Transportation Consortium of South-Central States (Tran-SET)

Karst Sinkhole Detecting and Mapping Using Airborne LiDAR

Highlight | Jan. 2019

Project No. 18GTUNM01

PI: Dr. Su Zhang, Dr. Susan Bogus, Dr. Shirley Baros (UNM)

POP: March 2018 – November 2019

Detecting and identifying sinkholes using airborne light detection and ranging (LiDAR) data

Sinkholes cause subsidence and collapse problems for many transportation infrastructure assets. Subsequently, transportation infrastructure management agencies dedicate a considerable amount of time and money to detect and map sinkholes as part of their infrastructure asset management programs. These collected sinkhole data are used by transportation agencies to determine the extent and severity of the sinkholes, and to make decisions about appropriate actions to avoid public safety hazards. Traditionally, sinkhole detection is performed on the ground by having experts visually inspect the condition of the sinkholes. This represents an expensive, time-consuming, and labor-intensive method. A recent advance in remote sensing, especially airborne light detection and ranging (LiDAR), allows for the examination of the change in the Earth's surface elevation accurately and rapidly. This research project is focused on exploring the utility of LiDAR in detecting and mapping the location of sinkholes. While the research project focuses on the state of New Mexico, the research results are expected to be applicable to any states with Karst terrain.

Background

Being able to accurately detect and map existing sinkholes is important for transportation planning and safety as well as infrastructure sinkhole risk assessment, hazard preparedness, and hazard mitigation. Traditionally, sinkholes are detected through area reconnaissance, which includes visual inspection of a site to locate existing sinkholes or previously filled sinkholes. This method is limited not only by the accessibility of the site but also by the ability of the inspectors or devices to observe the entire site. This method is also expensive, time-consuming, and labor-intensive. In addition, heavy vegetation may make it difficult or even impossible to view certain areas. Another method for sinkhole detection is through a review of topographic maps, contour maps, geologic maps, and sinkhole inventory maps. The detection of sinkholes from these maps depends on sinkhole size, map scale, contour interval, and slope of the ground surface around a sinkhole. Therefore, for transportation agencies there is a lack of reliable methods to rapidly detect and map sinkholes at a low cost. In recent years, LiDAR technology has been developed for detailed Earth's surface elevation data collection. LiDAR uses laser light to densely sample the Earth's surface to produce highly accurately measurements in x, y, and z dimensions, which permits the examination of the Earth surface elevation change accurately and rapidly. Coupled with advanced feature extraction techniques in remote sensing, airborne LiDAR data offer a great opportunity to detect sinkholes in a rapid, accurate, and cost-effective manner on an unprecedented regional, state, or national scale.

Project Summary

The main objective of this research project is to develop an accurate and rapid LiDAR-based sinkhole detection and mapping method and transfer the technologies to transportation agencies for implementation and workforce development. Specifically, this research project will: (1) develop a complete process and toolset for detecting and mapping sinkholes using airborne LiDAR data, (2) identify best practices for the effective implementation of a statewide sinkhole hazard management system (SHMS), and (3) develop a guidebook for LiDAR-based sinkhole detection and mapping. This study will use airborne LiDAR data in combination with auxiliary context information such as site and association to improve the accuracy of the existing morphological-based sinkhole detection methods, and implement these by developing a toolset that can be used in standard geographic information systems (GIS) such as ArcGIS. This toolset can provide an adequate degree of accuracy while maximizing the ability to assist inspectors with varying expertise.

Status Update

With the toolset for detecting and mapping sinkholes using airborne LiDAR being developed (see Figures 1 and 2), the project is conducting validation of the accuracy of detected sinkholes.

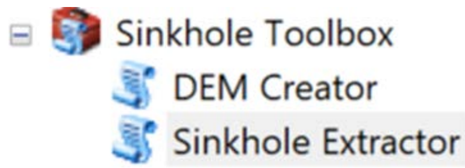

Figure 1. ArcGIS toolset for detecting and mapping sinkholes using airborne LiDAR data.

The next steps of the analysis will use the sinkhole data collected through ground survey as the ground-truth data and compare it to the sinkhole map generated through airborne LiDAR. Cohen's Kappa statistics will be used to measure the overall agreement between the predictive model (LiDAR sinkhole map) and a set of field-surveyed sample points (ground surveyed sinkhole maps). At an individual sinkhole level, the project team will use paired student t-test or Wilcoxon signed rank test to examine if LiDAR detected sinkholes and ground surveyed sinkholes have statistically similar morphometric measurements.

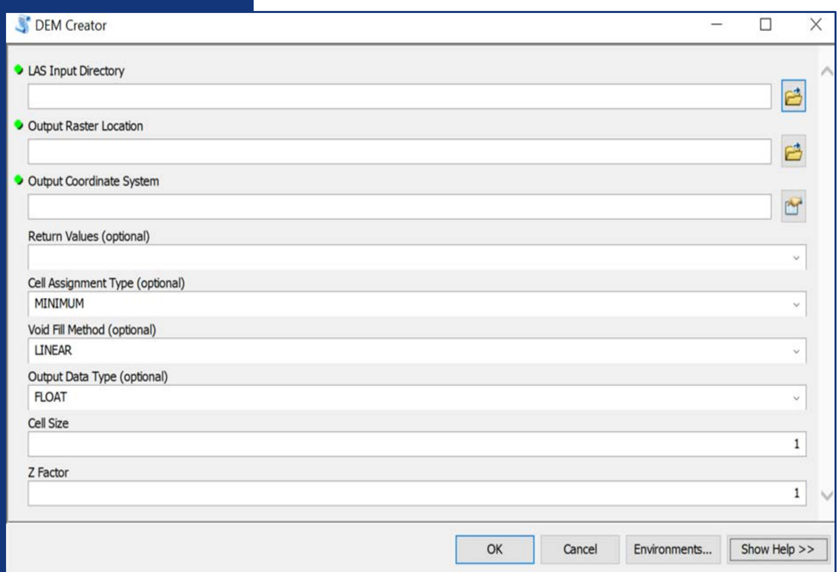

Figure 2. ArcGIS tool for processing raw LiDAR data to generate digital elevation models (DEMs) or digital surface models (DSMs).

Impacts

The main objective of this research project is to develop an accurate and rapid LiDAR-based sinkhole detection and mapping method and transfer the technologies to transportation management agencies for implementation and workforce development. This LiDAR-based sinkhole detection toolset will provide an adequate degree of accuracy rapidly while maximizing the ability to assist inspectors with varying expertise. As an additional benefit, playas and other surface depressions can be detected using this toolset.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Mr. Christopher Melson (Tran-SET Program Manager) directly at transet@lsu.edu.