H80 Multi-Factorial Estimation of Skeletal Age- at-Death Using the Sugeno Fuzzy Integral

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After attending this presentation, attendees will understand the basic principles of how to use the fuzzy integral to obtain a multifactorial age-at-death estimation for a single skeleton.

This presentation will impact the forensic science community by providing a new standardized method for combining multiple indicators of age along with their respective accuracies, into a single, accurate, age-at-death estimation. It will also cover a feature-based method to determine the degree to which age-at-death fuzzy set results belong to different anthropological classes. The final topic is an OWA-based contrast approach to measure the amount of specificity in an age-at-death fuzzy set.

Accurate and precise estimations of chronological age-at-death based on skeletal remains are vital in forensic anthropological analyzes to help narrow the search for potential missing persons and to aid in the identification of the skeleton. Combining multiple indicators of biological age (multifactorial method) from different regions of the skeleton provide a more accurate estimation of chronological age than using any single indicator. However, most currently published multi-factorial methods are not appropriate for forensic anthropology because they cannot be applied to a single skeleton, do not provide a confidence in the point estimate or prediction interval, or are restricted to a certain types of age indicators. Currently there are no "best practice" guidelines in forensic anthropology for combining multiple indicators of age. As a result, forensic anthropologists frequently develop their own guidelines for combining multiple indicators, often based on their past experience and the skeletal remains present for a specific case. A standardized method for combining multiple indicators of age from a skeleton into a single, accurate, and repeatable age-at-death estimation is needed in forensic anthropology.

A novel multifactorial approach is presented that uses the Sugeno fuzzy integral to analyze skeletal age and takes into account as much information as possible, including the accuracy of the method and the quality of the bone, to reach a decision about a hypothesis. Fuzzy integral acquired fuzzy sets are then used to provide results about the age-at-death estimation that are reproducible and can be understood by different scientists. Using this approach, forensic anthropologists obtain an age-at-death estimation, a measure of the confidence in the estimation, and additional results (numeric, graphical, and linguistic) regarding the type of graph and degree of specificity of the age-at-death estimation. This method has multiple advantages over other multifactorial methods. The procedure allows investigators to use nearly any well established and tested age-at-death indicator methods and fuse the information about the accuracy of the methods with other types of quantifiable information that cause uncertainty in the age-at-death estimation. No other method allows for the fusion of additional information such as the quality of the bone, the appropriateness of the method for the target age group, or inter-observer error in the methods used. Other advantages of the fuzzy integral method are that it does not require the use of a population so it can be easily used for a single skeleton, it can be used for both adult and immature skeletons, it can be customized to meet the investigator's needs on specific cases, and it provides informative graphs and a standardized reproducible way to generate linguistic descriptions of age-at-death estimations.

To demonstrate the use of the fuzzy integral method, we apply it to three aging methods commonly used by forensic anthropologists (pubic symphysis, auricular surface, and cranial suture closure) on a known-age skeletal sample from the Terry Anatomical Collection. The research shows that the fuzzy integral method produces results that are more accurate with smaller intervals than single indicator methods. Unlike other multi-factorial methods, the fuzzy integral approach allows investigators to estimate age-at-death for a single skeleton by applying the well-established age methods they are comfortable using and that are available to them based on the bones present, the condition of the bones, and the equipment they have accessible. Furthermore, unlike other methods, the fuzzy integral method allows the investigator to incorporate additional information about the quality of the bone or any other quantifiable variable about the uncertainty of the method.

Forensic Anthropology, Age-at-Death, Sugeno Fuzzy Integral

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