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Digital morphometric analysis of Upper Palaeolithic beads: Assessing artifact variability with user-friendly freeware

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ABSTRACT

Based on a case study of over 400 basket-shaped beads from Early Upper Palaeolithic (Aurignacian) deposits at four sites in the Aquitaine region of France, this article presents the results of morphometric analysis based on digital photographs using a freeware program developed in the biological sciences. The program, *Tomato Analyzer 3.0* presents a number of advantages in terms of portability, cost, efficiency, and ease-of-use. Adapting the program to the analysis of archaeological artifacts does require some modifications to the original protocol, which are described in this article. The morphological attributes assessed by the program are presented, as are the preliminary results of the case study. The ability of the program to quantify artifact color is briefly introduced, as is the potential applicability of the program to the study of other artifact-types.

1. Introduction

Digital analysis of artifact morphology has become an increasingly affordable and accessible method of archaeological inquiry in recent years. A wide range of digital options exists for the quantitative characterization of artifact morphology, and these options vary in terms of portability, cost, efficiency, and ease-of-use. This article presents a low-cost, efficient, highly portable, and user-friendly method for the morphometric analysis of archaeological artifacts. A case study of mammoth-ivory and talc beads from Early Aurignacian layers at four sites in southwestern France is employed as an example. The software uses digital images of artifacts to derive data on more than twenty-five morphological attributes in addition to morphometric outline data in the form of (x, y) coordinates, all of which can be exported as .csv files. The program can also be used in the quantitative characterization of artifact color. The method may be adapted to the analysis of artifacts of nearly any size, ranging from microscopic specimens to very large artifacts or features, if an undistorted digital image can be captured and the artifacts present a continuous, closed outline.

The freeware program (*Tomato Analyzer 3.0*) was developed for the purpose of genotype/phenotype studies in the biological sciences, and has been adopted and employed in numerous peer-reviewed publications in recent years (Brewer et al., 2006; Darrigues et al., 2008; Gonzalo et al., 2009; Gonzalo and van der Knaap, 2008; Hurtado et al., 2013; Merk et al., 2012; Panthee et al., 2013; Rodríguez et al., 2010a; Rodríguez et al., 2011). The present case study demonstrates its suitability to the analysis of archaeological artifacts and provides details on the protocol of adapting the program to the study of artifacts. The software allows for a high level of control of the attributes measured and the placement of attribute markers, and the only additional equipment required is: a digital camera and tripod, a computer with a Microsoft Windows operating system, and basic photo-editing software.

The case study was conducted on four assemblages of the "basket-shaped" ivory and soapstone beads (Fig. 1) typical of the Early Aurignacian of southwestern France. Morphological standardization is a salient feature of Early Upper Palaeolithic beads, frequently invoked with reference to production organization and the successful communication of culturally-specific information (Kuhn and Stiner, 2007; Vanhaeren, 2005; White, 1989, 2007; Wolf, 2015). In the case of perforated natural objects such as shells and teeth (low-modification ornaments), this morphological standardization is occurs naturally, though it is often augmented by human selection processes (Stiner, 2006, 2014; Vanhaeren, 2002). In the case of high-modification ornaments such as ivory and talc beads, standardization is imposed by the bead-maker, and the study of morphological variation may offer insight into the organization of production and patterns of regional circulation (Heckel, in review). Inter-site variation in bead assemblages is therefore of paramount interest in the case study. It has been previously hypothesized that certain sites, specifically those in the Castel-Merle *vallon* (Abri Castanet, Abri de la Souquette, and Abri Blanchard) served as significant "workshops" for intensive bead production and for the exchange of

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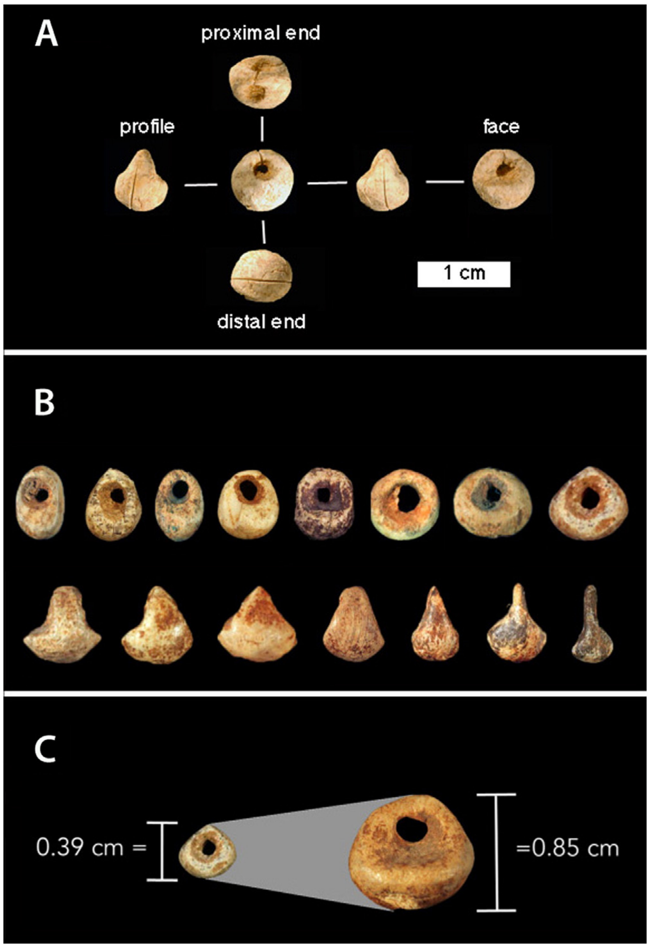

Fig. 1. A) Image of a basket-shaped bead from several perspectives, indicating the face, profile, proximal end, and distal end, which will be referred to in the text. B) Representation (not to scale) of the variation in face morphology (top row), and profile morphology (second row). C) The range of variation in Maximum Height of beads included in the case study, following removal of outliers (z-score +/−3) subsequent to analysis in *TA3.0*.

ornaments and other materials during periods of aggregation (Taborin 1993a; 1993b, White, 1989, 2007). The data collected in the case study present the opportunity to rigorously test the hypothesis that bead morphology does not vary significantly based on site (see Heckel, in review).

To date, few studies have examined morphological variation in this class of artifact beyond basic measurements. White (1989, 2007) has quantified variation in the morphology of Early Aurignacian basket-shaped beads in terms of attributes measurable by hand (length, width, and thickness) and has demonstrated compelling levels of standardization among assemblages from several sites. Wolf (2015) has recently published the results of detailed analyses of individual beads from several sites in southwestern Germany, where hundreds of high-modification ivory beads have been recovered in Early Aurignacian contexts. These small artifacts present a number of challenges to morphometric analysis. In the case of the basket-shaped beads examined in this study, the artifacts are curated at numerous institutions in North America and Europe, and highly portable equipment is required. They are small (rarely above 7 mm in greatest dimension) and sub-spherical in shape. The polished, rounded surfaces and absence of traditional landmarks presented numerous problems in attempts at 3-D scanning and photogrammetry (as attempted by the author). A number of approaches based on digital photographs were applied in a pilot study, and the *Tomato Analyzer* freeware proved ideal in terms of portability, cost, efficiency, ease-of-use, and the quality of the data obtained. In contrast to other freeware programs such as *Image-J*, *MorphoJ*, and the *SHAPE* suite of software, for example, *Tomato Analyzer* requires much less image-processing prior to analysis, no knowledge of computer programming languages. Additionally, the data is output in the form of specific shape attributes (in addition to morphometric outline data) in .csv format that requires no additional treatment or manipulation. While other programs do offer specific advantages that may be ideal in certain instances, *Tomato Analyzer* minimizes the amount of time and computer-programming skills required to go from digital image to data.

2. Materials and methods

2.1. Materials

As noted above, the materials required are the *Tomato Analyzer 3.0* (*TA3.0*) software, a digital camera, a tripod, a computer with a Microsoft Windows operating system, and basic photo-editing software. A photo scale and a contrasting background in an appropriate material will also be necessary, and additional lighting may be helpful in some research settings. *TA3.0* was developed at the Ohio Agricultural Research and Development Center at Ohio State University and can be downloaded from the following website: http://oardc.osu.edu/vanderknaap/tomato_analyzer.php . Two user's manuals are available for download at the same site, and will be referred to later in this text (Rodríguez et al., 2010b; Strecker et al., 2010).

In the case study, a total of 404 basket-shaped beads from the Early Aurignacian levels at four sites in southwestern France (Abri Castanet, Abri de la Souquette, Grotte des Hyènes at Brassempouy, and Grotte d'Isturitz) were analyzed. Table 1 lists the specimens by site and raw material, and the locations of the sites are shown in Fig. 2. Though broken beads and fragments of beads are present in these assemblages, only whole, unbroken beads were used for morphological analyses.

2.2. Methods

TA3.0 was designed to analyze tomatoes and other fruits, which are cross-sectioned and placed (with a photo scale) on a flatbed scanner for imaging (Rodríguez et al., 2010b). With some exceptions, such as artifacts that will lie flat on a scanner-bed, this is not a feasible method for imaging archaeological artifacts. Adapting *TA3.0* to the analysis of artifacts therefore requires some adjustments to the original protocol. The methods employed in the case study are described in detail in the sections that follow, in three stages of analysis: Artifact Imaging and Slide Creation (Section 2.2.1), Using *Tomato Analyzer* to Collect and Export Data (Section 2.2.2), and Using *Tomato Analyzer* to Assess Artifact Color (Section 2.2.10). The latter did not feature in the case study and is only briefly presented.

2.2.1. Artifact imaging and the creation of slides

For artifacts that can be scanned on a flatbed scanner to produce images suitable for analysis, the instructions in the user's manual can be followed exactly. This is not the case for basket-shaped beads, and digital photographs were used in place of scans, requiring certain adjustments to the analysis protocol. In capturing digital images for use in *TA3.0*, four primary factors are of importance: even lighting, a

Table 1
Beads analyzed in the case study listed by site and raw material. The category "other" includes bone, antler, limestone, and amber.

	Ivory	Soapstone	Other	Total n =
Castanet	110	16	7	133
La Souquette	149	25	11	185
Brassempouy	24	18	0	42
Isturitz	34	8	2	44

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