A62 Geographic Information Systems and Spatial Analysis – Part 1: Quantifying Fingerprint Patterns and Minutiae Distributions

Ryan J. Stanley, BS, Western Oregon University, 345 North Monmouth Avenue, Monmouth, OR 97361; Emma K. Dutton, PhD, Oregon State Police, Forensic Services Division, Oregon State Police General Headquarters, 255 Capitol Street NEt, Salem, OR 97310; Stephen B. Taylor, PhD, Western Oregon University, Division of Natural Science and Mathematics, 345 North Monmouth Avenue, Monmouth, OR 97361; and Patrick R. Aldrich, MS, and Bryan E. Dutton, PhD, Western Oregon University, Department of Biology, 345 North Monmouth Avenue, Monmouth, OR 97361*

After attending this presentation, attendees will understand how Geographic Information Systems can be used to quantify spatial relationships in fingerprints. Furthermore, attendees will learn how custom GIS tools can be used to run fingerprint matching simulations and calculate false match probabilities.

This presentation will impact the forensic science community by making a significant contribution toward forensic practice in the laboratory by establishing a degree of certainty for fingerprint uniqueness and by defining the limits for latent print identifications.

A Geographic Information System (GIS) is a collection of hardware and software components that integrate digital map elements with relational database functionality. GIS data is typically captured in the form of either raster grids (i.e., pixels) or vector features (i.e., points, lines, and polygons) with points in space using x, y and sometimes z coordinate values. While GIS is widely used for crime pattern analysis and emergency management applications, its spatial analysis capabilities have not been applied to fingerprint characterization and pattern recognition. The methodologies presented herein provide a framework for cataloging, characterizing, and quantifying fingerprint patterns and minutiae using custom and standard GIS tools. The power of a GIS is in its ability to allow users to integrate, store, edit, and analyze spatial features and relationships, as well as query and display spatial information. Such systems include traditional mapping capabilities (e.g., land surveying and aerial photography) and provide users with tools to interactively search and analyze spatial information. GIS is increasingly being applied to a field of study referred to as spatial analysis, which involves analyzing the positions, patterns, and relationships between objects located in a defined space. Collections of objects in a defined space may be linked or associated with one another geometrically or by functional associations. Given that fingerprint analysis and latent print identification is based on spatial associations between minutiae and ridge lines (e.g., ridge counts and minutiae locations, directions, and distributions), GIS-based tools for spatial analysis are a natural extension. Utilization of GIS in conducting dactylographic research is particularly appealing given that fingerprint minutiae and ridge patterns are very analogous to geometries reflected in Earth surface topography, a traditional focus of GIS.

The Python programming language was used in conjunction with GIS software to create custom tools and automate complex project workflows. Python tools designed for fingerprint data collection, pattern characterization, and statistical analysis were created and deployed within a GIS toolbox. Initial minutiae detection was conducted using latent fingerprint processing software, with results exported as ANSI/NIST Type-9 records. A tool was created to parse finger and minutiae information from a Type-9 text file and transpose the data into Cartesian coordinate graph space. Coordinate referencing places the image and minutiae in quadrant I (+,+) of a Cartesian coordinate system. The Type-9 ULW summary output file was georeferenced to adjust the X-axis and Y-axis origins -100mm from the fingerprint core. Thus, all cores of each fingerprint image were positioned at (100,100mm) within Cartesian coordinate space. Once imported and registered in GIS, minutiae were subjected to an additional level of quality control and secondary processing. Minutiae were re-positioned to more accurately mark their placement and falsely marked minutiae were corrected. Minutiae files were aggregated within a GIS geodatabase for querying and spatial analysis. Custom GIS tools were built and implemented for extracting specific fingerprint metrics. A ridge counting tool provides the capacity to count fingerprint ridges between all minutia, and a ridge skeletonizing tool converts ridges into vector polylines, which allows for additional levels of analysis compared to raster grids. Pattern characterization tools were created to analyze point density and percent minutiae frequency by spatially intersecting minutiae with pre-established templates, such as a 2mm grid overlay and a core-centered "dart board" diagram. Distance and azimuth (0-360 degrees) from the finger core were calculated for all minutiae within the database. Using these values, minutiae were combined by print type and summarized in rose diagrams, which provide succinct figures for displaying minutiae distributions relative to the core. In addition, a Monte Carlo simulator was built to randomly sample n minutiae from a given fingerprint and iteratively match said minutiae against a database of fingerprints. This statistical analysis tool creates data suitable for building false match probabilities. Impacts of this work include making a significant contribution toward forensic practice in the laboratory by establishing a degree of certainty for fingerprint uniqueness and by defining the limits for latent print identifications.

This project was supported by Award No. 2009-DN-BX-K228 awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice. The opinions, findings, and conclusions or recommendations expressed in this publication/program/exhibition are those of the author(s) and do not necessarily reflect those of the Department of Justice.

GIS, Fingerprint, Analysis

 ** Presenting Author*