



GIS based 3-D landscape visualization for promoting citizen's awareness of coastal hazard scenarios in flood prone tourism towns



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ABSTRACT

This research aims to develop a comprehensive geospatial method for visualizing GIS based 3-D landscape visualizations in flood prone tourism towns and geospatial web applications containing multi-media information. In particular, the research determines potentially vulnerable portions generated by the SLOSH and SLR models on a global scale, statistically computed by the historical shorelines and the most recent LiDAR-derived shoreline on a local scale. The flood risk areas selected in the global and local scales are assessed by a field trip survey and finally visualized through integration of GIS and remotely sensed LiDAR data. In order to visualize the GIS based 3-D landscape, the most accurate geographic objects are extracted through the LiDAR multiple return points flown in 2010. This research proposes improved accuracy for identifying the small geographic objects which can enhance a 3-D flooding visualization and then, the GIS based 3-D landscape is visualized based on three flood risk scenarios which have accurately georeferenced geographic information. Furthermore, this research develops a geospatial web application which allows the general public to communicate with coastal managers, or even policy makers, and which provides the chance to aid the public's participation in coastal management planning. Accordingly, the geospatial approaches used in this research not only help non-experts or policy makers have a better understanding of the coastal hazards through realistic visualization, but can also improve the public's spatial perception in the primary coastal tourism towns. Of significance, being able to predict future flooding portions is likely to become important as development of coastal areas continues. Thus, this research helps coastal residents improve lack of personal experience on the coastal hazards and communicate with the coastal management planners.

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1. Introduction

Storm surges brought on by storms are the most destructive coastal hazards on the East and Gulf Coasts of the United States (Pava et al., 2010). Therefore, it is important for beachfront supervisors, inhabitants or even tourists to spatially or temporally comprehend their exposure to coastal hazards. This information would be advantageous for decision support systems attempting to establish a coastal hazard evacuation procedure and is vital for individuals cooperating with coastal planners to develop beachfront management plans that take into account diverse administration alternatives. Researchers and coastal planners usually utilize landscape analysis, which allows an individual to define the area to be monitored and analyzed, thereby providing more meaningful and recognizable information (Costanza, Sklar, &

White, 1990; Fedra & Feoli, 1998; Klemas, 2001; Burnett & Blaschke, 2003; Brown, 2006; Zhou & Xie, 2009; Burch, Sheppard, Shaw, & Flanders, 2010; Yang, Song, & Kim, 2010; Chen, Xu, & Devereux, 2014; Magarotto, Costa, Tenedório, Silva, & Pontes, 2014; Grant, Baldwin, Lieske, & Martin, 2015).

In general, the 2-D representation of landscape analysis is straightforward, but it lacks the advantages of 3-D landscape visualization, which provides intuitive results, enables the effortless comprehension of complicated and dynamic geographic phenomena (Wang, Song, Chen, Zheng, & Crow, 2006) and presents these phenomena without temporal and spatial impediments (Bishop, Stock, & Williams, 2009; Grêt-Regamey, Celio, Klein, & Hayek, 2013; Song et al., 2006). Moreover, the 3-D representation of landscape analysis can enable a variety of alternative management scenarios and adoption of sensible landscape patterns, for example, predicting highly hazardous regions likely to be flooded (Yang, Hwang, & Cordell, 2012b). For these reasons, numerous studies have integrated remotely sensed data and geographic

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information system (GIS) data (Kelmas 2001; Brown, 2006; Zhou & Xie, 2009; Yang et al., 2012b; Chen et al., 2014; Magarotto et al., 2014). Through the integration of GIS and remotely sensed data, landscape analysis can produce a more realistic and georeferenced 3-D visualization environment, enabling end users to identify real locations using geographic coordination systems (Manyoky, Wissen Hayek, Heutschi, Pieren, & Grêt-Regamey, 2014). GIS-based 3-D visualization has been proven to facilitate the communication among various stakeholders, professionals, and the public (Lange and Hehl-Lange, 2005; Otero et al., 2012). However, the author found through this study that, despite these advantages, the application of 3-D visualization is hindered by the following challenges.

First, a spatial scale (i.e. spatial resolution) for the elements of the 3-D visualization allows individuals to perceive the spatial components of complicated geographic phenomena effortlessly and can reveal the vertical structure and elements of the geographic objects. Digital elevation models (DEMs) or digital terrain models are typically used for GIS-based 3-D visualization, specifically for modeling vulnerability to sea-level rise (Coveney & Fotheringham, 2011; Cowell & Zeng, 2003; Dobosiewicz, 2001), coastal flood risk (Gornitz, Couch, & Hartig, 2002; Webster, Forbes, MacKinnon, & Roberts, 2006), and erosion sensitivity (Leatherman, Douglas, & Labrecque, 2003; Woolard & Colby, 2002). In DEMs, the spatial resolution can significantly affect the detection of topographic features, especially when visualizing sea-level rise (Poulter & Halpin, 2008). Although light detection and ranging (LiDAR) information has been utilized to increase the spatial resolution of DEMs up to 3 m and the spatial resolution is sufficient to create flood inundation maps and distinguish the earth surface, DEMs cannot recognize small geographic features on the earth's surface and are not suitable for use on multiple or fine scales. This implies that a fine-scale DEM cannot adequately visualize small geographic scenes without earth digital surface models (DSM) to indicate which small geographic objects (e.g., houses, streets, or trees) will be flooded and at what levels. In this way, the improvement of the spatial resolution on a local scale is necessary for visualizing flooding activities.

Furthermore, GIS-based 3-D landscape analysis requires spatially explicit geographic elements with exceptionally precise georeferenced information (Burnett & Blaschke, 2003; Blaschke, Lang, & Hay, 2008; 2014). This type of analysis helps individuals perceive the spatial and temporal characteristics of geographic areas or phenomena in areas of interest. Thus, accurate geographic features must be extracted by optimized methodologies. In particular, extracting small components has been problematic for homogeneous territories, which is unfortunate because small components can reveal more sensitive geographic phenomena in geographic simulation or 3-D landscape visualization. As such, if using the highest possible level of accuracy, it is conceivable that individuals could easily recognize spatial patterns and, in particular, the sea level at which ground elements will flood. Thus, GIS-based 3D visualization is a highly practical means of assessing the impacts of sea-level rise or storm surge flooding.

Finally, although advanced GIS-based 3-D visualization makes waterfront dangers easily recognizable and provides precise information on their impact, an absence of direct experience with beachfront dangers requires coastal land planners to formulate new specialized routines or methods, providing an opportunity to promote public involvement in coastal management. This public participation would require a new GIS-based web application to enable communication between coastal residents or tourists and coastal managers or even policy-makers.

In light of these three issues, this study aims to develop effective GIS-based 3-D landscape representations of flooding scenarios at

the smallest possible scale and spatial resolution. It helps improve the ability of the general population of a major beachfront tourism town to comprehend the spatial characteristics of the analysis results. In addition, this study develops a Web GIS application that facilitates the involvement of the general public in beachfront administration and improves waterfront tourism towns' understanding of hazards. In particular, this study addresses multiple research objectives. First, this study investigate the general geographic characteristics and current coastal hazard maps of the study area and the potential flood risk areas on a global scale as estimated by the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) and simple linear regression models. Second, this study statistically determines the most vulnerable zones for flooding on a local scale within the potential flood risk areas. Third, essential small geographic features are extracted in the most dangerous zone identified, and simultaneously the most accurate bare-earth DEM are created based on LiDAR multiple-return points. The extracted geographic features and the bare-earth DEM then are integrated in another GIS database, which will be important for the 3-D flooding visualization. Fourth, the bare-earth DEMs and such small geographic features as building roofs, tree stands, revetment rocks, and streets are visualized to identify likely inundation zones under three waterfront risk scenarios. Finally, a Web GIS application is developed to distribute the GIS-based 3-D landscape visualization and dynamic interactive maps to the general public and coastal managers. The study area, Jekyll Island State Park (JISP), is a barrier island and part of the Georgia State Park system (Fig. 2). As a public park, the study area provides the community with opportunities to generate economic profit, and this area is well known for having been subject to minimal human impact because of a 1971 law restricting construction on the land.

2. Methodology

2.1. Proposed work-flow and participatory processes

Fig. 1 shows the workflow proposed in this research and also illustrates the communication process to promote people's interest and awareness for coastal risks in tourism towns. As illustrated in Fig. 1, once the geospatial datasets and 3-D visualization have been constructed (Steps 1 to 2), through the web GIS application developed in Step 3, not only the general public can view or visualize the results of GIS analysis, but also customize to make their own decision, as well as even participate in this coastal management plan by inputting their messages in the web GIS application. In other words, Step 1 serves to inform decision-makers and in Steps 2 the decision-makers could and contribute to deciding the type and number of scenarios. Finally, the coastal planners or policy makers can collect people's opinions and make citizen driven decision making system for the coastal risky areas.

2.2. Principal methods and materials

In this research, three geospatial processes are proposed to meet the procedure of the decision making system in the coastal tourism town. Firstly, this research explored regions that are generally overflowed taking into account the SLOSH created by the National Weather Service (NWS). The SLOSH model utilized high resolution DEMs which focus on at what storm surge height the grid cell in the DEMs will flood. The SLOSH model anticipated the regions overflowed by the potential surge considering weight, area, course, sweep of max wind and forward pace. The model utilized as a part of this research was classified by the Saffir-Simpson hurricane wind scale (Kantha, 2006), but did exclude Category 5 hurricane. This model is referenced to the North American Vertical Datum of 1988

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