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Airborne LiDAR acquisition, post-processing and accuracy-checking for a 3D WebGIS of Copan, Honduras

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ABSTRACT

Archaeological projects increasingly collect airborne LiDAR data to use as a remote sensing tool for survey and analysis. Publication possibilities for LiDAR datasets, however, are limited due to the large size and often proprietary nature of the data. Fortunately, web-based, geographic information systems (WebGIS) that can securely manage temporal and spatial data hold great promise as virtual research environments for working with and publishing LiDAR data. To test this and to obtain new data for archaeological research, in 2013, the MayaArch3D Project (www.mayaarch3d.org) collected LiDAR data for the archaeological site of Copan, Honduras. Results include: 1) more accurate archaeological maps, 2) identification of unrecorded archaeological features, 3) an assessment of combining LiDAR and ground-checking to increase data accuracy in ecologically and topographically diverse landscapes, and 4) new LiDAR datasets that are hosted in a 3D WebGIS and integrated with other archaeological data to enhance data accessibility and collaborative research.

1. Introduction

In May 2013, the MayaArch3D Project (www.mayaarch3d.org), under the direction of the German Archaeological Institute (DAI), commissioned an airborne LiDAR (Light Detection and Ranging) mission to collect remotely-sensed data of the landscape surrounding the UNESCO World Heritage site and ancient Maya city at Copan, Honduras. This mission had four objectives: First, generate new, more accurate archaeological maps for research and cultural resource management at Copan. Second, locate previously unrecorded archaeological structures or features. Third, combine LiDAR and ground-checked data to increase data accuracy in an ecologically and topographically diverse landscape. Fourth, develop new LiDAR datasets that can be integrated with other archaeological data and hosted in a 3D WebGIS to enhance data accessibility and research possibilities for researchers, cultural heritage managers, and the public, while at the same time protecting proprietary data by offering appropriate levels of access to different user groups.

Airborne LiDAR—a remote-sensing method that captures 3D data points from a laser mounted on an aircraft—is revolutionizing landscape archaeology (e.g., Chase et al., 2011, Chase et al., 2012, Chase et al., 2014a,b, Johnson and Ouimet, 2014, Prufer et al., 2015). LiDAR rapidly acquires high-resolution topographic data across landscapes, partly penetrates forest canopy and captures many features generally difficult to identify from a ground-perspective. These capabilities allow archaeologists to locate, map, and contextualize archaeological sites within their broader cultural and environmental landscapes and to generate high resolution Digital Terrain Models (DTMs) that are essential for accurate spatial and visual analysis. However, archaeological projects engage with widely varying environmental conditions, logistics, and research questions, and so the methods used to acquire, post-process, and integrate LiDAR data into archaeological projects vary across the globe (Opitz and Cowley, 2012).

What is common among researchers working with airborne LiDAR is that they conduct GIS analyses offline in 2D or 2.5D-views; online 3D analytical tools do not exist because the data are often too heavy for online visualization (Fernandez-Diaz et al., 2014; Rosenswig et al., 2014).

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The data must be optimized for online visualization but in doing so many details in the data are lost that are often necessary for analysis. Moreover, it is a particular challenge to make these data available to researchers or cultural heritage managers who may not have the technical tools or training to work with the data, yet whose work would benefit in efficiency and quality through access to more accurate information. There are many ways that aerial LiDAR data can enhance archaeological research and cultural heritage management. Archaeologists can use the data to improve their settlement pattern maps, to do hydrological modeling, test landscape reconstructions, and if integrated with 3D architectural data, run visibility studies. Cultural heritage managers can use it to monitor their archaeological sites for damage, or to label archaeological sites with information. Increasingly workshops and summer schools are training archaeologists to work with LiDAR data, but generally the possibilities for accessing or publishing LiDAR data are limited to 2D, non-interactive publications. Now that archaeologists can carry out 3D surveys and are becoming accustomed to 3D perspectives, they are calling for 3D or even 4D GIS tools (Bodenhamer et al., 2013; De Roo et al., 2013, 2014, Desjardin et al., 2014; von Schwerin et al., 2012). Such tools would enable researchers to integrate LiDAR data with other archaeological, architectural and environmental data into a Geodata Infrastructure (GDI) with interactive features for 3D analysis and visualization. Moreover, if archaeologists could integrate LiDAR data with their own datasets on a 3D WebGIS tool, they could carry out more accurate and comprehensive spatial analyses.

A central goal of the MayaArch3D Project (Billen et al., 2013, Loos et al., 2013, Reindel et al., 2013, 2014, von Schwerin et al., 2013) is to develop a 3D WebGIS tool for researchers to integrate and query complex archaeological data online. In 2012 the project adapted the DAI's archaeological database (iDAI.field) for Mesoamerican archaeology and to record 3D metadata and linked the database to a PostgreSQL with PostGIS database containing the project's 3D data. These are linked to a 2D Geobrowser and 3D Scene Viewer that give users access to view and analyze a test-set of data from Copan including shapefiles, 3D models, images, and attributes on archaeological sites, structures, architectural sculpture, monuments, and inscriptions. Queries of settlement plans, topographic features, orientation, and artifact distribution – that until now were carried out in 2D – are now possible in an online 3D environment with a 4D (temporal) time-slider. Additionally, 3D WebGIS visibility tools in the system enable the user to investigate in the 3D Scene Viewer, for example, the intervisibility of Copan's stelae, alignments of structures to topographic features, or alternate lighting on 3D models of sculpture to reveal details of inscriptions. The tool, "QueryArch3D-WebGIS", is a 3D WebGIS visualization and analytical tool that can be adapted for other archaeological sites worldwide.

Until 2013, the 3D data collected for QueryArch3D-WebGIS included reality-based 3D models of selected structures, architectural sculpture, and monuments at Copan ranging from 3 cm–0.5 mm resolution (Agugiaro et al., 2011; Remondino et al., 2009, see also: http://www.mayaarch3d.org/research/tools-in-development/3d-object-viewer), but the Digital Terrain Model (DTM) of the bare-earth features of the Copan valley landscape had been generated from scanned and georeferenced survey maps (Fash and Long, 1983) with accuracy ranging from 2 to 10 m. To analyze relationships between architecture and landscape in three-dimensions, the project needed a more accurate DTM of bare-earth, as well as a Digital Elevation Model (DEM) including bare-earth and architectural features; hence, the 2013 LiDAR mission.

This paper summarizes how these LiDAR data have been post-processed, partially ground-checked, and further processed for

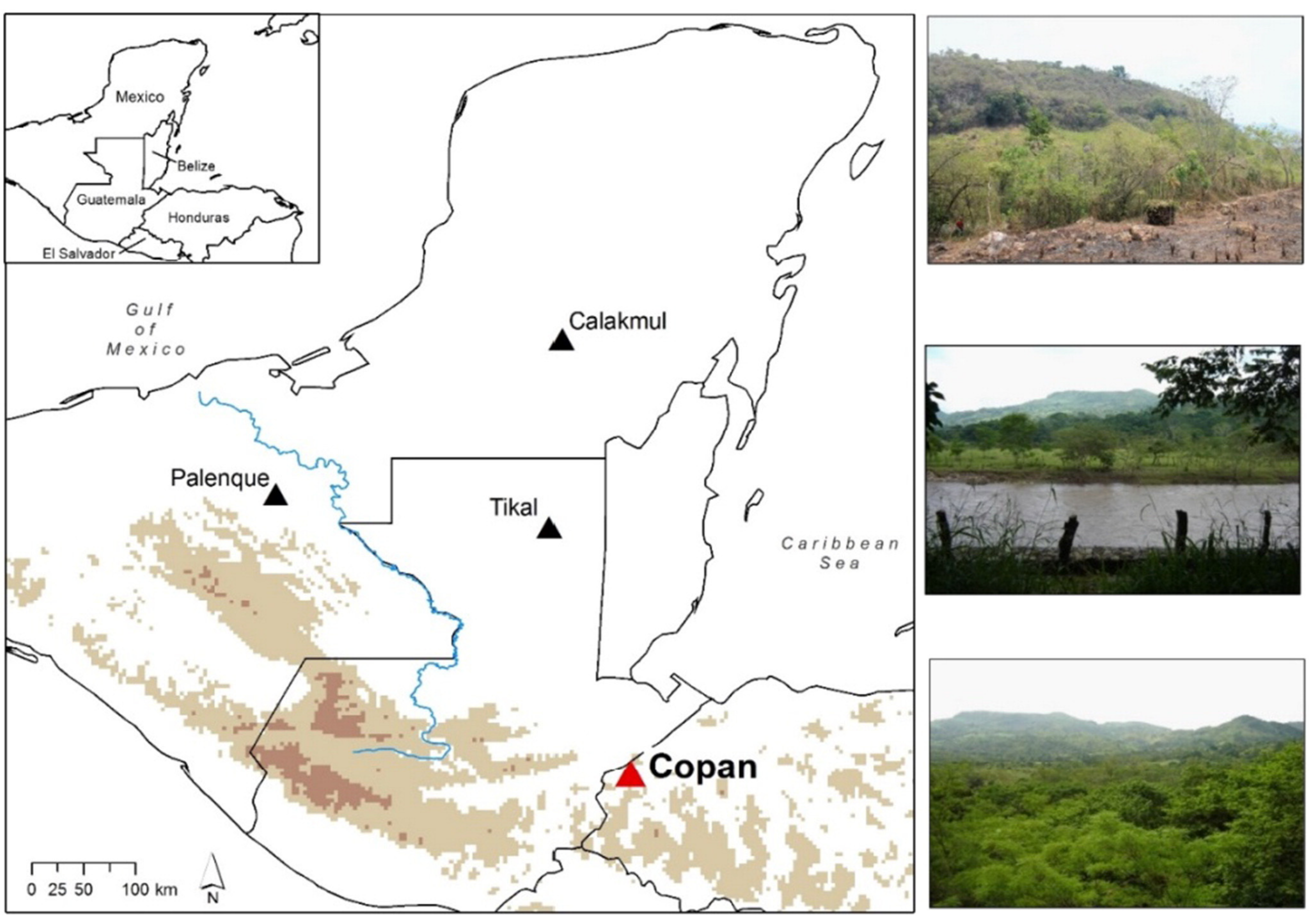

Fig. 1. Map of Copan's location on southeast periphery of Maya region.