Coastal geomorphological change analysis based on big LiDAR remote sensing data

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Abstract: Coastal geomorphological change analysis based on big LiDAR remote sensing data Hongxing Liu, Qiusheng Wu, and Yige Gao Keywords: coastal profile; feature extraction; change analysis; bluff; LiDAR 1. Introduction Traditionally, coastal topographic mapping has been based on classical ground surveys, and photogrammetric processing of stereo aerial photographs to acquire three-dimensional (3-D) data along a beach. In recent years, airborne LiDAR remote sensing technology has been widely used in surveying, mapping and monitoring coastal environmental conditions and changes. LiDAR technique provides a much more cost-effective and efficient means of collecting topographic information, which allows a detailed analysis of micro-geomorphology of the coastal area over a broad region (Brock et al. 2004; Foyle and Naber 2012; Liu et al. 2010; Liu et al. 2009; Sherman et al. 2013). Topographic LiDAR data along the U.S. coastline have been collected by a cooperative research program among U.S. Geological Survey, NASA and the U.S. Army Corps of Engineers. Repeat LiDAR data before and after major storm events for U.S. coastal regions have become increasing available to the public. One of the major challenges brought by the LiDAR technology is to develop methods to fully exploit high resolution LiDAR data for information extraction and knowledge discovery. 2. Methodological Framework for Beach Profile Geomorphological Feature Extraction Previous studies were primarily based on the visual interpretation of profiles and/or simple statistical analysis of profiles. The ultimate goal of this research intends to develop an innovative method for extracting cross-shore profiles, identifying critical points, and calculating important cross-shore morphological properties from LiDAR data with automatic process and higher quality in comparison to previous methods. For each location on a beach profile, several indicators could be derived to quantify the morphological characteristics of major beach features at that location, such as elevation, slope (first derivative), second derivative, and curvature. The extraction of critical feature points such as dune crest, dune toe, and berm crest can be based on the combination of second derivative and curvature. First, a vertical threshold is given to roughly divide the coastal zone into beach zone and dune zone. When searching in the direction from the shoreline to the dune, the berm crest corresponds to the point with the minimum signed curvature value in the beach zone, and the dune/bluff crest corresponds to the point with the minimum signed curvature value in the dune zone. Once the locations of dune crest and berm crest are determined, the dune/bluff toe can be identified by searching for the point with maximum signed curvature between the dune/bluff crest and the berm crest, which indicates a dramatic slope change and a substantially concave profile shape. After dune/bluff crest, dune/bluff toe and berm crest are extracted for each profile, a set of attributes can be derived to support a detailed quantitative analysis of coastal morphology in the cross-shore direction. For beach feature points such as berm crest, dune crest, and dune toe, the elevation of the points and their horizontal distance from the origin point of corresponding profile can be calculated.

For segments between the point features, such as dune face and beach berm, the corresponding height, width, and slope of each segment can also be calculated. For time series of profiles from repeat LiDAR surveys, the magnitude of changes can be calculated for each attributes, such as the horizontal and vertical displacement of each feature point, as well as the change in height, width, and slope of each segment along the profile. The dune volumetric change is calculated based on the horizontal position of pre-surface dune toe and the dune crest location that is furthest from shoreline among different time periods. 3. An application example to Monterey Bay, California The automated algorithm for beach profile feature extraction and change analysis was applied to a case study area that is characterized by typical rocky bluff profile. The study area with rocky bluff is located at southern Monterey Bay, California, in the Pacific coast of the US. Southern Monterey Bay is characterized by a sandy shoreline backed by extensive bluffs. 4. Conclusions Coastal geomorphology provides scientific knowledge for coastal management and planning. This research presents numeric algorithms and associated software tools for coastal geomorphological feature extraction and change analysis. Based on a tidal referenced shoreline, a set of cross-section profiles perpendicular to shoreline are extracted from LiDAR data at a specified interval. A numerical approach is then applied to identify critical morphological feature points on each coastal profile, such as, beach berm crest, dune crest, dunetoe, bluff crest and bluff toe. After the feature points for each profile are derived, a set of attributes can be derived to support a detailed quantitative analysis of coastal geomorphology in the cross-shore direction. The numerical algorithms have been implemented as an ArcGIS extension module and successfully applied to the analysis of Monterey Bay, California. This automated coastal profile feature extraction and analysis method minimizes human interaction and greatly increases the efficiency of coastal mapping and geomorphological analysis. The numerical methods and software tools are developed for costal geomorphological analysis, but these methods and tools can be easily adapted to analyze fluvial geomorphology of a river valley. References Brock, J.C., Krabill, W.B., & Sallenger, A.H. (2004). Barrier island morphodynamic classification based on lidar metrics for north Assateague Island, Maryland. Journal of Coastal Research, 20, 498-509 Foyle, A.M., & Naber, M.D. (2012). Decade-scale coastal bluff retreat from LiDAR data: Lake Erie coast of NW Pennsylvania, USA. Environmental Earth Sciences, 66, 1999-2012 Liu, H., Wang, L., Sherman, D., Gao, Y., & Wu, Q. (2010). An object-based conceptual framework and computational method for representing and analyzing coastal morphological changes. International Journal of Geographical Information Science, 24, 1015-1041 Liu, J.K., Li, R., Deshpande, S., Niu, X., & Shih, T.Y. (2009). Estimation of blufflines using topographic lidar data and orthoimages. Photogrammetric Engineering and Remote Sensing, 75, 69-79 Sherman, D.J., Hales, B.U., Potts, M.K., Ellis, J.T., Liu, H., & Houser, C. (2013). Impacts of Hurricane Ike on the beaches of the Bolivar Peninsula, TX, USA. Geomorphology