, et al [9] this research develops an augmented reality application in supporting damage and safety assesement. Irfan Subakti [10] Insap Santoso [11] is a book about human interaction and computer with the purpose to identify knowledges on how to desaign a visual appearance and writing in order to make a more enjoyable application for the user. Giving a result before and after using the application.

Kurniawan Teguh Martono [12] this research discusses the development of augmented reality on various field such as military, health, education, and others. By using augmented reality technology the users are expected to experience a direct interaction.

3. ORIGINALITY

This study produces learning media to recognize the impact of earthquakes on towers through mobile devices. Application from this learning media not only contains graphical and textual information, but also an interactive module that lets users feel in the true environment. This application use AR technology and interaction in gaming technology to produce immersive effects. In the use this application used visualization object 3D tower and 3D character. Users can know whether they are in secure position or not using moving character that provided in this application. The safety positioning use data trends method like already done in the research about earthquake effect to damage of high buildings. The determination safe positioning use approach of data trend that already done in the research about earthquake effect to damage of tower. The mobile application usage able to reach wider communities, thus socialization and simulation process in order to acquaint the impact of earthquake nearby the tower will be more convenient to be carried out by the society.

4. SYSTEM DESIGN

System design of this research is shown in figure 2. There are three main processes in this system that is: Damage Calculation, Visualization and Simulation (Game-Interaction).

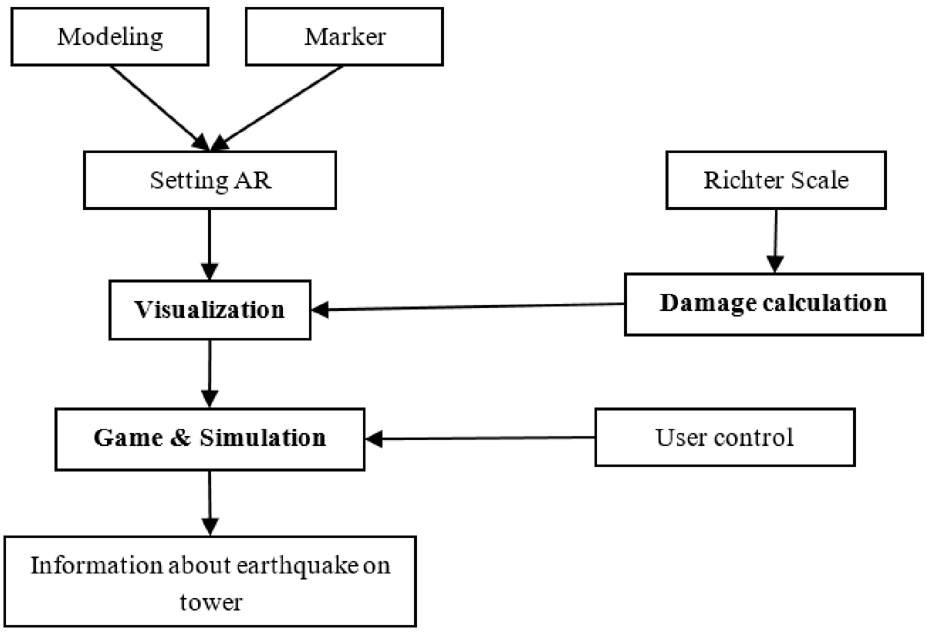


Figure 2. System Design

4.1 Damage Calculation

There are three steps to calculate the damage on surrounding area of the tower when earthquake stroke it: specify the strength of earthquake, calculate the building damage and calculate the minimum distance to reach safe area. Strength of earthquake is in Richter scale. The damage is calculated using the strength of earthquake to generate the intensity and its impact on the building. The distance of safe area is calculated by referring on the damage. This research use reference data that show the effect of earthquake on the tower using Richter scale [3][4][5]. These studies provide two tables. Table 1 shows the effect of earthquake on the epicenter area [3]. Table 2 shows the effect of earthquake on the damage of tower [4][5].

Table 1. Strength effect of earthquake [3]

Kekuatan	Keterangan	Rata-Rata	Intensitas Dekat Episentrum
0 – 1,9	-	700.000	Recorded, but unfelt
2 – 2,9	-	300.000	Recorded, but unfelt
3 – 3,9	MINOR	40.000	Felt by few people
4 – 4,9	LIGHT	6.200	Felt by many people
5 – 5,9	MODERATE	800	Slightly damaging
6 – 6,9	STRONG	120	Damaging
7 – 7,9	MAJOR	18	Highly damaging
8 – 8,9	GREAT	1 in 10 – 20 years	Destroying

Table 2 is the reference for building the animation of damage on the tower. This research uses 3DSmax to create animation with 8th floor tower and plugin "FractureVoronoi_v1.1" to create the damage on building randomly in accordance with the specific scale of characteristics of earthquake as shown on figure 3. This animation presents the broken and cracked parts that fall down when the strength of earthquake is given. This animation also use to rigid body that has been provided in 3dsmax for calculating density, so the create building can be set weight or density. And then on the base is made shifted left and right so it generate effect swaying building

Table 2. Effect of strength earthquake on tower damage.

Scale	Damage outside of building	Animation
4	Nothing	The building can only shake
5	Nothing	The building can only shake
6	Minor damage in the glass	The building rocked and experienced broken glass on the eighth floor
7	Minor damage to parts of glass and cracked walls	The swaying building was great causing broken glass on the sixth to eighth floor and the wall cracked on the seventh floor
8	Large damage to the glass and wall	The building rocked so violently that the glass broke on the fifth and eighth floor and the wall was badly cracked on the sixth to eighth floor
9	The enormous damage caused the building to collapse	The incredible swaying building resulted in a foundation failure so the building collapsed

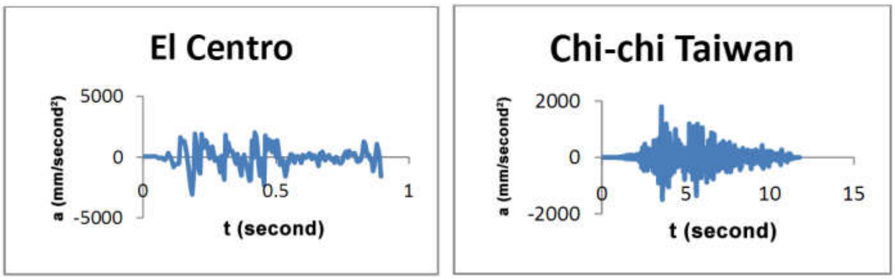


Figure 3. Accelerator earthquake [4]

Calculation of the distance of safe area can be set with earthquake data rocks from *El Centro* and *Chi-chi Taiwan* as shown on table 3 and table 4. We use correlation values from each parameter from the horizontal and vertical deviation. This earthquake data was taken because it has the characteristics of simple equations to determine the correlation. This is important considering the use of mobile applications to be heavy when using complex calculations and high-level. Table 3 shows the earthquake load on *El Centro* America in figure 3 with a maximum shift of close to 5000 mm / second^2. And the earthquake in Chi-chi Taiwan in figure 3 with maximum shift of nearly 2000 mm / second^2.

Table 3 and table 4 show the horizontal and vertical deviation on each floor during earthquake stroke it. The animation use these tables to create the change of deviation on each frame in according to the Richter scale. Table 3 uses 7 Richter, and table 4 uses 7.3 Richter.

Table 3. Maximum displacement of buildings in earthquake *El Centro* [4]

R Scale		Floor								
		1	2	3	4	5	6	7	8	9
7	Y(m)	4	8	12	16	20	24	28	32	36
	X(m)	0.08	0.24	0.41	0.58	0.73	0.87	0.98	1.06	1.12

Table 4. Maximum displacement of buildings in earthquake *Chi-chi* Taiwan [4]

R Scale		Floor								
		1	2	3	4	5	6	7	8	9
7.3	Y(m)	4	8	12	16	20	24	28	32	36
	X(mm)	0.11	0.28	0.61	0.55	1.35	4.05	6.51	7.76	7.85

After getting the value of the shift, we can calculate the highest horizontal difference of the horizontal side using the maximum deviation table as shown in table 5 [5]. Table 5 shows the maximum deviation on each floor based on the Ricther scale.

Table 5. Maximum deviation

R Scale		Floor							
		1	2	3	4	5	6	7	8
4	Y(m)	4	8	12	16	20	24	28	32
	X(m)	0.05	0.06	0.08	0.1	0.12	0.13	0.15	0.17
5	Y(m)	4	8	12	16	20	24	28	32
	X(m)	0.05	0.07	0.1	0.12	0.15	0.2	0.26	0.32
6	Y(m)	4	8	12	16	20	24	28	32
	X(m)	0.055	0.092	0.13	0.18	0.26	0.32	0.39	0.45
7	Y(m)	4	8	12	16	20	24	28	32
	X(m)	0.094	0.14	0.22	0.32	0.42	0.55	0.66	0.75
8	Y(m)	4	8	12	16	20	24	28	32
	X(m)	0.11	0.19	0.305	0.503	0.74	0.98	1.2	1.4
9	Y(m)	4	8	12	16	20	24	28	32
	X(m)	0.24	0.38	0.5	0.89	1.2	1.6	1.9	2.2

The maximum distance to reach safe area have two parameters; stiffness of glasses and walls, and the slope of building. These parameters cause the different effect of damage when earthquake stroke it. The slope value on the each floor is calculated by gradient equation (1).

$$\nabla m = \frac{dx_2 - dx_1}{dy_2 - dy_1} \quad (1)$$

Next result of the derived gradient as perpendicular is written by equation (2).

$$\nabla \dot{m} = -\frac{1}{\nabla m} \quad (2)$$

We use the median of the gradient derivative.

$$\tilde{X} = \sum_{i=n} \nabla \dot{m} \quad (3)$$

Then the minimum value of the gradient derivative is written by equation (4).

$$min = \sum_{i=n} \nabla \dot{m} \quad (4)$$

The quarter value is average of the median result and the minimum value.

$$Q = \frac{\tilde{X}+min}{2} \quad (5)$$

The angle of the quarter value is written by equation (6).

$$\theta x = 90 - Q \quad (6)$$

The last calculation is the distance to reach safe area,

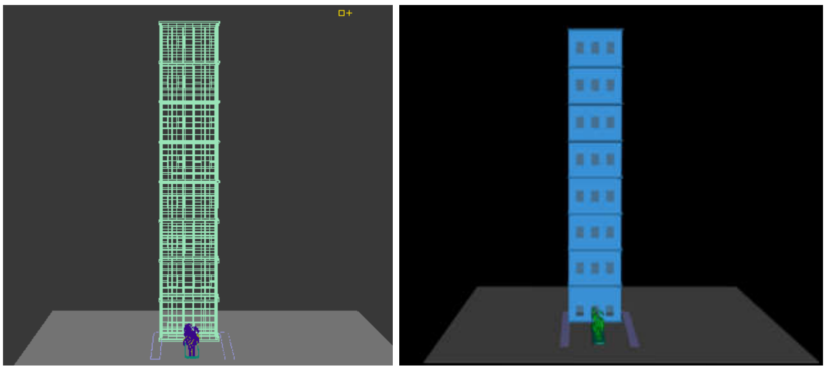
$$J = dy_{max} \cdot \sin(\frac{\theta x}{57.3}) \quad (7)$$

This distance is compared by the distance between person and tower to show that it is safe or not. So, the user will move to other place and the system will show the current condition comparing with the distance to safe area. Then, user feel this system as the real condition by mobile application. The AR system visualize the damage and user move to reach safe area bya simulation. We calculate the distance using euclidean distance theory on 3 dimensions, using the following formula

$$d(p,q) = \sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2 + (p_3 - q_3)^2} \quad (8)$$

4.2 Modeling

This research uses 8th floor tower with uniform rectangular model. The height of each floor is 4m so the total height of the building is 32m as shown in figure 4. The regular building construction withstand when it was affected by earthquakes because there is not the soft floor. Almost all of the destroyed buildings have collapsed when the floor is softer the the above parts.



(a) (b)

Figure 4. Building modeling: (a) framework, (b) the end result

This application is learning application, so this application provide information and material about impact of earthquake on around area tower. This application just work in smart phone android. Figure 5 show menu and information provided by this application such as learning application. Material learning start from introduction about earthquake and characteristics, up to the impact caused including damage to tower.

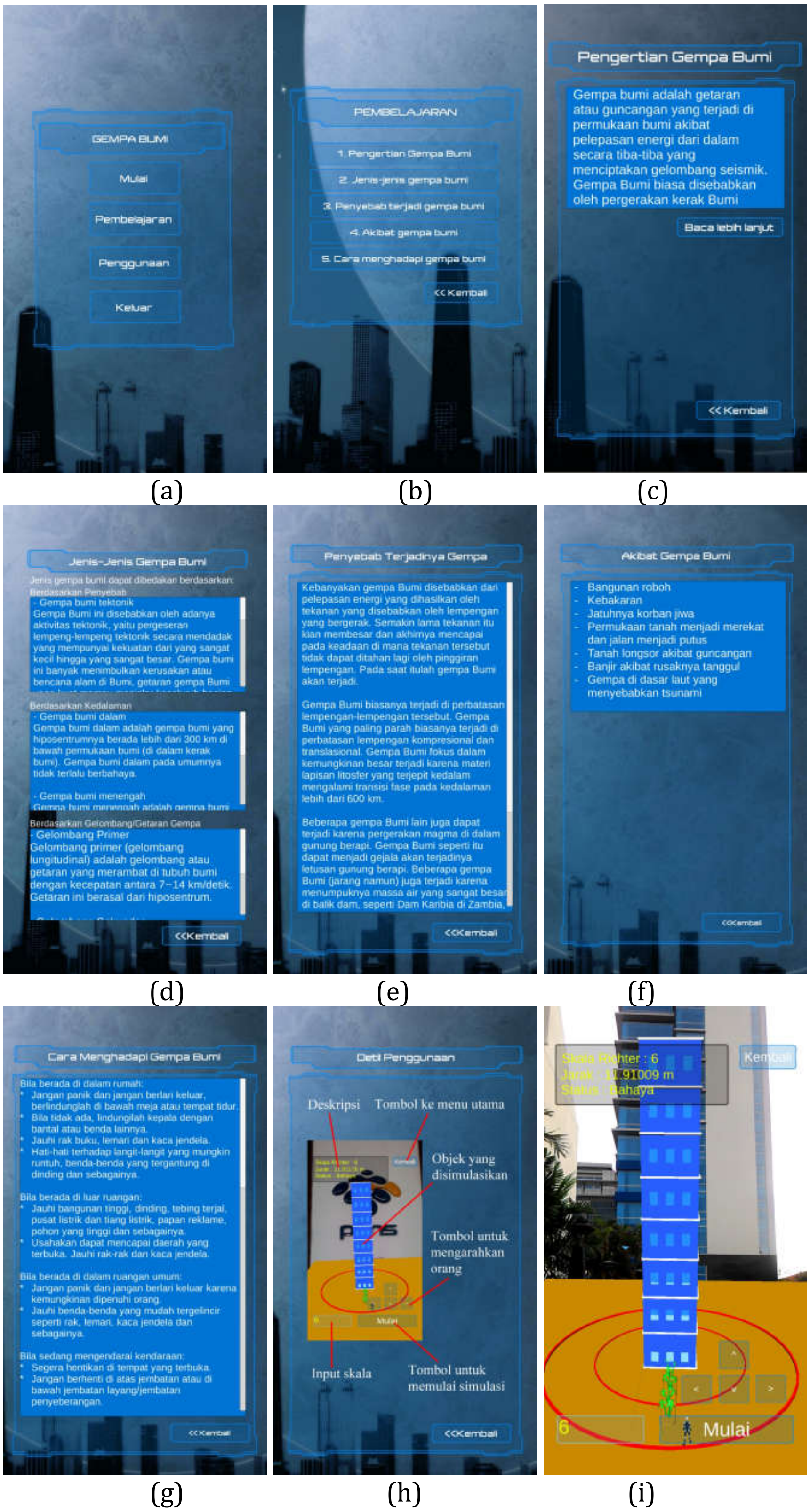


Figure 5. Information and media learning has provided

4.3 Marker

The key of augmented reality is the marker. This research uses marker in the form of an image of Postgraduate Building of Electronic Engineering Polytechnic Institute in Surabaya. After calibration is done, we try to use smartphone camera to detect whether the marker made is working properly. In order to fit the purpose, we use the original building that we capture online and capture the marker results as shown in Figure 6. The number of star shows the rating or success rate of marker detection.

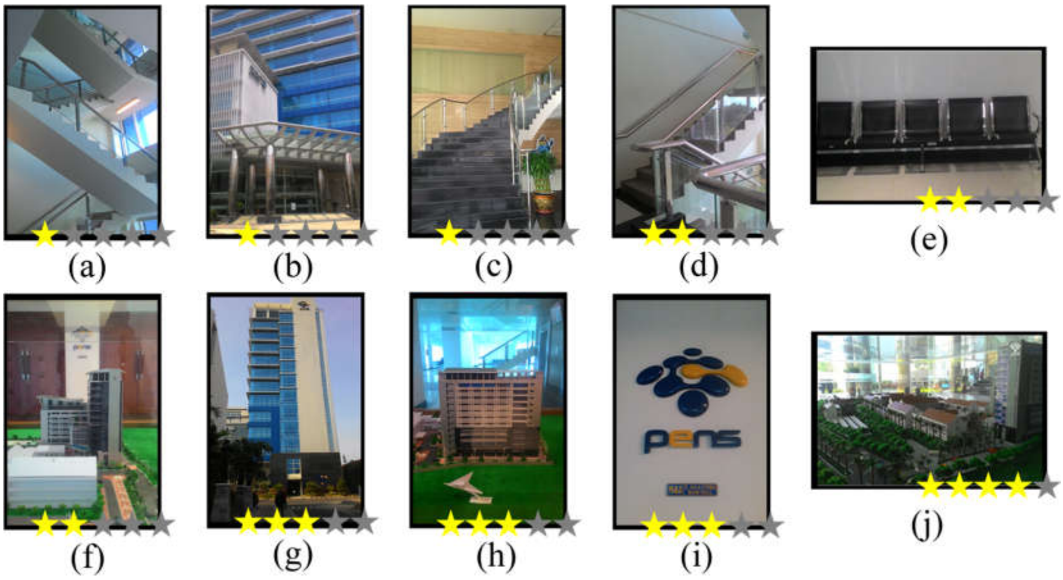


Figure 6. Marker : (a) Marker 1, (b) Marker 2, (c) Marker 3, (d) Marker 4, (e) Marker 5, (f) Marker 6, (g) Marker 7, (h) Marker 8, (i) Marker 9, (j) Marker 10

5. EXPERIMENT AND ANALYSIS

Experiments do to know performance from learning application the impact of earthquake in area around tower through several stages. Start testing from checking running application with good in all the parts until testing maximum deviation for to show safe distance.

5.1 Running Application

This application work on all device mobile with operating system Android. System calibrate with printing marker, and implement on printing marker or direct at the front of building for example the front of Pascasarjana Building, PENS as shown in figure 7. Implementation like this make users feel the simulation as if it were in the virtual world

Figure 7. Running Application

5.2 Analysis of building damage

We determine the deviation on each floor based on the strength of earthquake stroke and data from table 3 and 4. We test animation to measure the change shift on each frame and on each scale of 3D modelling of tower. Every scale is taken one frame that has rate of change the highest shift. The value of the highest shift produce maximum deviation as shown on figure 8.

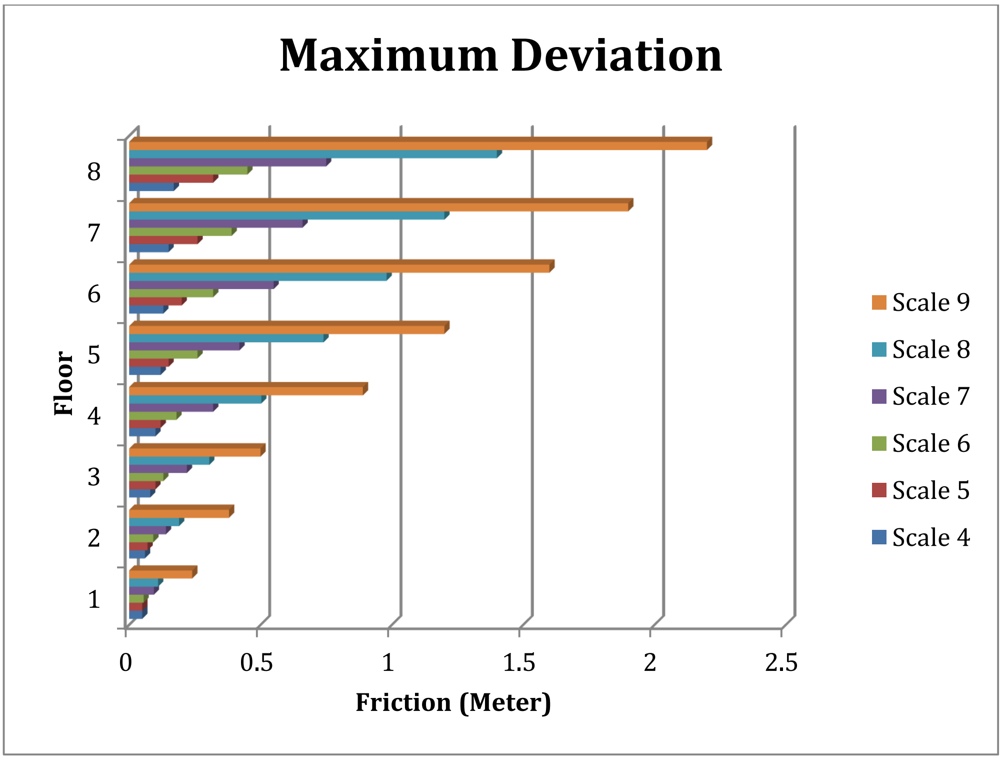
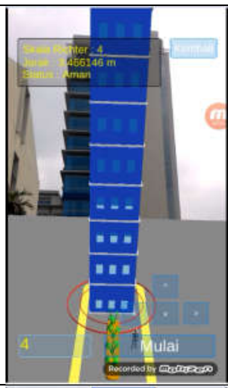
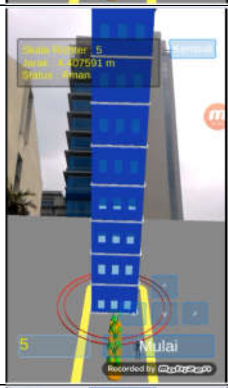
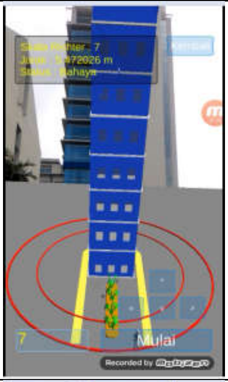
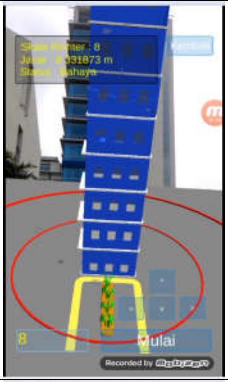
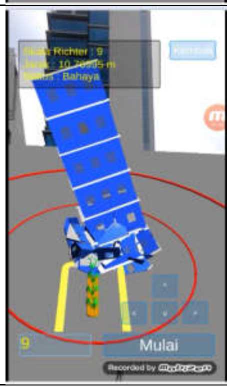


Figure 8. Diagram of maximum deviation

Table 6 shows the implementation result for calculating the distance to reach safe area and animation the damage of tower with entered Richter scale. User know the damage of tower from result animation and information the safe distance based on the determined seismic strength.

Table 6. Safe distance and building damage

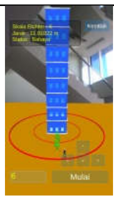
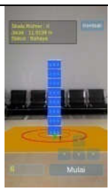
Scale	Safe Distance of Building Area	Result	Damage Outside The Building
4	1.75 m		Nothing
5	2.51 m		Nothing
6	3.45 m		Minor damage to the glass

7	5.70 m		Minor damage to parts of glass and cracked walls
8	11.02 m		Large damage to the glass and wall
9	17.58 m		The enormous damage caused the building to collapse

5.3 Analysis Marker

Table 8 explains that on marker on some trial experiments from small rating until large rating as shown table 7. For the small object, we need small the distance to identify the marker perfectly. Some marker are not perfectly identified caused by the large distance from the marker to user for example on experiment 4, 6 and 8. The other factor to make marker is not identified is object complexity. This system need complex marker to identify the tower.

Table 7. Marker

No	Marker		Distance	Result	Accuracy
1			3.5 m	Appear perfect	0.0045 m/pixel
2			8.4 m	Appear perfect	0.023 m/pixel
			11.4 m	Appear perfect	
3			2.4 m	Appear perfect	0.01 m/pixel
4			0.5 m	Appear perfect	0.0084 m/pixel
			1 m	Appear perfect	
			1.8 m	Do not appear	
5			1.8 m	Appear perfect	0.0047 m/pixel
			2 m	Appear perfect	
			3.9 m	Appears imperfect	
6			0.5 m	Appear perfect	0.0097 m/pixel
			1.7 m	Appear perfect	
			1.8 m	Do not appear	
7			24.3 m	Appear perfect	0.021 m/pixel
			25.8 m	Appear perfect	
			28.8 m	Appear perfect	

8			0.5 m	Appear perfect	0.003 m/pixel
			1 m	Appears imperfect	
9			1 m	Appear perfect	0.003 m/pixel
			4.5 m	Appear perfect	
			6.6 m	Appears imperfect	
10			0.5 m	Appear perfect	0.0042 m/pixel
			1 m	Do not appear	

5.4 Users Evaluation

We implement this system for 20 respondents with various background to check the user responses. The questionnaire is asking about the interactive factor and the learning material. Table 8 shows the result of user evaluation for using the system. This system has easy navigation (80% user agree). Presentation of information is enough or fairly good (70% user consider good), but not completely written. It needs improvement to make user know about impact of earth quake. The other function of this system is good such as aesthetic and cognitive substance. Overall function of this system can implement by user to simulate the effect of earthquake on the surrounding area of tower. The overall result from table 8 shows that 84% of respondents think that the earthquake application is up to the standard of interactive multimedia application.

Table 8. Users Evaluation

No	Criteria	Result
1.	Navigation Easiness	80% Agree
2.	Informational Presentation	70% Good
3.	Arts and Aesthetic	90% Very Appealing
4.	Cognitive Substance	80% Good
5.	Overall Function	100% Very Good

6. CONCLUSION

Based on the above experiment, it can be concluded that the 8th floor tower if exposed to earthquakes with large-scale magnitude then the greater the damage to buildings and secure areas around the building. At the marker retrieval is not always a high rating resulting in better recognition, because of marker retrieval is not from the 2D field, but directly from the object in real time without an intermediate print. The results of the user evaluation show an average of 84% of respect with this application, with this learning application users already understand the importance of earthquake risks in high rise buildings.

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