

Research Article

Review of Visualization Techniques for Landslide and Flood Disaster Data

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Abstract: The aim of this study is to review the data visualization techniques that have been used for landslide and flood research. Landslide and flood are two of the natural disasters that commonly occur in Malaysia. Due to the large amount of damage that both landslide and flood can cause, it is important for researchers to predict where and when these two disasters will occur and the extent of damage that can happen. Data visualization techniques have been used by researchers in both areas to facilitate them in making a better prediction. However, data visualization techniques are used differently in the two areas. In landslide research, the visualizations techniques are used to visualize monitored landslide data. In flood research, the visualization techniques are used to visualize the predicted impact of flood, where they are used as a component in a flood simulation system. In both cases, data visualization technique has not been used to its full potential and this opens up a door for further research opportunities with regard to using data visualization to improve our prediction on landslide and flood occurrence.

Keywords: Flood, landslide, natural disaster, visualization techniques

INTRODUCTION

Natural disaster can be defined as internal and external processes that change the earth's surface at a fast rate. Landslide and flood are two natural disasters that commonly occur in Malaysia. When they occur, these two disasters always have a disastrous impact on the economy and life of the people involved, where properties may be damaged and people may get injured, made homeless or even killed. Therefore, research works on understanding landslide and flood occurrence as well as methods to mitigate their impacts are of utmost importance.

Landslide is defined as a massive mass of soil and rock debris that move downhill because of the action of gravity. Landslides are caused by rain, earthquakes, volcanoes or other factors that make the slope unstable. Due to the large amount of damage that can be caused by landslides, it is important to identify landslides, define their characteristics and assess the landslide susceptibility, hazard and risk (Razak *et al.*, 2011). In order to monitor and predict the occurrence of landslide, researchers have to install various sensors and measuring instruments at landslide-prone sites to collect various types of data. Among the common types of data collected are subsurface movements and deformations, groundwater measurement, soil moisture level and precipitation. With the use of modern wireless technologies, these data can even be collected and transmitted in near real-time. However, with the large

amount of data collected, researchers may need an effective tool to analyze and explore the data.

Flood happens when too much rain, water rises in the rivers and overflows onto normally dry land. Floods may also occur when artificial structures such as dams fail (Ye *et al.*, 2012). If the dam is poorly designed or built in a place where earthquakes and landslides occur, the dam will break and water will flood the land. Flood disaster has been a serious disaster in many areas in the world because it frequently occurs in many countries and causes serious damage (Li *et al.*, 2012). Flash flood and river flood disasters occur frequently in Malaysia. Besides these two types of flood, there are also other types of flood such as coastal flood, urban flood, areal flood and storm-surge flood. In order to mitigate the impact flood, it is important to be able to predict the occurrence of flood. This is done by monitoring water-related environmental data such as river water level and precipitation. It is also important to be able to predict the extent of flood that is going to occur. By knowing the expected rise in water level as well as the areas that are going to be affected, the authority as well as the community can get prepared for the incoming flood and this, in turn, will reduce the amount of damage that will occur.

Predicting the occurrence of flood and landslide requires the researchers to monitor and collect a large amount of environmental data, both spatial and temporal. With the huge amount of data involved, it can sometimes be difficult to analyze the data. In computer science, one of the emerging tools that can be used to

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analyze and explore large amount of data is data visualization. Data visualization refers to the study of visual representation of data, where data is represented using graphical means. Since human beings are very visual creatures, visually represented data should be more easily understood compared to numbers or written words. The purpose of this paper is to give a review on data visualization techniques that have been used in landslide and flood research. The study starts by explaining the importance and benefits of data visualization, its applications and the categorization of data visualization techniques. This is followed by a review of data visualization techniques that have been applied by landslide and flood researchers.

Importance and benefits of data visualization: Data visualization has been increasingly used in many different areas because it can convey information in a universal manner and make it simple to share ideas with others. However, the most important aspects of data visualization is that it makes challenging data sets to be easily comprehensible, enables data exploration and provides useful information in an efficient way. Data visualization does not only provide graphical representation of the data, but also allows changing the form, omitting what is not required and browsing deeper to get further details.

Applications of data visualization: Data visualization techniques have been successfully used in a diverse range of applications. Among them are financial asset management (Smeulders and Heijs, 2005), marine environment research (Yawen *et al.*, 2010), information system (Xiaoguo and Xinying, 2012), data queries (Mizuno *et al.*, 1997), chemical research (Yamazawa *et al.*, 2008), meteorological research (Treinish, 1997) and air traffic management (Rehm *et al.*, 2007). Of

particular interest to this study, data visualization techniques have also been utilized in landslide as well as flood research.

METHODOLOGY

Visualization techniques categories: Table 1 shows the various types of visualization techniques that can be found in the literatures. The techniques can be classified based on two approaches: technical approach and interactive approach (Ltifi *et al.*, 2009). The technical approach categorizes the visualization techniques based on the type of data structures. As apparent from the table, different visualization techniques are required for different types of data structures. The visualization techniques given by the technical approach will give an overview of the data set. The interactive approach, on the other hand, allows for data search and exploration. This will, in turn, enable an in-depth analysis of the data so that a meaningful insight or conclusion can be obtained.

Data visualization techniques used for landslide: In landslide research, data visualization techniques have been used to visualize landslide data from several different aspects. Since landslide data is normally associated with geographical information, all of the data visualization techniques for landslide found in the literature lay their visualized information on top of a map or an image representing the landform of the area. The use of map is also natural for landslide researchers since most of them use a Geographical Information System (GIS) to identify landslide-prone areas.

Saro and Chandra (2011) used color codes to identify the level of susceptibility of an area to the occurrence of landslide. The risk level is specified using different colors, with light blue showing areas

Table 1: Visualization techniques and categories (Ltifi *et al.*, 2009)

Technical approach (data structures oriented)	
Data structures	Visualization techniques
Linear data	Data tables
	Perspective wall
	Times lines
Multidimensional data	Scatter plots
	Plyline system
Hierarchies (tree structures)	Approach by metrics
	Approach by indented list
	Approach by diagrams
	Surface approach
	Tree maps slices
	Hyperbolic approach
	3D or cone approach
	Landscape approach
Networks	Hyperlink network
	Cocitation network
	Social network
Vectorial model	Approach base on similarities
	Approach based on relevance
Interactive approach (user oriented)	
	Dynamic projection
	Interactive filtering
	Interactive zooming
	Interactive distortion
	Interactive linking and brushing

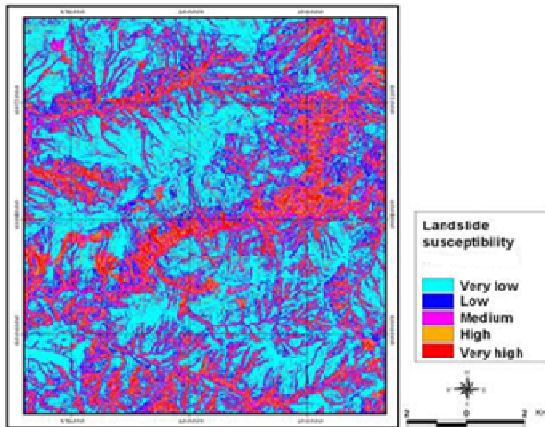


Fig. 1: Using visualization technique to specify the level of susceptibility of an area to the occurrence of landslide (Saro and Chandra, 2011)

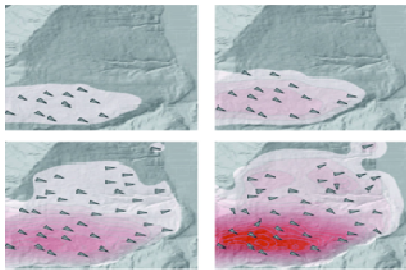


Fig. 2: Using visualization technique to identify soil displacement during the occurrence of landslide (Oberholzer and Hurni, 2000)

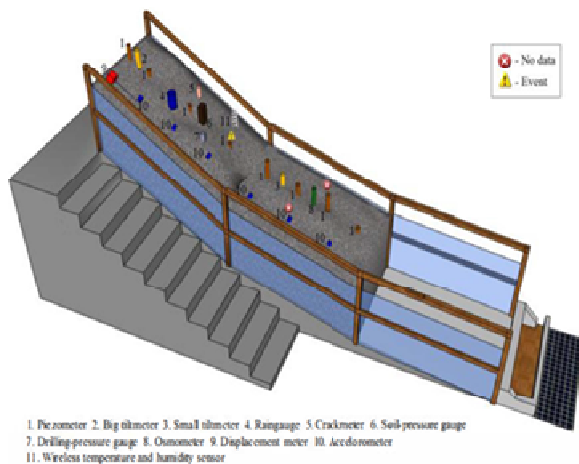


Fig. 3: Using visualization technique to visualize the spatial distribution of the employed sensors and the data read by the sensors (Wen *et al.*, 2012)

with the lowest risk and red showing areas with a high risk. An example of this can be seen in Fig. 1. Since the size of areas to be monitored for landslide can be huge, identifying high-risk areas will enable the researchers, as well as the relevant authorities to monitor these areas

more closely and provide the necessary preparations should landslide occurs.

Oberholzer and Hurni (2000) used a visualization technique to identify soil displacement during the occurrence of a landslide event. An example of this can be seen in Fig. 2. This technique enables the areas affected during a landslide event to be identified. It also allows the reconstruction of the landslide event for further analysis. If a technique for predicting soil displacement during landslide were to be developed, this visualization technique can also be used to visualize the predicted landslide.

Wen *et al.* (2012) experimented with the use of sensor network to collect landslide data. Sensor nodes equipped with different types of sensors are deployed in an area of interest. However, instead of simply collecting raw data from the sensors, the researchers utilized a visualization technique to visualize the spatial distribution of the employed sensors and the data read by the sensors. In the visualization technique used, different types of sensors are represented with different colors and shapes, as can be seen in Fig. 3. The sensor reading and status are also specified on the image, near each respective sensor. The use of this visualization technique can ease the tasks of monitoring the sensors and understanding the sensors' readings.

Data visualization techniques used for flood: In flood research, data visualization is mostly used to visualize the predicted impact of flood, instead of visualizing the flood data itself. Therefore, many flood visualization techniques reviewed here are used as a component in a flood simulation system. Similar to the visualization techniques used in landslide research, GIS data is used to specify the flooded area. However, many flood researchers went one step further by developing a 3D environment of the affected area. The use of a 3D model of the affected area enables the impact of the flood to be more accurately visualized and this can greatly facilitate flood control and disaster mitigation efforts.

Li *et al.* (2012) presented a 3D flood routing simulation system based on Geographical Information System (GIS) and Virtual Reality (VR) technology. Flood routing is the process of computing the progressive time and shape of a flood wave at successive points along a river. To perform flood routing, the authors improved a 2D hydrodynamic flood model so that the model can be used for 3D environment (Fig. 4). The paper also presented the procedure which they performed to come up with the flood routing visualization model, as well as the system design. Unlike other papers on 3D flood visualization, the implementation is not done using OpenGL, but instead uses the ArcGIS Engine, which is a collection of GIS components and developer resources that can be used to embed GIS capabilities to applications. The



Fig. 4: Example of flood visualization developed by Li *et al.* (2012)

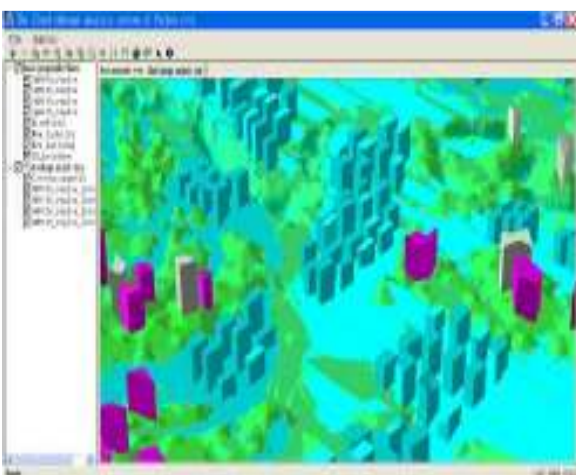


Fig. 5: Example of flood visualization developed by Guo *et al.* (2009)

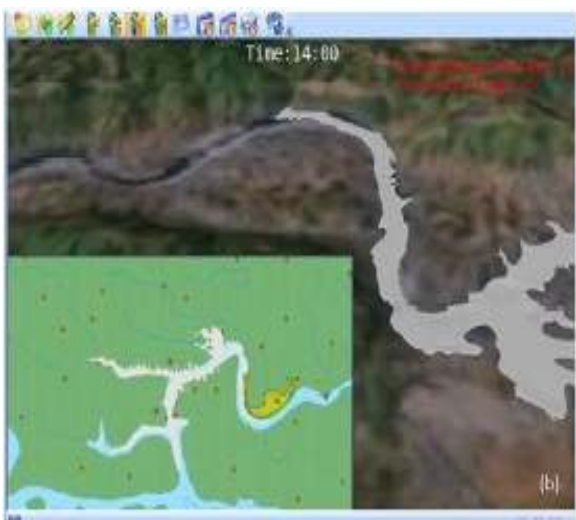


Fig. 6: Example of flood visualization developed by Ye *et al.* (2012)

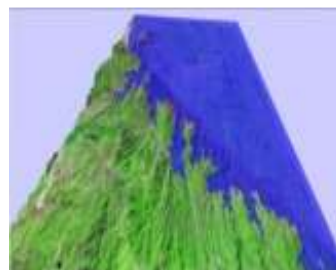


Fig. 7: Example of flood visualization developed by Xinxin *et al.* (2012)

developed system can be used as an input for decision support for flood control and disaster mitigation.

Guo *et al.* (2009) developed a 3D visual query model system for flood submerging based on ArcEngine. The use of ArcEngine means that the system is built on a 3D GIS platform which requires GIS data. The goal of the system is to enable the visualization of water level on the terrain based on inputs such as flood frequency and the water level. The system can also be used to estimate the extent of economic damage by visualizing the level of submerging for buildings within the affected area (Fig. 5). By being able to visualize the flooded and submerged areas, the system enables decision makers to make an informed decision for flood control or disaster relief operations.

Ye *et al.* (2012) proposed an integrated geoinformatics technologies and system hydrodynamics method to evaluate the effects of dam-break and flood disaster. A technique called Smoothed-Particle Hydrodynamics (SPH) is used to model the flow of water during dam-break and flood occurrence. The output of SPH computation is then used as an input to a 3D spatio-temporal GIS application to dynamically visualize dam collapse and flood scenarios (Fig. 6). Specific layers can also be added to the GIS application show public infrastructures so that the effect of the disaster on the area can be seen more clearly. The proposed system can be effectively used as decision support for disaster response.

Xinxin *et al.* (2012) described the use of OpenGL to realize a system for flood simulation in 3D. Initially, the 3D terrain and sky is developed as the background of the 3D scenery. After that, water simulation is developed to be overlaid on top of the terrain using texture mapping (Fig. 7). The water simulation can visualize both the depth of the water as well as the water movement. The contribution of the paper is in terms of the generation of realistic flood visualization through the use of realistic 3D terrain.

Jiang *et al.* (2010) developed a Web-based 3D visualization system based on WebGIS to visualize flood inundation (Fig. 8). The WebGIS system used is called World Wind, which is a 3D GIS system developed by NASA. To visualize flood inundation, the

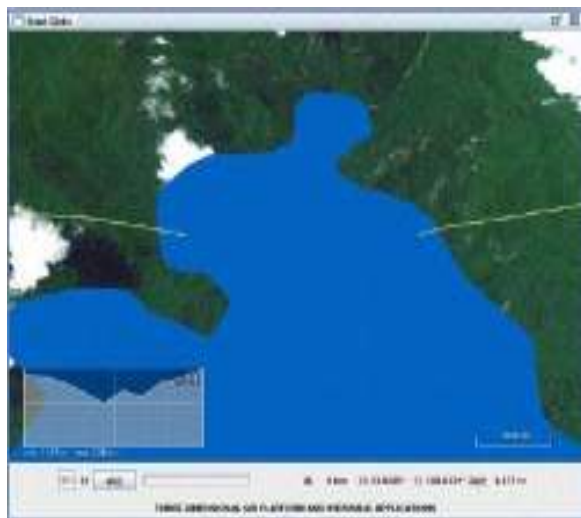


Fig. 8: Example of flood visualization developed by Jiang *et al.* (2010)



Fig. 9: Example of flood visualization developed by Zhang *et al.* (2006)

system implements mathematical models and algorithms for flood inundation, as well as flood information of the respective area. Once the inundated areas have been identified, the areas are displayed on the map using JOGL (Java binding for OpenGL).

Zhang *et al.* (2006) developed a 3D visualization and animation system to display the effects of storm surge flooding due to hurricanes. The unique feature of this system is that the researchers developed a realistic and geo-referenced 3D environment of a particular area, where objects in the environment are given accurate sizes and shapes. The development of this realistic and accurate environment is made possible due to the use of data from various sources such as remote sensing, ground surveys and GIS databases. The flood itself is modeled using numerical data from previous hurricanes. By using a 3D environment that closely mimics the real environment, users can view the

impacts of storm surge flood on the landscape as well as on the properties in the environment (Fig. 9). The system can be used to perform both near real-time animation of forecasted hurricanes and offline animation for hypothetical hurricanes. Figure 9 show a real situation during surge flooding in 3D animation.

DISCUSSION AND CONCLUSION

In the two sections above, three visualization techniques for landslide and six visualization techniques for flood have been reviewed. It is interesting to note that the visualization techniques are used differently for the two natural disasters. In landslide research, the visualization techniques are used to visualize the monitored data, while in flood research, the visualization techniques are used to visualize the predicted impact of flood. This could be because the aim for landslide and flood research is slightly different.

In landslide, the affected area is relatively small and frequency of occurrence is also lower. It is also difficult to know where landslide will occur. Therefore, researchers are more interested in knowing where and when landslide will occur, instead of what happen when landslide occurs. By identifying the high-risk areas, it may also be possible to take some preventive measures to delay or even prevent landslide from happening. Flood, on the other hand, affects a relatively larger area and almost cannot be prevented. The flood-prone areas and the time on which flood may occur can be estimated based on weather forecast, geographical and historical data. Furthermore, the amount of damage and the number casualties during flood are also higher. Therefore, most flood researchers would prefer to focus on the impacts of flood.

However, it is still useful for flood researchers to visually analyze flood data the way landslide researchers do. Even though the location and the time when flood will occur can be roughly estimated, perhaps visualizing flood data can reveal more insights to provide a more accurate estimation. With data visualization techniques, various types of data including meteorological data (such as precipitation), hydrological data (such as water level and discharge), geological data (such as type of soil), geographical data and historical data can be viewed and analyzed together. Even for landslide research, the three visualization techniques reviewed above are only used as an enhancement to geographical information. No attempts have been made to visualize the data itself using various visualization techniques as described in Ltifi *et al.* (2009). Therefore, there is a big research opportunity on the use of data visualization techniques to facilitate the understanding, exploration and analysis of landslide and flood data.

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