Journal of Archaeological Science 53 (2015) 482–491

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Determining depositional events within shell deposits using computer vision and photogrammetry

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ARTICLE INFO

Article history:
Received 18 April 2014
Received in revised form
17 September 2014
Accepted 27 October 2014
Available online 13 November 2014

Keywords:
Deposition
Computer vision
Photogrammetry
Shell midden
Digitization
ImageJ

ABSTRACT

Shell deposits are notoriously difficult to excavate, analyze, and interpret as their makeup often precludes the application of traditional stratigraphic models. Using novel methods in which photographs of shell deposits are digitized and analyzed through image-pattern recognition, computer vision, and photogrammetry, a new avenue of research is suggested in which the processes and events responsible for shell deposits are elucidated. These methods are applied to two shell deposits from the southeastern United States and show that, despite overall morphological similarity in their final form, each was created in very different manners.

1. Introduction

Research into the depositional histories of shell middens is an important evidentiary line as it allows researchers to investigate site formation processes (Morey et al., 2002; Stein, 1992a,b; Stein et al., 1992), past climatic conditions (Arnold and Tissot, 1993; Cannon, 2000), and recurrent behavioral patterns (Erlandson and Rick, 1999; Tonner, 2005). These investigations often depend on stratigraphic analyses in which both small- and large-scale events are traced through time. Recent studies have applied novel techniques, including micromorphology of sediments, geochemical characterization, and detailed AMS dating and isotopic fractionation of individual specimens and deposits, to better characterize shell middens and to create both more rigorous and standardized methods of analysis (Bateman et al., 2008; Cannon, 2000; Colonese et al., 2011; Compton and Franceschini, 2005; Morey and Crothers, 1998; Villagran et al., 2009, 2011a,b). While these projects have greatly expanded our ability to interpret complex depositional events, they generally require extensive training, expensive equipment, and a substantial time commitment.

This paper presents a novel method of documenting, analyzing, and presenting stratigraphic data from shell middens through a computer-aided analysis of depositional morphometrics. Specifically, photographs of wall profiles are segmented into unique elements, often to the scale of individual shells, through both automated and user-driven object definitions. Segmenting entire deposits into individual elements allows detailed analyses using computer vision and photogrammetry software and algorithms. While the presented methods require a level of familiarity with imaging software as well as a moderate amount of labor to isolate and define elements within imagery, they are not unduly burdensome nor do they require equipment beyond a digital camera and computer. Additionally, these methods can be applied retroactively as long as imagery is of high enough resolution and coverage, meaning that past excavations can be reevaluated and compared with current projects.

The fields of computer vision and photogrammetry have advanced dramatically in recent years (Bernardini and Rushmeier, 2002; Carbonetto et al., 2004; Forsyth and Ponce, 2002; Grimson and Huttenlocher, 1990; Palmer, 1999) and are now being applied to archaeological data at an increasing rate. To date, the application of photogrammetric analysis within archaeology has been largely limited to the investigation of aerial photographs (Casana et al., 2014; Creamer et al., 1997; Lasaponara and Masini, 2007;

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http://dx.doi.org/10.1016/j.jas.2014.10.026
0305-4403/

Verhoven et al., 2013), objects (Gansell et al., 2014; Gilboa et al., 2013; Koutsoudis et al., 2013), rock art (Chandler et al., 2007; Domingo et al., 2013; Sanz et al., 2010), and architecture (Winter-Livneh et al., 2013). These data can be further investigated through the application of computer vision software, which utilizes geometric statistics and spatial algorithms to detect and define patterns and discontinuities (De Reu et al., 2013; Koutsoudis et al., 2013). In each of these studies, the application of computer-aided recognition software produced rigorous datasets which were capable of being standardized and shared among a community of interested individuals as well as generating novel evidentiary lines leading to innovative interpretations and new lines of research. To the extent that data acquisition was automated or based on digital rather than analog methods, analysis time often decreased even as accuracy increased. These benefits, as well as the increasing availability and affordability of the hardware and software needed to capture, manipulate, and manage visual and spatial data, suggests that computer-aided analyses of morphometrics will continue to gain importance and applicability within many disciplines, including archaeology.

While still in its nascent stages, the few examples in which computer vision and photogrammetry have been applied to recording and analyzing ongoing excavations (Dellepiane et al., 2013; De Reu et al., 2013) have proven remarkably effective and suggest a new direction of research that this study builds upon. Specifically, within this paper, I suggest that methods utilizing computer vision and photogrammetry can be beneficially applied to stratigraphic analysis, particularly of shell middens as these deposits consist of numerous individual objects whose combined morphological and locational profiles can suggest overall patterns which are otherwise difficult, if not impossible, to document and characterize. Using readily available equipment and software, I offer methods of analysis, which can be widely applied and produce standardized and transferrable datasets. I operationalize and test these methods through two case studies drawn from the archaeological record of the American southeast. By applying these methods, I find that these two sites, which are morphologically very similar to one other, are nonetheless deposited in very different manners, which speaks to the types of events occurring at each.

2. Study area

Two moderate sized shell deposits located on St. Catherines Island, Georgia (USA) were the subject of a series of surveys and excavations between 2005 and 2011 by the American Museum of Natural History (AMNH) (Fig. 1). Located on opposite sides of the island and separated by a shallow depression, the deposits are circular in shape, measuring roughly 70 m in diameter, with broad shell-free plazas in their interiors (Sanger and Thomas, 2010) (Fig. 2). Each deposit consists of a range of mollusks but is largely made up of eastern oyster (*Crassostrea virginica*), quahog (*Mercenaria mercenaria*), Atlantic ribbed mussel (*Geukensia demissa*), knobbed whelk (*Busycon carica*), and periwinkle (*Littoraria irorata*). The deposits are part of the Larger Late Archaic Shell Ring tradition, which includes more than forty circular or C-shaped shell deposits found along the coastline from South Carolina to Mississippi (Russo, 2006). Tens of thousands of pottery sherds were recovered from each of the rings on St. Catherines Island (Sanger et al., 2012) along with lithic tools and debris (Ogden, 2011), carved bone and shell objects, and a remarkable assortment of faunal and botanical remains (Colaninno, 2010). The interior plazas of both rings are marked by numerous pits, likely used for storage, that are distributed in non-random patterns (Sanger and Thomas, 2010). Numerous radiocarbon results suggest that the two rings have a significant temporal overlap with one another and generally date to ca. 2200–1900 cal. B.C. (Kennett and Culleton, 2012; Sanger and Thomas, 2010: 67).

Interpretations of shell rings are deeply contested as researchers disagree to the extent that the sites were formed by refuse generated through daily meals, intermittent ritual events, or a mixture of activities (Russo, 2004; Saunders, 2004a,b; Thompson, 2006; Thompson and Andrus, 2011). While seasonality studies have proven useful in investigating the timing of shell deposition (Thompson and Andrus, 2011), most shell ring

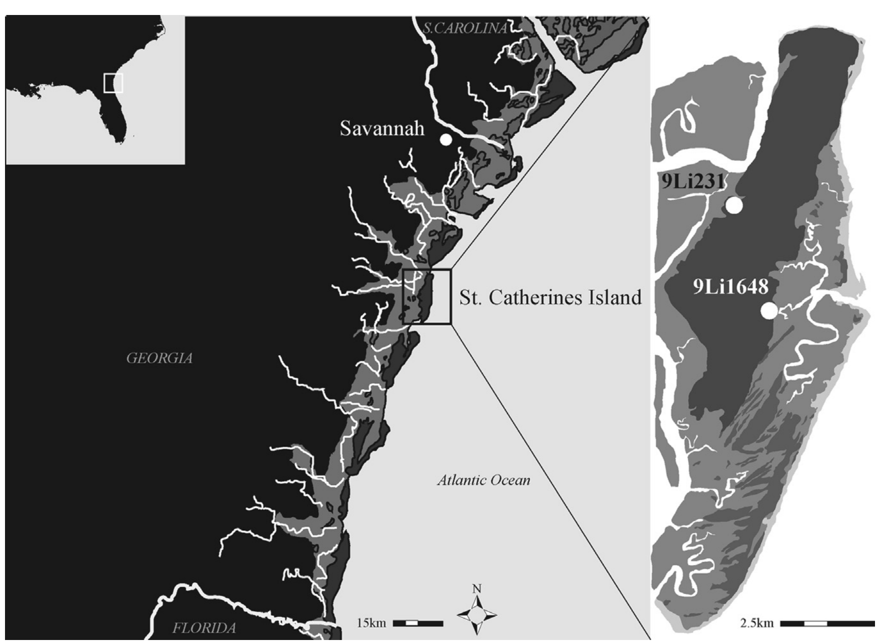

Fig. 1. Overview of southeastern U.S. coastline with study area highlighted.