2D and 3D Geovisualization: learning user preferences in landslide vulnerability

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Abstract. Geovisualization in both 2D and 3D forms can be used as a medium for disseminating information of landslide vulnerability. Determining proper geovisualization is very important so that the information carried about landslide vulnerability is truly helpful and can be understood by the community as end-user. There are very few research in current literature explaining the user preferences on geovisualization 2D and 3D related to landslide vulnerability. In this paper, the user preferences of both 2D and 3D geovisualization will be evaluated. This study will focus to find out which geovisualization suits most users and their literacy spatial among those provided geovisualizations. Geovisualization of landslide disaster vulnerabilities will be displayed to users in 2D and 3D. Then to find out their spatial literacy and preferences, interviews were conducted with users regarding the geovisualization presented. The results of the user's answers are then collected and evaluated. From our results, 90\% of users prefer 3D geovisualization over 2D. Furthermore, our analysis shows that 2D geovisualization has the advantage of being easily understood by users in all ages. Meanwhile, 3D geovisualization is better at increasing users' spatial literacy at all ages and levels of education in knowing the causes of landslide vulnerability. Choosing the proper geovisualization will provide information and knowledge that is useful for communities in regards of landslide vulnerability for better disaster awareness.

Keyword: Participants, Visualization

1 Introduction

Landslide is the velocity of stone, soil, and organic substances under the impact of gravity and also the landform that emerges from such movement \cite{1}. This type of disaster cause billions in financial losses, long-term economic disruption, population displacement, and are responsible for thousands of deaths and injuries each year. Action like disaster awareness program needed to reduce the impact of the disaster. A study by Karanci \textit{et al} \cite{2} empirically proved that disaster awareness creates significantly more preparedness behaviours to the people who participate in disaster awareness training programs. Disaster awareness is a part of disaster management program where the goal of this program is to control disaster impacts. One of technological approaches that can be used in the disaster management program is Geographic Information System (GIS) \cite{3}.
Geovisualization (example: maps) as a part of GIS technology that can support as the virtual representation of a disaster situation [4]. Selecting the proper geovisualization as a medium for disseminating disaster’s information is very important so that the information conveyed is truly useful and can be understand by the community as an end-user. Thus, learning user preferences in terms of proper geovisualisation in disseminating information on landslide vulnerability is noteworthy. However, to our knowledge, there is not enough study evaluating the end-user preferences of geovisualization in regards to landslide vulnerability.

In this study, Geovisualization will be evaluated based on user preferences. Landslide vulnerability maps will be visualized in 2D and 3D form. Digital Elevation Model (DEM) from [5] is analyzed using QGIS software to assess landslide vulnerability and to create geovisualization. The 2D and 3D geovisualization result is tested to the end-users. Bumiaji district, Batu City East Java Province in Indonesia is selected as study area of this research. The result of this research could be important for stakeholder who involved in disaster management to decide which geovisualization suits for end user in regards to landslide vulnerability mapping.

2 Methodology

2.1 Study Area

The study area of this research is located in Bumiaji District, Batu City, East Java Province, Indonesia. Located in 112°17'10,90"-122°57'11" Longitude and 7°44'55,11"-8°26'35,45" Latitude. This city is based in the mountainous region with the elevations range between 600 to 3000 masl [6]. Bumiaji District has the highest elevation in Batu City with the total 12852,34 hectare of wide-area [6].

Because it is located in the mountainous region, it has a high vulnerability of landslide. Government’s disaster response organization Badan Penanggulangan Bencana Daerah (BPBD) stated that from 2013 to 2018 at least there are 69 occurrences of landslide in Bumiaji District. Figure 1 depicts the Batu City with its village boundary, the dotted maps is Bumiaji District.

2.2 Sampling Method

Stratified random sampling is the sampling method we will use. This method is performed by dividing data into various strata which are classified in the same characteristics [7]. Stratified Random Sampling methods are best used in heterogeneous populations. The heterogeneous population is then grouped into homogeneous groups or called strata [8].

According to Badan Pusat Statistik Kota Batu [9], in 2017 there is 21,34% of the population is elementary school educated, 22,72% of the population is junior high school educated, 29,18% of the population is senior high school educated and only 9% of population is in post high school educated. Also there are 18% of the population do not have any educational certificates. Thus, the sample will be taken in accordance with the ratio of population-based on education. 10 participants from Bumiaji District Batu City selected as sample with the distribution of 3 participants in elementary school level, 3 participants in junior high school level, 3 participants in high school level and 1 participant in bachelor level.
2.3 Experiment Method

In our approach, interview-based data acquisition methods were carried out by using questions related to geovisualization. The interview method is a data acquisition activity by conducting question and answer in the intention to obtain information and opinions from participants [10]. Question lists and test scenarios need to be defined before conducting the interview. In this study we did not use any framework to define interview questions and test scenarios to further enhance our contribution and uniqueness.

Table 1 – The question list of participant’s attribute

| Participant’s Attributes | 2D geovisualization experience? | 3D geovisualization experience? |
|--------------------------|---------------------------------|---------------------------------|
| Age:                     | Yes | No                            | Yes | No                            |
| Education Level:         | N/A | ES | JH | HS | > Graduated                 | 2D geovisualization experience? | Yes | No | 3D geovisualization experience? | Yes | No |

Test scenarios in terms of this research is a set of steps on how the geovisualization were operated during the interview process. The interview process was organized into two sections. Participant’s attributes in section 1. There were three questions concerning the participant’s education level, age and experience with 2D or 3D visualization. Table 1 is the question list of participant’s attributes used by this research.

In the second section was tested part. 2D and 3D geovisualization will be shown to participants in accordance with the previously formulated test scenarios. In the first question and scenario, participants will be asked about the study area that is visualized with a different geovisualization (2D and 3D). The question is simple to ask “where is it?”. This step is intended to check whether participants can answer incorrectly between...
the two geovisualizations. The next step in the second section is the explanation step. Participants will be given insights related to maps of the landslide vulnerability. The explanation related to the map colour why certain area was in red colour, also the example of vulnerable sub-district. The minimum ability that must be possessed by participants is to have no problems with their vision, especially color blindness. After participants can understand, then we proceed to the main step question and scenario in the second section. The minimum requirements for participants.

In the main step of the second section, participants will be asked five questions focusing on user’s spatial literacy and preferences. 4 of 5 questions are the two same questions asked twice to cover each geovisualization. Those 4 questions asked to explore whether participants can identify the landslide and its causes from different geovisualization. The last question is to check the final user’s preferences between two given geovisualization. The complete scenarios and questions list can be seen in Table 2 and the flowchart of this research can be seen on Figure 2.

Table 2 – Complete scenarios combined with questions list

| Test Scenario (operated by the researcher) | Interview Question | Correct Answer | Participant’s Answer |
|------------------------------------------|-------------------|---------------|---------------------|
| Show 3D map with 100% zoom              | Where is it?      | Batu City     |                     |
| Show 2D map with 100% zoom              | Where is it?      | Batu City     |                     |
| **Landslide vulnerability explained**    | Possible Answer   | YES | NO |
| Show 2D map with focus/zoom to Sumbergondo sub-district | Is Sumbergondo sub-district vulnerable to landslides? | Yes / No | |
|                                          | According to the map you see now, can you find the cause of the landslide in this sub-district? | Yes / No | |
| Show 3D map with focus/zoom to Sumbergondo sub-district | Is Sumbergondo sub-district vulnerable to landslides? | Yes / No | |
|                                          | According to the map you see now, can you find the cause of the landslide in this sub-district? | Yes / No | |
| Show 3D map (zoom out 100%)             | Which geovisualization (2D or 3D) suit for you? | 2D | 3D |
| Show 2D map (zoom out 100%)             | Which geovisualization (2D or 3D) suit for you? | 2D | 3D |
2.4 Landslides Vulnerability Assessment

QGIS is used for analyzing and mapping landslide vulnerability. QGIS is an open-source and easy-use Geographic Information System (GIS) licensed under the GNU General Public License. QGIS is cross-platform that works on Windows, Linux, Unix, Mac OSX and Android and supports various vector, raster, and database formats and functionalities. QGIS is also an Open Source Geospatial Foundation (OSGeo) official project [11].

The first step of our landslide vulnerability assessment is data preparation. In this phase we collect all required data such as DEM and Batu City polygon administrative boundary. Both DEM and Bumiaji’s polygon administrative boundary was obtained from Badan Informasi Geospasial (BIG) [12]. BIG is an official organization from Indonesia government providing geo-spatial data. DEM and polygon data then loaded, merged and clipped using QGIS.

By using DEM, elevation value from study area can be extracted. Elevation value is then converted to aspect and slope value. We use elevation, aspect and slope value as cause factors of the landslide in Bumiaji district using QGIS plugin ‘slicer’. This plugin will generate classes for each corresponding factor. In the next phase, we are using ‘fuzzify’ function for all cause factor to generate landslide vulnerability value. The threshold values we use for each cause factor are, 1000 m for elevation value, 15% for slope value and 4 for aspect value. All those factors then combined to generate final landslide vulnerability value.
Fig. 3. – 2D Geovisualization of Batu City. The Darker Indicates Landslide Vulnerability

Fig. 4. – 3D Geovisualization of Batu City. The Darker Inside Administrative Area Indicates Landslide Vulnerability
Another plugin is used for presenting 3D visualization. Qgis2threejs is a plugin to enable 3D conversion in QGIS. This plugin will automatically generate javascript code for 3D geovisualization. QGIS basic function ‘composer’ is also used to generate 2D geovisualization. Both 2D and 3D geovisualization are presented with the same feature. Figure 3 presents 2D geovisualization and Figure 4 presents 3D geovisualization used for user preferences testing.

During the interview processes, we will assess the literacy spatial of the study area visualized by the map with minimum details, therefore we omit all details such as compass, scale, legends and inset map. All maps presented in this paper are in grayscale colour whereas, during the interview process, all maps will be presented with colourful (such as red) visualization.

3 Analysis of the Experiment Result

As explained in the previous section in this paper, the experimental process is carried out by direct interviews with 10 participants where the researcher shows 2D and 3D geovisualization while asking a list of predefined questions. Participant’s answers are then recorded and entered into a computer for further processing. The software used to process participant data is RStudio version 1.2.1335.

Figure 5 shows the percentage of user preferences between two different geovisualization. From the barplot depicted in Figure 5, only 10% participants choose 2D geovisualization, the remaining 90% of participants prefer 3D over 2D. Some of participants also told us why they preferred 3D. Not only they argue that 3D looks better, but also some participants think that with 3D geovisualization they can see the slope more clearly.

Figure 6 shows a plot of the correlation between the participant’s age and the level of education of participants against their ability to identify study areas in different geovisualizations. The results are shown in Figure 6 explain that all participants were able to recognize or identify the area indicated by 2D geovisualization. This shows that there is no correlation between the level of education and the age of participants to recognize or identify the area displayed by 2D geovisualization.

In 3D geovisualization shows that there is a correlation of participant’s age ($p=0.42$, $r^2=0.16$) and education level ($p=0.46$, $r^2=0.25$) towards the ability to identify the study area. The positive linear model explains the higher level of education and age of participants, the higher their ability to recognize or identify the area indicated by 3D geovisualization.
Fig. 6. – Correlation between the participant’s age and the level of education of participants towards their ability to identify study areas in different geovisualizations

Fig. 7. – Correlation between the participant’s age and the level of education of participants against their ability to identify the cause of landslide vulnerability

The Spearman Rank analysis (\( \rho \) value) for the participant's age correlation in 2D Geovisualization is 0.42 (\( r^2=0.25 \)). While the value of analysis for the correlation of age towards participant's ability to identify the cause of the vulnerability of slides in 3D geovisualization is 0.04 (\( r^2=0.57 \)). Meanwhile, the Spearman rank analysis for the correlation between the level of Education of participants with their ability to identify
the cause of the vulnerability in both geovisualizations is 0.66 ($r^2=0.38$) for 2D and 0.63 ($r^2=0.3$) for 3D respectively.

The correlation of participant's age and level of education towards their ability to identify causes of landslide vulnerability in 2D and 3D geovisualization according to Figure 7 shows a positive value. It means that there is a relationship between the two, specifically the higher level of education and the age of the participant influences their ability to recognize the causes of landslide vulnerability.

4 Conclusion and Discussion

Previous studies have discussed the application of 3D geovisualization and its advantages over 2D geovisualization in various case studies [13] - [20]. However, there are not enough studies that address user preferences related to geovisualization and differences in spatial literacy between each geovisualization in the case study of disaster vulnerability. In this paper, based on the results of the analysis in the previous section of this paper, we can conclude some facts: there was no difficulty for all participants in recognizing the areas indicated by 2D geovisualization. While on the other hand, there are participants who failed to identify the area indicated by 3D geovisualization. this is shown by the fact of the plot in Figure 6 that there is no relationship between the participant's age and level of education in terms of their ability to identify the area displayed in 2D geovisualization.

However, other facts show that 3D geovisualization is more effective in conveying information about the cause of landslide vulnerability than 2D geovisualization. Analysis of positive value on the linear model with a correlation value of 0.42 on 2D geovisualization shows that the older a person is, the easier it is for them to identify the cause of landslides displayed with 2D geovisualization. In other words, 2D geovisualization is not good at conveying information about the causes of landslides at a younger age. In contrast, with the same correlation type, the 3D geovisualization value gives a better result, with the correlation value only 0.04. It can be concluded that there is almost no relationship between the participant's age and his ability to identify the causes of landslides in 3D geovisualization. Thus, 3D geovisualization can provide better spatial literacy at all participant's ages compared to 2D geovisualization.

In terms of its correlation with the participant's Education level, 3D geovisualization has little advantage over 2D geovisualization. this is indicated by the correlation value that is not much different, it's 0.66 for 2D geovisualization and 0.63 for 3D geovisualization. Nevertheless, there is still a relationship between the effect of the participant's education level on their ability to identify the causes of landslide vulnerability displayed by the two different geovisualizations.

3D geovisualization was chosen by 90% of the participants as their preference in the case study for disseminating information on landslide vulnerability. 3D geovisualization also has advantages in increasing participants' spatial literacy in identifying causes of landslide vulnerability. Based on the results of some of the participants' answers this is due to 3D geovisualization that can display slopes, where the slope is one of the factors causing landslides [21]. Besides, some participants with older age were more able to recognize the cause of landslide vulnerability in 2D geovisualization, in our opinion, it is because of the participant's spatial literacy experience. so that they were more aware of landslide vulnerability.

2D and 3D geovisualization of landslide vulnerability have been tested in relation
to user preferences and level of spatial literacy. Educational level and age of participants variable were used in this study to explore the relationship between these two variables with the user spatial literacy of different geovisualizations. The results of this study can be used as input to related parties such as official government organizations that focus on disaster response. The disaster response organization can consider selecting appropriate geovisualization media in conveying information related to landslide vulnerability. In addition, this study can be used as empirical evidence for further research with further exploration, such as increasing the number of participants and more varied test scenarios. The r-squared value obtained in this study is still relatively low (0.25, 0.3, 0.38 and 0.57), however, this can be used as a reference in choosing better correlation variables. which means, there are still other causes besides the level of education and age of participants in terms of their preferences and spatial literacy in the case study of geovisualization of landslide vulnerability.

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