W2 A Computational Framework for Skeletal Age-at-Death Estimation Using Laser Scans of the Adult Pubic Symphysis: Theory, Methods, and Software

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After attending this presentation, attendees will understand state-of-the-art skeletal age estimation, the problems forensic anthropologists face when estimating age by conventional methods, the needs of the medicolegal community, and the potential for advancing the field using new shape-based methods. Attendees will receive instruction in three new methods that apply numerical shape algorithms to laser scans of the skeletal age indicator. Attendees will also receive hands-on training in using the equipment, software, casts, and data.

This presentation will impact the forensic science community by delivering instruction on implementing three new fully computational methods for age-at-death estimation from skeletal laser scans that produce estimates that closely approximate true age, with minimal risk of subjectivity or low-method/observer-induced error.

The estimation of age-at-death in forensic anthropology represents an essential component of the biological profile, providing information on the individual that is key to medicolegal case identification. Skeletal indicators of age are widely used to estimate age-at-death from adult remains in this casework context. Of the pelvic, thoracic, and cranial features for which age-related change is known, the pubic symphysis remains the preferred, most frequently studied indicator. Common practice requires the macroscopic comparison of the bone surface morphology to a set of population-specific criteria that represent a series of pre-defined scores or phases. The case-specific age-at-death is then estimated from an age range previously associated with the assigned score or phase. While the simplicity of this approach is attractive, the limitations of this kind of visual analysis are well-documented across the field, not only for age-at-death estimation and but also for other parameters of interest to the biological profile. In general, this methodology is known to introduce a large degree of subjectivity and intra/inter observer-related error. For age estimation especially, these problems have been shown to variably impact the reliability and repeatability of results; therefore posing, significant challenges to meeting current medico-legal standards of evidence and successful forensic case identification.

In response to these concerns, an alternative, fully computational approach to the macromorphoscopic assessment methods traditionally applied to skeletal indicators of age and, specifically, to the pubic symphysis has been proposed. It is argued that accurate, precise, and objective age estimates can be obtained by sourcing three-dimensional coordinate data from laser scans of the pubic symphysis, subjecting these data to shape-analysis algorithms, and combining the resulting shape measures in multivariate regression models. In recent publications the value of this novel approach for contemporary skeletal analysis have been demonstrated. Using Bass Collection samples, forensic cases, and the Suchey-Brooks and McKern & Stewart casts, these methods produce estimates that differ from the exact age-at-death by ≈11.72 ± 0.97 years. To standardize implementation, a protocol for

data collection and extraction has been formalized. The software, forAge, was developed to facilitate accurate and efficient method application among forensic practitioners, whose levels of familiarity with laser scanning technology, statistical computing, and the morphological characteristics of the pubic symphysis may vary.

This workshop will introduce forensic practitioners to the theory that underlies the methods and provide laboratory instruction on its implementation. It will also be broadly applicable to other scan and shape-related research. To contextualize the work, a review of the current state of the art of age-estimation, the demands that working within the medico-legal context places on forensic case analysis, and the advantages that these methods offer for estimation, evidence, ease of use, and data preservation or sharing. The anatomical properties of pubic symphyseal morphology that make this indicator well-suited to shape-based inference as well as the mathematical theory that supports the calculation of our shape measures will be explained. The appropriate use of these measures and clarification of how an estimate of age is generated will be discussed. To provide practical instruction, protocols for laser scan collection using the NextEngine scanner, scan editing and manipulation using ScanStudio or Meshlab, extraction of shape information as three-dimensional coordinates, file storage of these data, and for standardization and processing of the coordinates prior to analysis will be demonstrated.

The detailed implementation of the following will be discussed: (1) the *SAH-Score* method that captures the variance on the symphyseal face to capture the gradual flattening of the surface associated with aging;[1] (2) the thin plate splines method that determines the bending energy required for transforming a perfectly flat, infinitely thin plate to match the surface of a pubic symphysis scan;[2] and, (3) the ventral curvature method that quantifies the progressive formation of a rim around the entire symphyseal surface and its later erosion.[3] A tutorial on the use of the forAge software for these analyses and to produce age-estimates via multivariate regression will be provided. With France Casting, the age-determination casts for calibration and validation will be discussed. Finally, recommendations for data collection in the field and laboratory will be offered. Workshop attendees will have the opportunity to train on the scanning equipment and software and produce age estimates directly from specimens and coordinate data in various stages of processing.

Reference(s):

1. Slice D, Algee-Hewitt, B. 2015. Modeling Bone Surface Morphology: A Fully-Quantitative Method for Adult Age-At-Death Estimation Using the Pubic Symphysis. J Forensic Sci 2015: 60(4): 835-843.
2. Stoyanova D, Algee-Hewitt B, Slice D. An Enhanced Computational Method for Age-At-Death Estimation Based on the Pubic Symphysis Using 3D Laser Scans and Thin Plate Splines. Am J Phys Anthropol 2015: 158: 431-440.
3. Stoyanova D, Algee-Hewitt B, Kim J, Slice D. A Computational Framework for Age-at-Death Estimation from the Skeleton: Surface and Outline Analysis of 3D Laser Scans of the Adult Pubic Symphysis. J Forensic Sci 2016: in review (submitted April. 26, 2016).

Age-at-Death Estimation, 3D Laser Scans, Computational (Shape) Analysis