A114 Fuzzy Inference System (FIS) as a Novel Statistical Method for Forensic Ancestry Estimation

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After attending this presentation, attendees will understand how fuzzy set theory may assist in ancestry estimation and the advantages of this type of analysis in the field of anthropology.

This presentation will impact the forensic science community by presenting a previously untested statistical technique for the process of forensic ancestry estimation that is built to accommodate such issues as multiple group affiliation and uncertainty in membership classification.

Fuzzy set theory, or fuzzy logic, is a statistical concept developed in the field of engineering.[1] Fuzzy logic is based on the premise that distinct groups are not an accurate reflection of reality due to inherent uncertainty and variation. Individuals may not perfectly belong to any delineated group, or they may identify with multiple groups. Individuals tested are given a membership value, or function, between 0.0 (no membership) to 1.0 (full membership), similar to posterior probabilities that are often presented as part of discriminant function analyses; however, fuzzy logic does not estimate the probability that an individual is part of a group, but rather estimates the degree of membership for each of the groups based on similarities.[2] Previous biological anthropological research has examined its utility in understanding group affiliation of paleoanthropology, primate behavior, and age estimation.[3-5] The accommodation of uncertainty and the analysis of membership to multiple categories makes this statistic an appealing choice for use in estimating the ancestry of individuals with diverse population histories. The objective of the present study is to examine this statistical technique's utility in producing an ancestry estimate for use in the biological profile.

Dental morphological data on eight traits collected by Tsuneiko Hanihara on global populations organized into three major geographic groups (i.e., African, European, Asian) commonly employed in forensic anthropology were used for the present analysis. These traits were not correlated with each other and previous research has shown utility of these traits in distinguishing between populations. This dataset was utilized as a starting point from which to create the system's rules and as a testing sample of the constructed equations. Data collected on Hispanic individuals from New Mexico and Mexico were also used to examine the method's efficacy in estimating individuals of admixed ancestry. A Mamdani FIS analysis in the MATLAB® (R2016a) Fuzzy Logic Designer package was utilized in the present analysis. This FIS uses a system of IF-THEN rules based on *a priori* knowledge to "fuzzify" the data and then "defuzzify" it around the centroid, producing a single membership score. These rules were based on population frequencies of traits gathered from the literature.[6,7] Each individual is then assigned a membership group output that corresponds to a particular ancestral group (e.g., 0.2 would suggest European-derived).

Preliminary results suggest potential utility of this statistic in estimating ancestry; however, the nature of the dataset used in the present analysis precludes a complete picture of its efficacy as the results tend toward a defuzzified membership score of 0.5. Patterns are seen that suggest the FIS is distinguishing between simple and complex dentitions. Any morphological complexity drives membership scores toward African- or Asian-derived estimates. There is also difficulty allocating between African- and Asian-derived populations due to crown complexity. These issues may be due to the use of dichotomized variables and overlapping frequencies of traits in multiple populations. The greatest success occurs when distinguishing between European and African/Asian-derived populations due to European-derived individuals typically having the least complex dentitions.

Breaking down each trait into separate grades, inclusion of more traits, such as enamel extensions and molar crenulations, and refinement of IF-THEN rules may improve the success of this method. Future tests will include a larger, more inclusive dataset to capture the range of variation present in the dentition as well as explore the effects of missing data. While this study represents an early use of fuzzy logic in forensic anthropology, there is great potential to explore this and other statistical methods to improve estimations of ancestry as part of the biological profile.

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