Watersheds, Volcanoes, and Fingerprints: Applications of Geographic Information Systems in the Earth Science Program for Undergraduate Research at Western Oregon University

Steve Taylor, Brandon Snook Ryan Stanley, Bill Vreeland
Earth and Physical Sciences Department
Western Oregon University
Monmouth, Oregon 97361

WESTERN OREGON UNIVERSITY

Geology & Earth Science

- Introduction to Geographic Information Systems

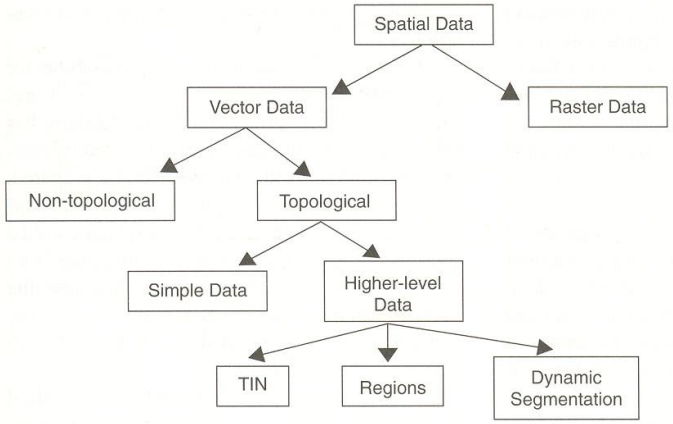
GIS RESEARCH APPLICATIONS AT WOU

- Watershed Science
  - Geomorphology / Basin Morphometry
  - Plant Distribution Patterns
  - Land-Use / Land Cover Analysis
  - Rapid Bio-Assessment / Fish Surveys
- Cinder Cone Analysis at Newberry Volcano
- Fingerprint Analysis / Forensic Science

INTRODUCTION
What is GIS?

Geographic Information Systems (1960's-Present)

- Roots: SYMAP, 1966, "Harvard Graphics Lab"
- ESRI spinoff – Industry leader since 1980's
- Computer hardware and software
- Digital cartography
- Relational Database Management System
- Spatial, location-based, information
- Creative and knowledgeable users



Spatial Data Input	1. Data entry: use existing data, create new data 2. Data editing 3. Projection and re-projection 4. Geometric transformation
Attribute Data Management	1. Data entry and verification 2. Database management
Data Display	Use of maps, charts, and tables
Data Exploration	1. Attribute data query 2. Spatial data query 3. Geographic visualization
Data Analysis	1. Vector data analysis: buffering, overlay, distance measures, map manipulation 2. Raster data analysis: local, neighborhood, zonal, global 3. Terrain mapping and analysis 4. Spatial interpolation: global, local 5. Regions-based analysis 6. Network analysis
GIS Modeling	1. Binary models 2. Index models 3. Regression models 4. Process models

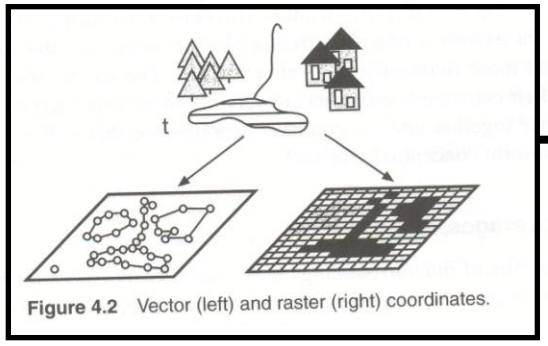
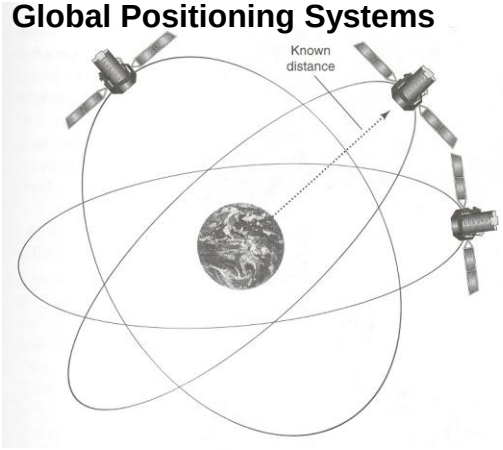


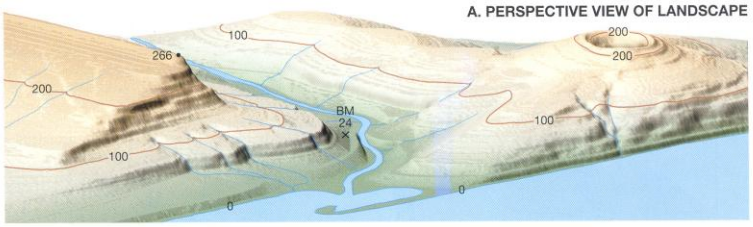
Figure 4.2 Vector (left) and raster (right) coordinates.

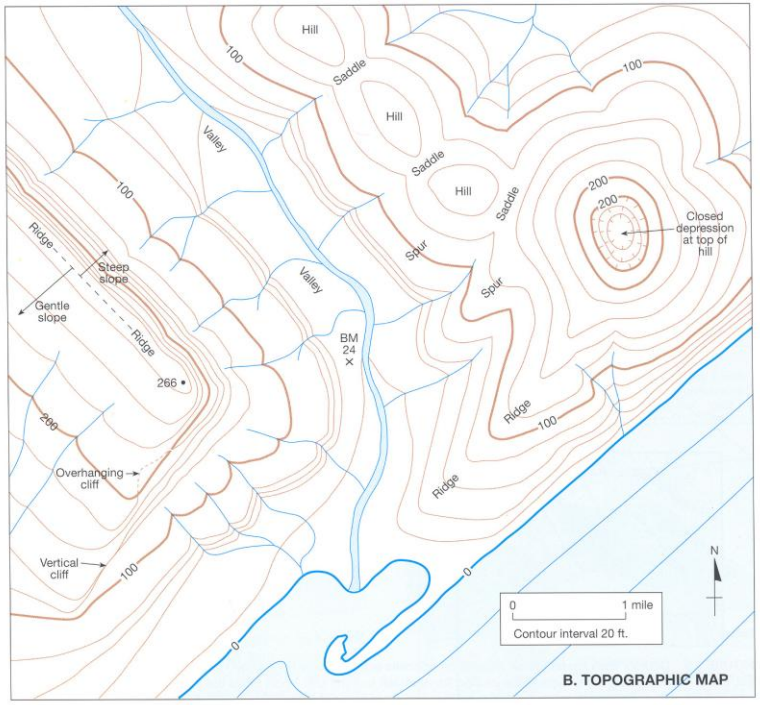
Table 1.1 GPS-linked spatial and aspatial data

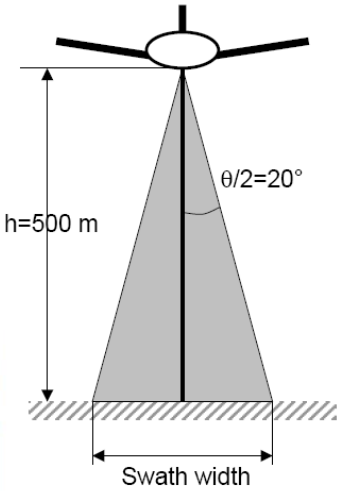
	Spatial Data		Aspatial Data		
Object	*x*-Coordinate	*y*-Coordinate	Height (ft)	Age (years)	Species
1	3	3	25	81	Pine
2	6	2	14	42	Fir
4	5	5	23	51	Spruce
5	7	6	14	33	Spruce
6	8	4	25	94	Pine
7	9	7	24	82	Fir
8	6	8	21	63	Aspen
9	5	9	18	67	Pine
10	4	1	23	71	Spruce

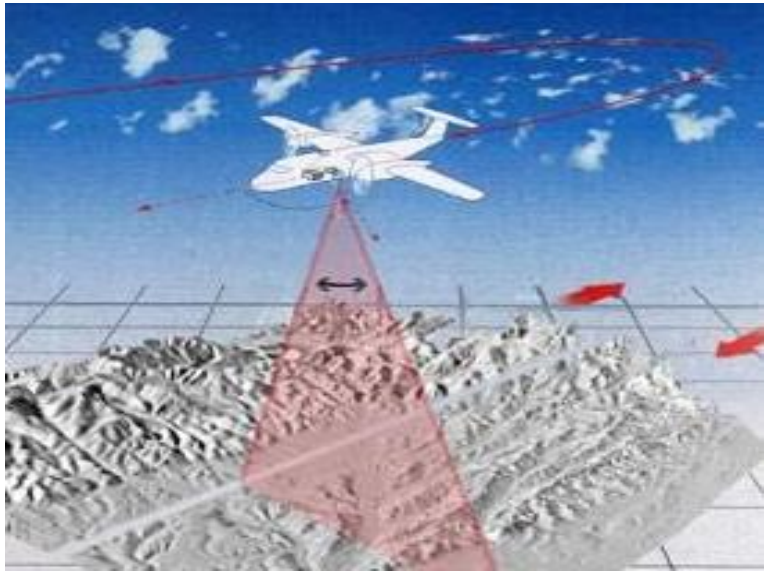
GIS and Earth Science: Spatial Data Management



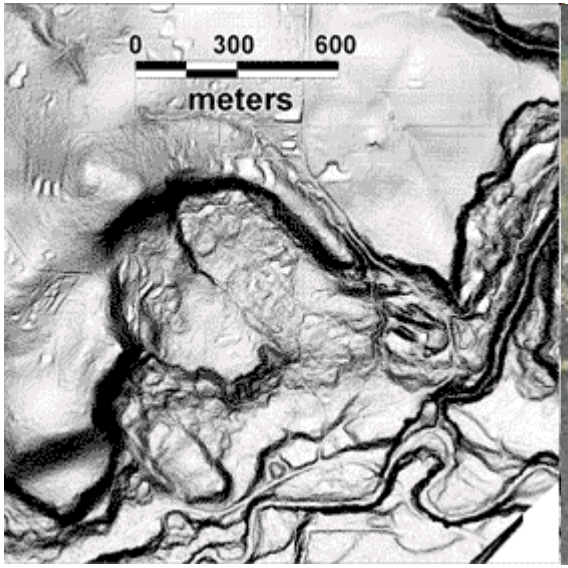


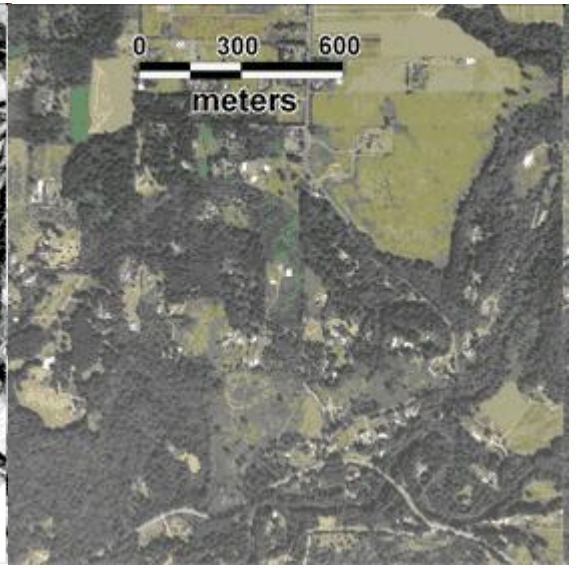






Next-generation mapping: Emerging Lidar Technology (Light Detection and Ranging – Laser Altimetry)





Overview of GIS-Based Research Associated with the Earth Science Program at Western Oregon University

1999-2006	Geology and Geomorphology of the Luckiamute Watershed
2003-Present	Invasive Plant Studies in Luckiamute Watershed
2004-Present	Geomorphic Analysis of Cinder Cones at Newberry Volcano
2008-Present	Land Cover Analysis in Luckiamute Watershed
2008-Present	Rapid-Bio Assessment / Fish Population Studies – Luckiamute and Nehalem Watersheds
2010-Present	Spatial Analysis of Fingerprint Patterns

Total Project Funding 1999-Present: ~$820,000

US Geological Survey, Oregon Community Foundation, National Institute of Justice, Murdock Trust, WOU Faculty Development Fund, WOU Foundation, Cascades Volcano Assoc., US EPA, Oregon Watershed Enhancement Board

Collaborators: Bryan Dutton (Biology), Jeff Templeton, Emma Dutton, Pat Alrdrich, Ryan Stanley, Brandon Snook, Bill Vreeland, Jered Thommen, Nicole McLaughlin, Katie Noll, Daniel Asakawa, Catherine Drury, Moriah LaChappel-Schalock, Ian Macnab, Rachel Pirot, Benjamin Purkerson, Ryan Stanley, Alicia Thompson, Thomas VanNice, Shannon Wineland, Diane Hale, Jeff Budnick, Jamie Fisher, Chandra Drury, Jeff Kent, Tony Faletti, Denise Giles, Diane Horvath, Pirot, Summer Runyan, Ryan Adams

APPLICATION OF SPATIAL STATISTICS TO LATENT PRINT IDENTIFICATIONS:

TOWARDS IMPROVED FORENSIC SCIENCE METHODOLOGIES

Patrick Aldrich[1,] Emma Dutton[1,2], Steve Taylor[1], Bryan Dutton[1]

[1]Division of Natural Sciences and Mathematics
Western Oregon University
[2]Oregon State Police, Forensic Services Division

FINGERPRINT ANALYSIS AND CHARACTERIZATION TEAM

FACT@WOU

Interdisciplinary Team Work:

- Biological Science
- Geoscience
- Forensic Science

Tools and Novel Applications:

Biometrics, Morphometrics, Geographic Information Systems, Spatial Analysis, Principles of Bio- and Geo-Statistics

Background: The impetus for our study

- 2009 NAS report, “Strengthening Forensic Science in the United States: A Path Forward”

- The report indicated the need to improve the scientific accuracy and reliability of impression based evidence.

Scope and Objectives

Scope

- Examine the current practice of latent print comparisons (ACE-V methodology)
- Apply principles of spatial analysis
- Develop standardized statistical certainty measures to latent print identifications

Objectives

- Evaluate fingerprint characteristics (e.g., minutiae type, frequency and position) and derive probabilistic models for
  - predicting fingerprint uniqueness
  - establishing certainty levels for latent print identifications

Goals of Analysis

- Frequency of minutiae type per finger
- Frequency of minutiae type per pattern type
- Density of minutiae per finger, pattern type and quadrant
- Probabilities of occurrence of minutiae to quadrants and azimuthal bins

Feature Categorization

Pilot Test Output Data Categories

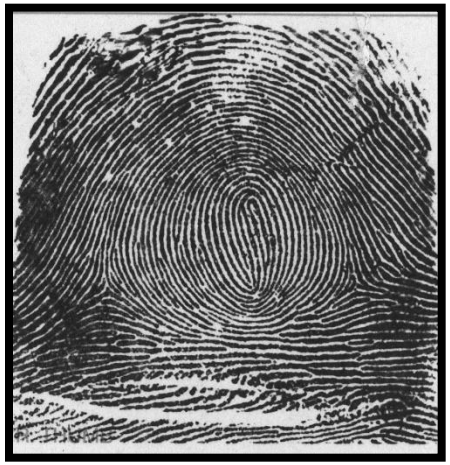
1. Gender
2. Race
3. Finger (1, 2, 6, 7)
4. Pattern Type
   - right slant loop, left slant loop, arch, tented arch, whorl
5. Minutiae
   - bifurcations
   - ridge endings

Research Methodology

- Acquire ten-print cards (OR State Police)
- Qualitative image assessment
- Scan and process image
- Spatial orientation and coordinate referencing
- Minutiae detection, core and delta marking
- Data entry and management
- GIS spatial analysis
- Statistical analysis

Qualitative Image Assessment

Best



Good

Fair

Poor

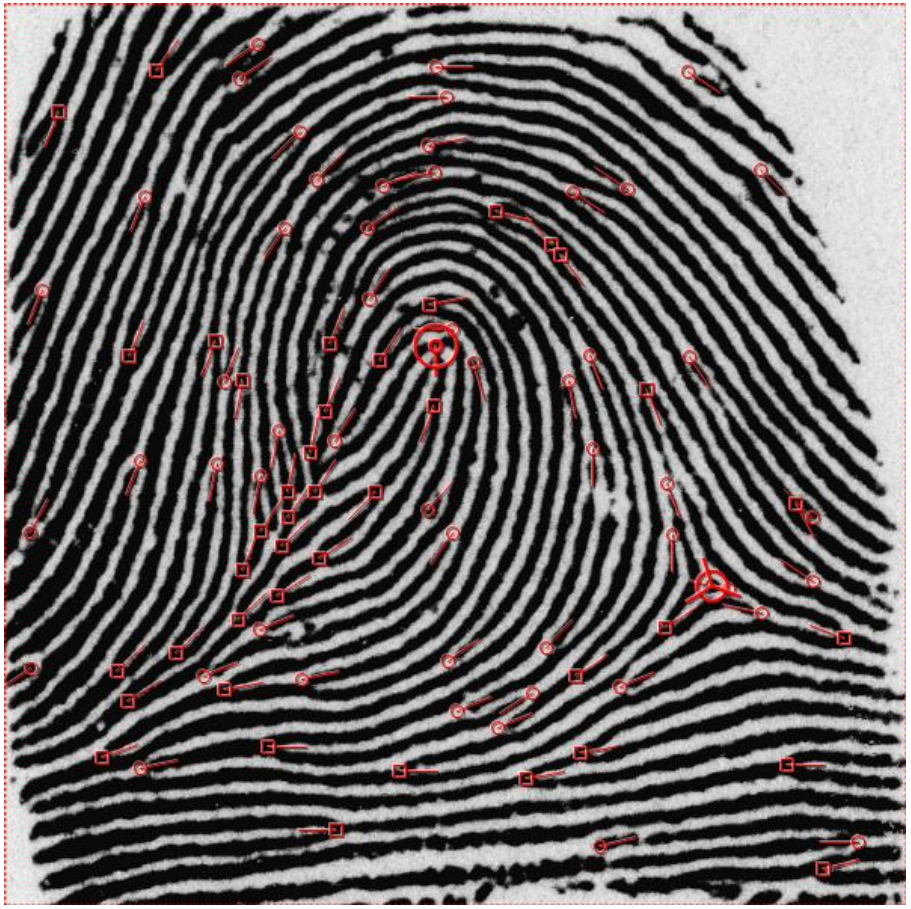
Image Processing

- Noise filter
- Black/white balance
- Contrast, brightness enhancements

Minutiae Detection Software and Database Development

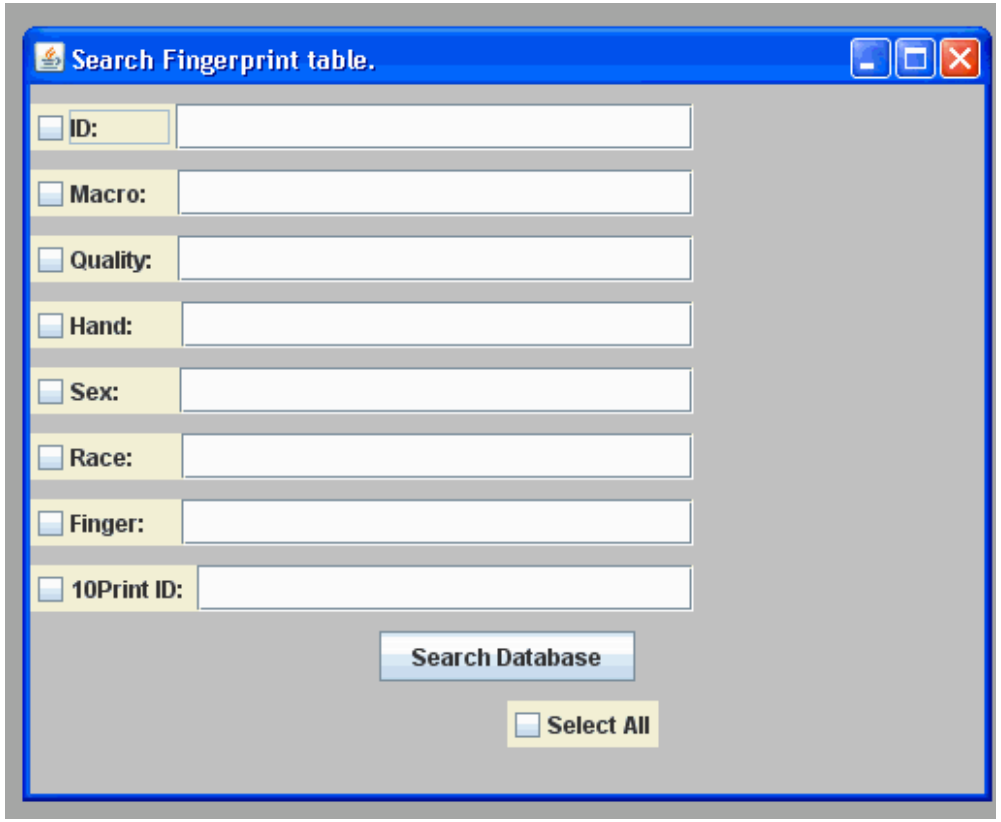
Testing Minutiae Detectors

- Two readily available software applications for minutiae detection
- Mindtct and ULW
- Each has its own set of pros and cons



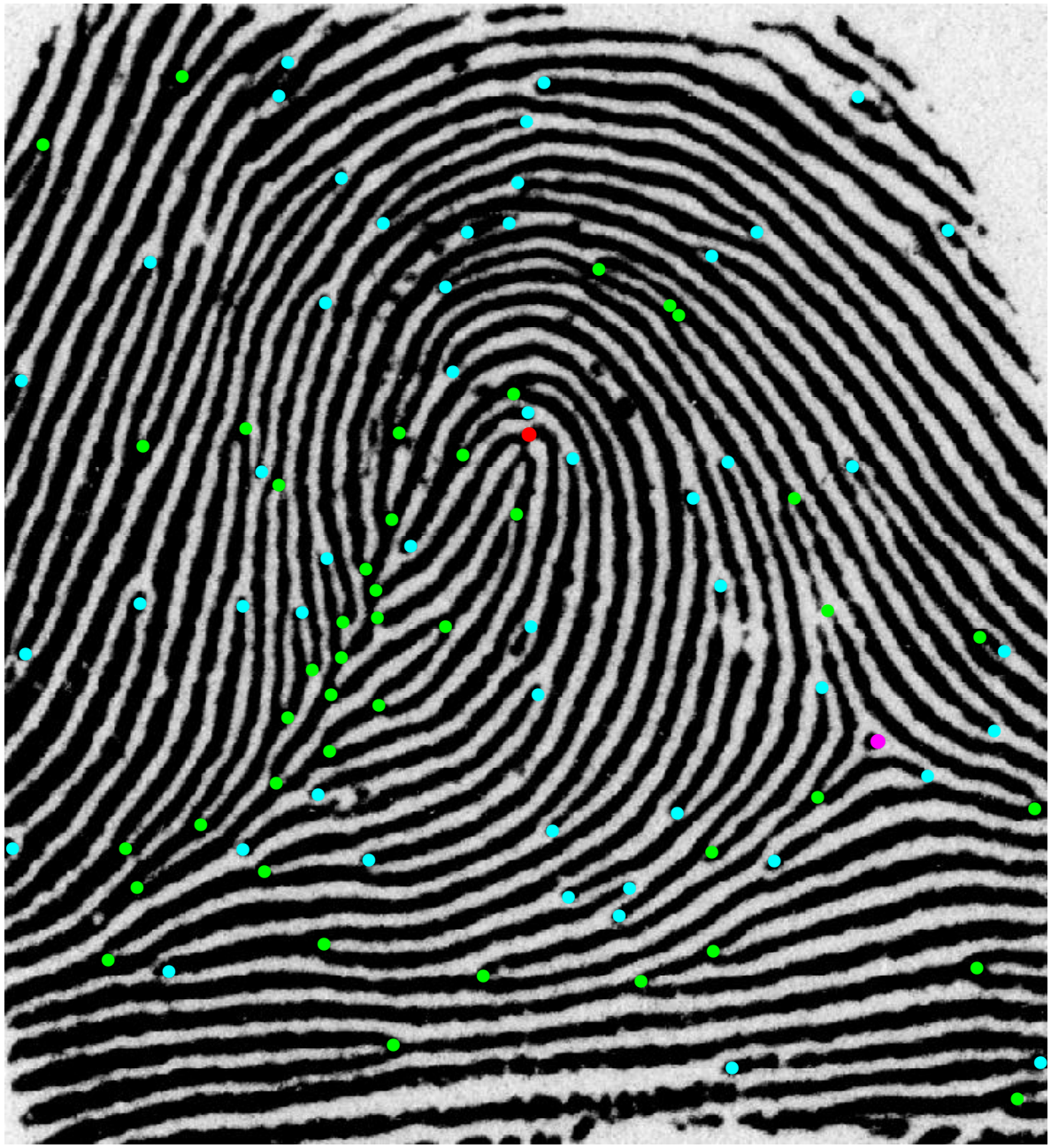
Database Creation

- Created a SQLServer 2005 database
- Wrote front end scripts for data entry and data query scripts
- Queries based on metadata, such as sex, race, print type



Spatial Analysis

Underlying Premise: Traditional Minutiae Detection Techniques

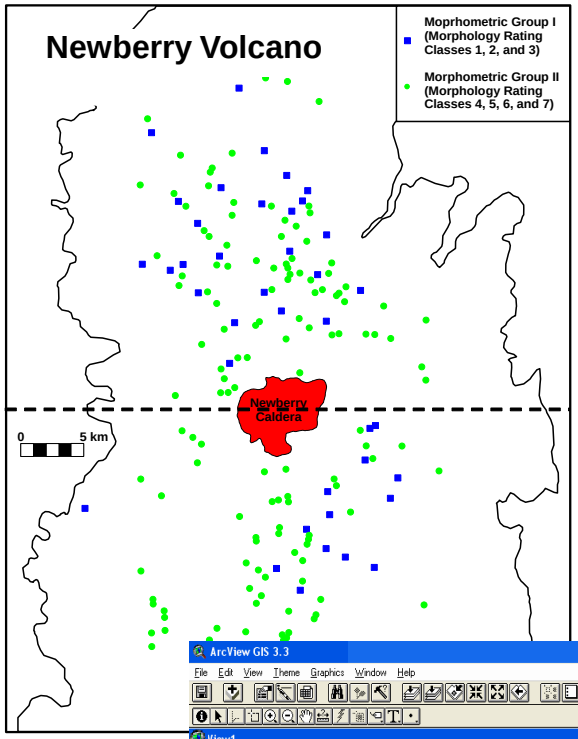


- Core
- Delta
- Ridge Ending
- Bifurcation

Print Type = LS

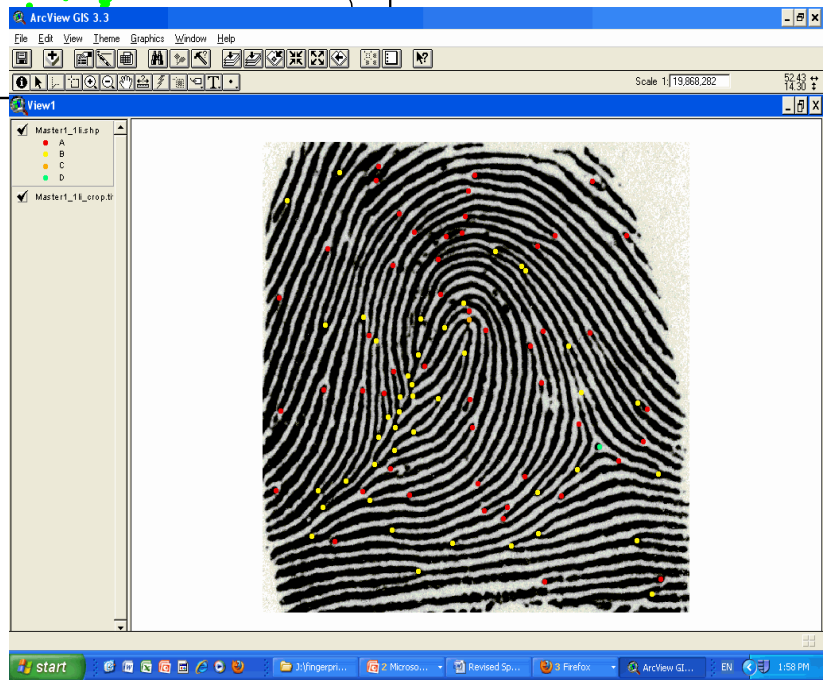
Master 1_1li

Application of Geographic Information Systems



Fundamental Map Elements

- **Points**
- **Lines**
- **Polygons**



Components of a GIS

Spatial Data Input	1. Data entry: use existing data, create new data 2. Data editing 3. Projection and re-projection 4. Geometric transformation
Attribute Data Management	1. Data entry and verification 2. Database management
Data Display	Use of maps, charts, and tables
Data Exploration	1. Attribute data query 2. Spatial data query 3. Geographic visualization
Data Analysis	1. Vector data analysis: buffering, overlay, distance measures, map manipulation 2. Raster data analysis: local, neighborhood, zonal, global 3. Terrain mapping and analysis 4. Spatial interpolation: global, local 5. Regions-based analysis 6. Network analysis
GIS Modeling	1. Binary models 2. Index models 3. Regression models 4. Process models

GIS Workflow

1. Scan Prints

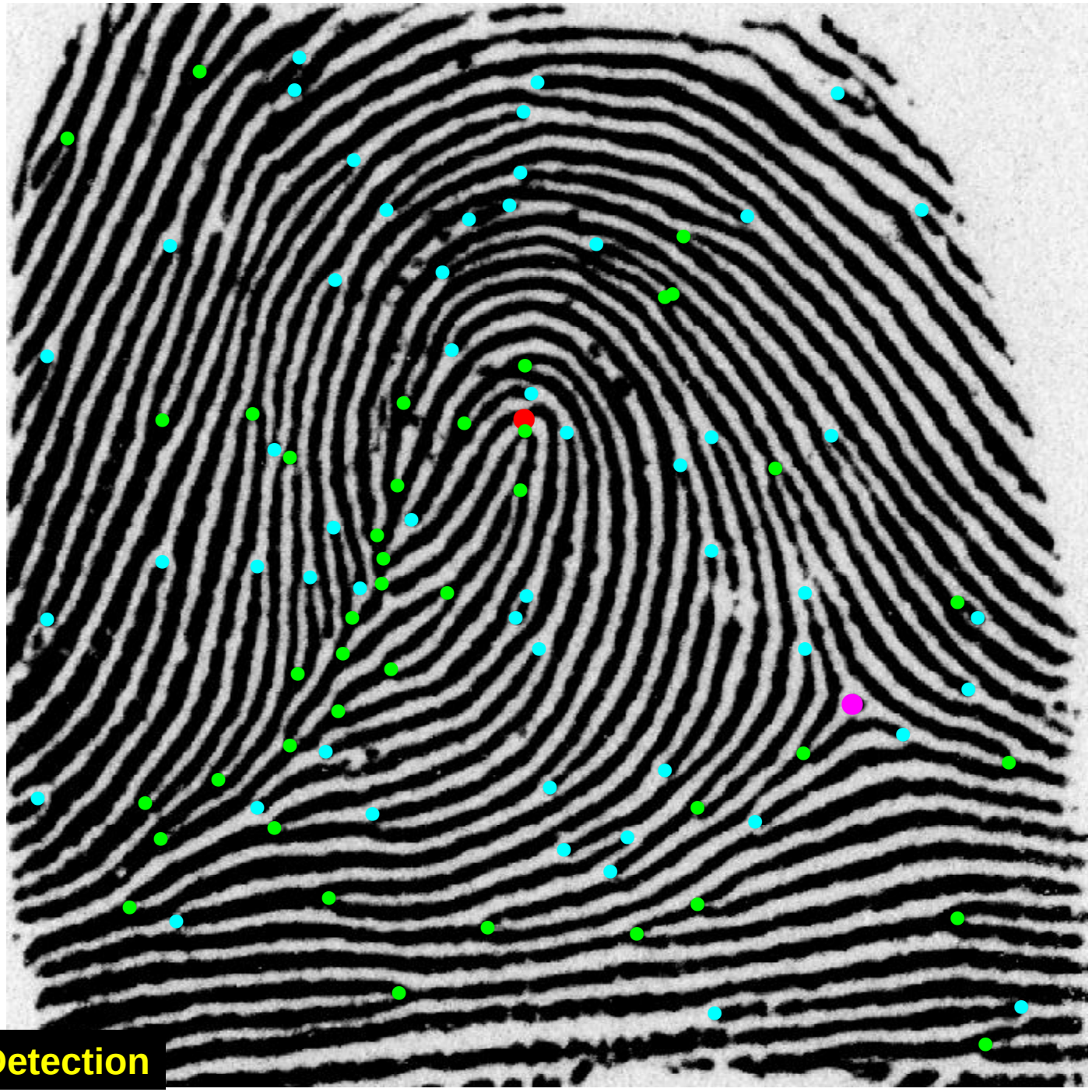
2. Image-ULW Processing

3. Identify Minutiae Locations and Type

4. Georegister Images in Finger Coordinate Space

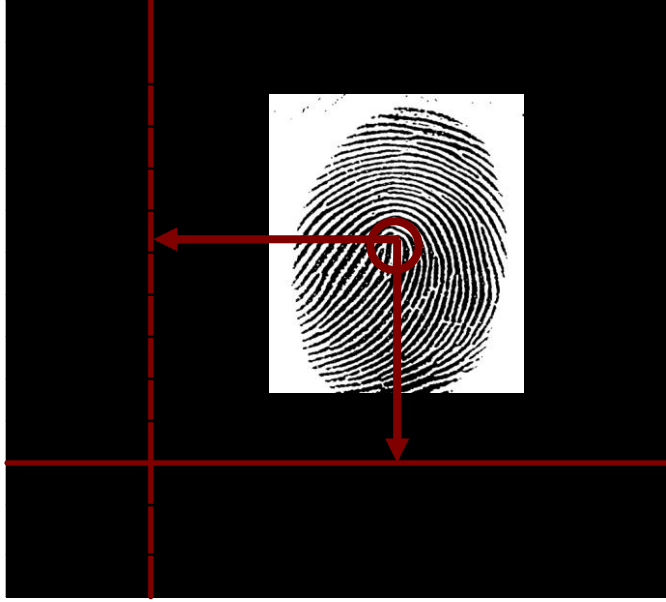
5. Digitize - Attribute Minutiae Points and Ridge Lines

Scanned Prints from OSP Print Cards

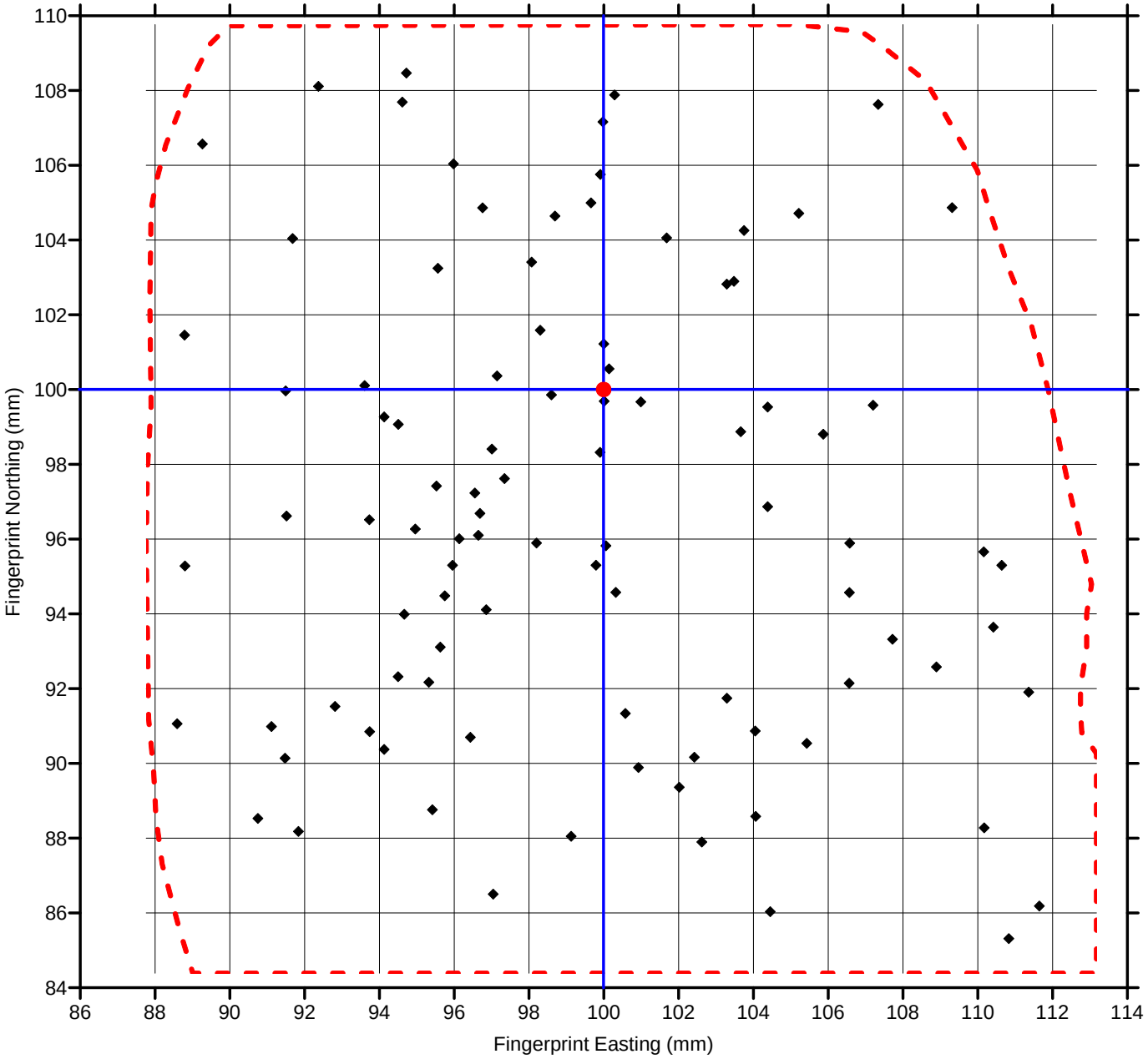


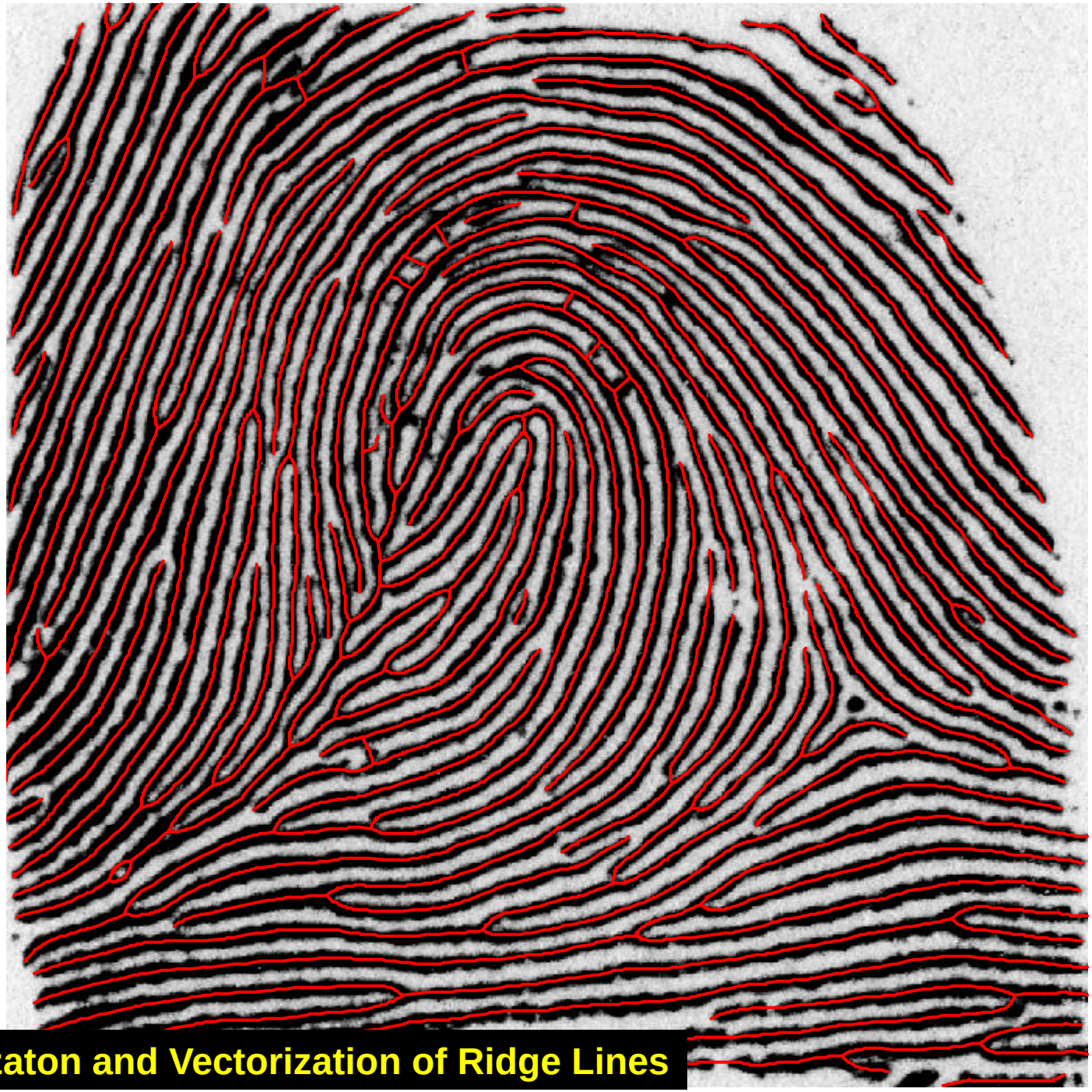
Minutiae Detection

Reference Locations and Standardized Coordinate System

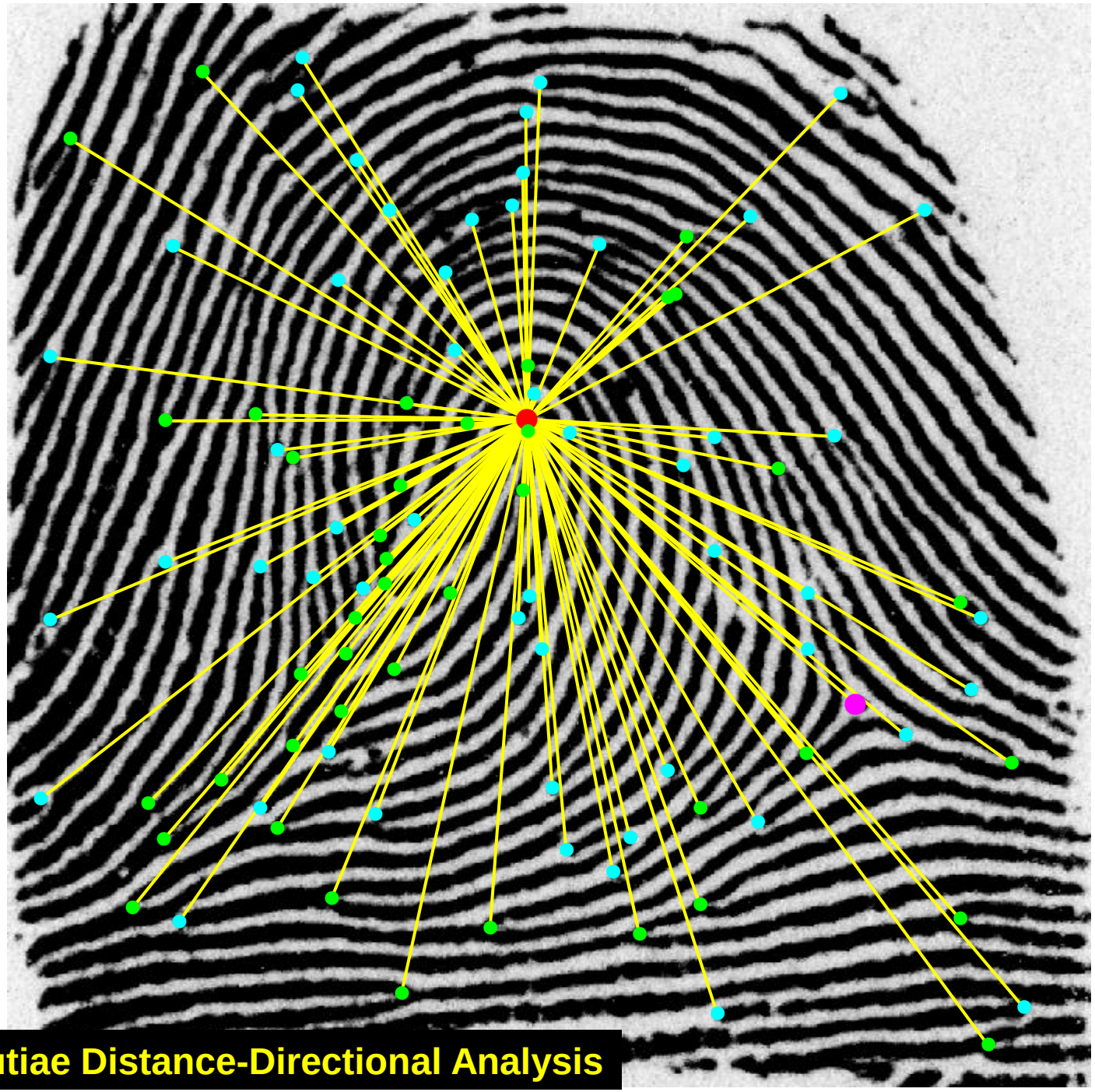


- Center Point (Core) Location
  - Arches = highest point of recurve
  - Loops = ridge ending at top of 1st full loop
  - Whorls = ridge ending or bulls eye at core
- Core centered at (100,100) mm in graph space
- Places print in NE quadrant with +,+ coordinates
- Latent Print Analysts to review for consistency

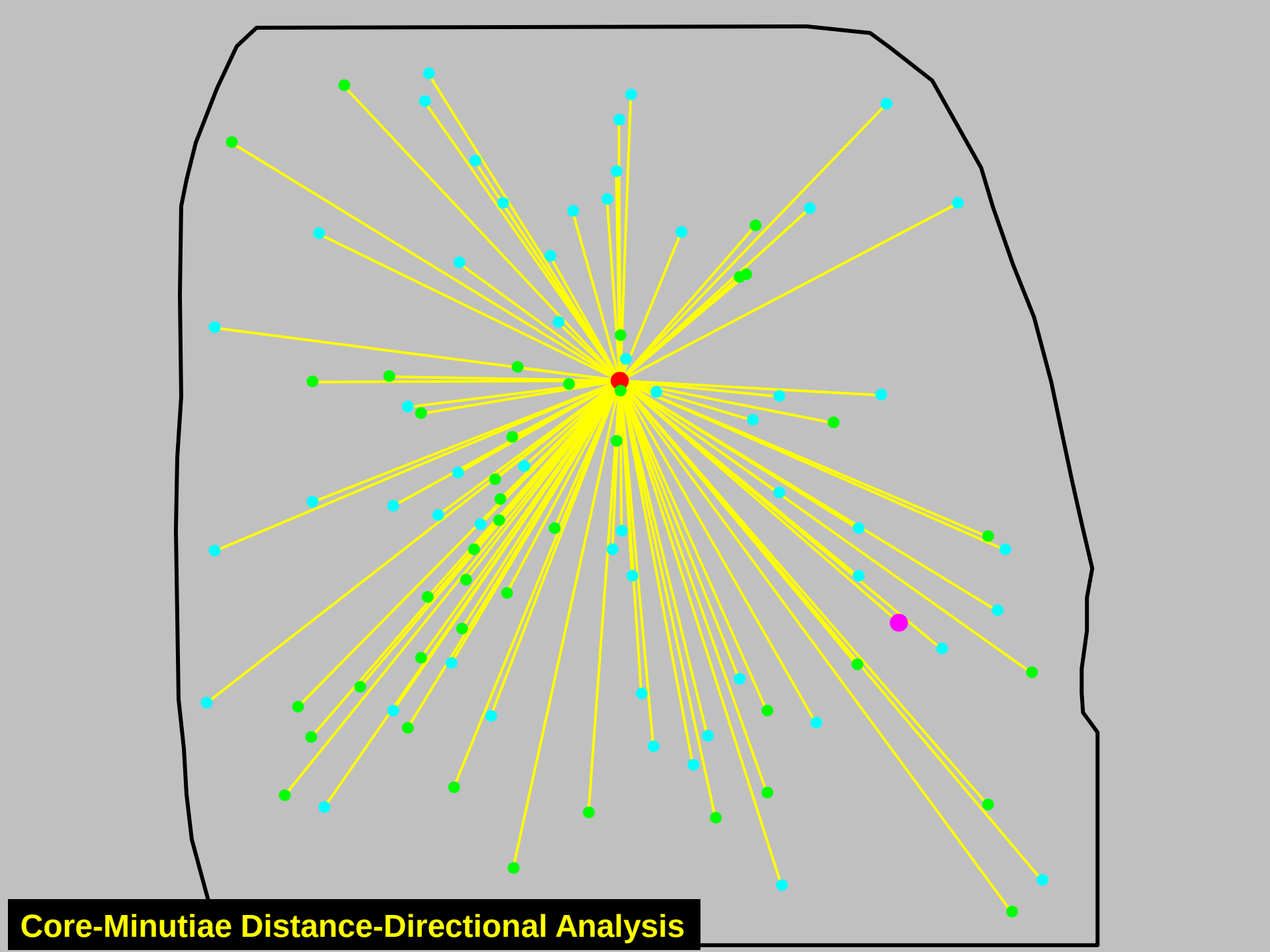

Finger Print Georeference System
(Core-Centric Model: Grid Center at 100,100)
Fingerprint Northing (mm)
Fingerprint Easting (mm)
110
108
106
104
102
100
98
96
94
92
90
88
86
84
86
88
90
92
94
96
98
100
102
104
106
108
110
112
114

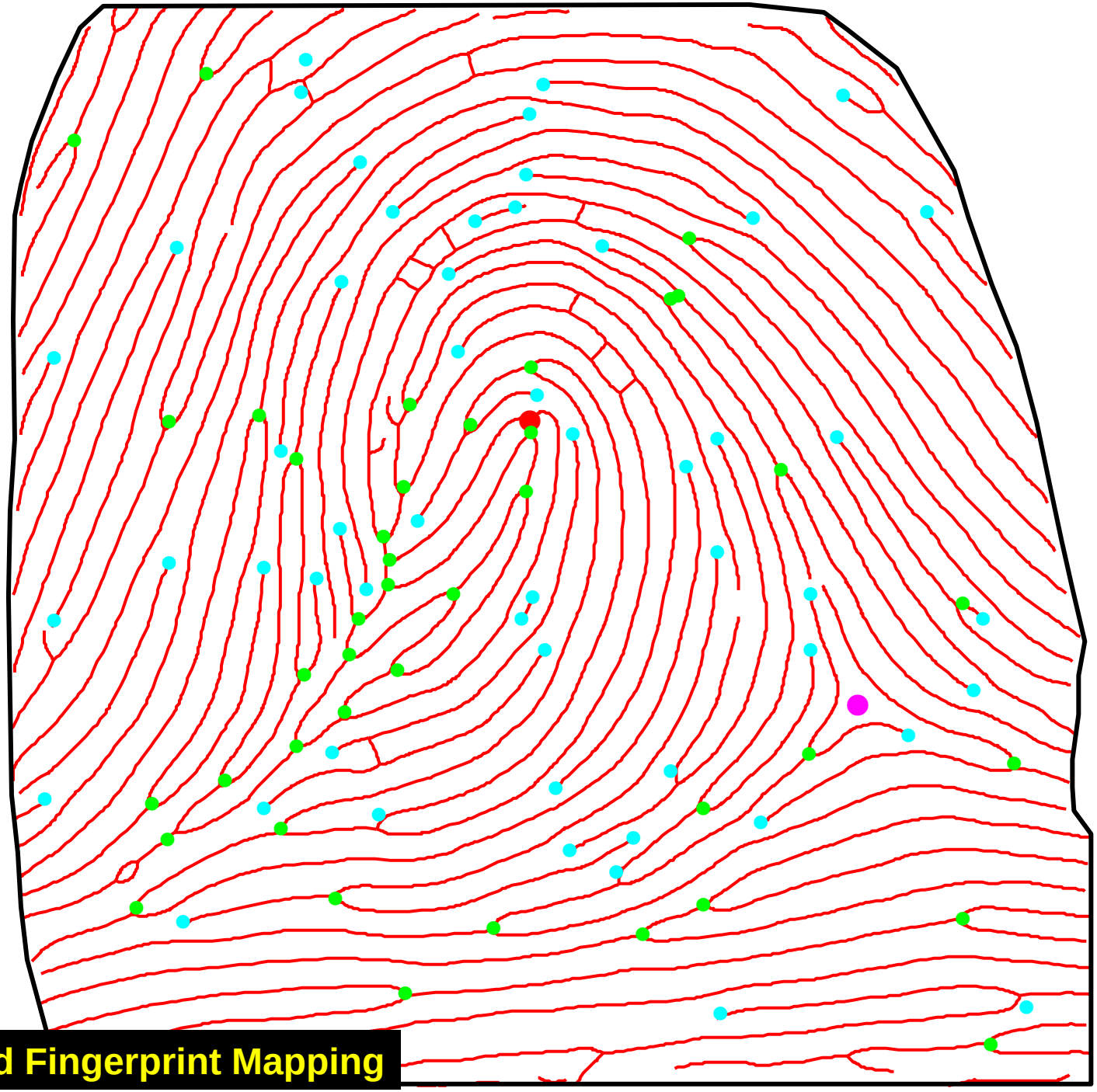


Skeletonizaton and Vectorization of Ridge Lines

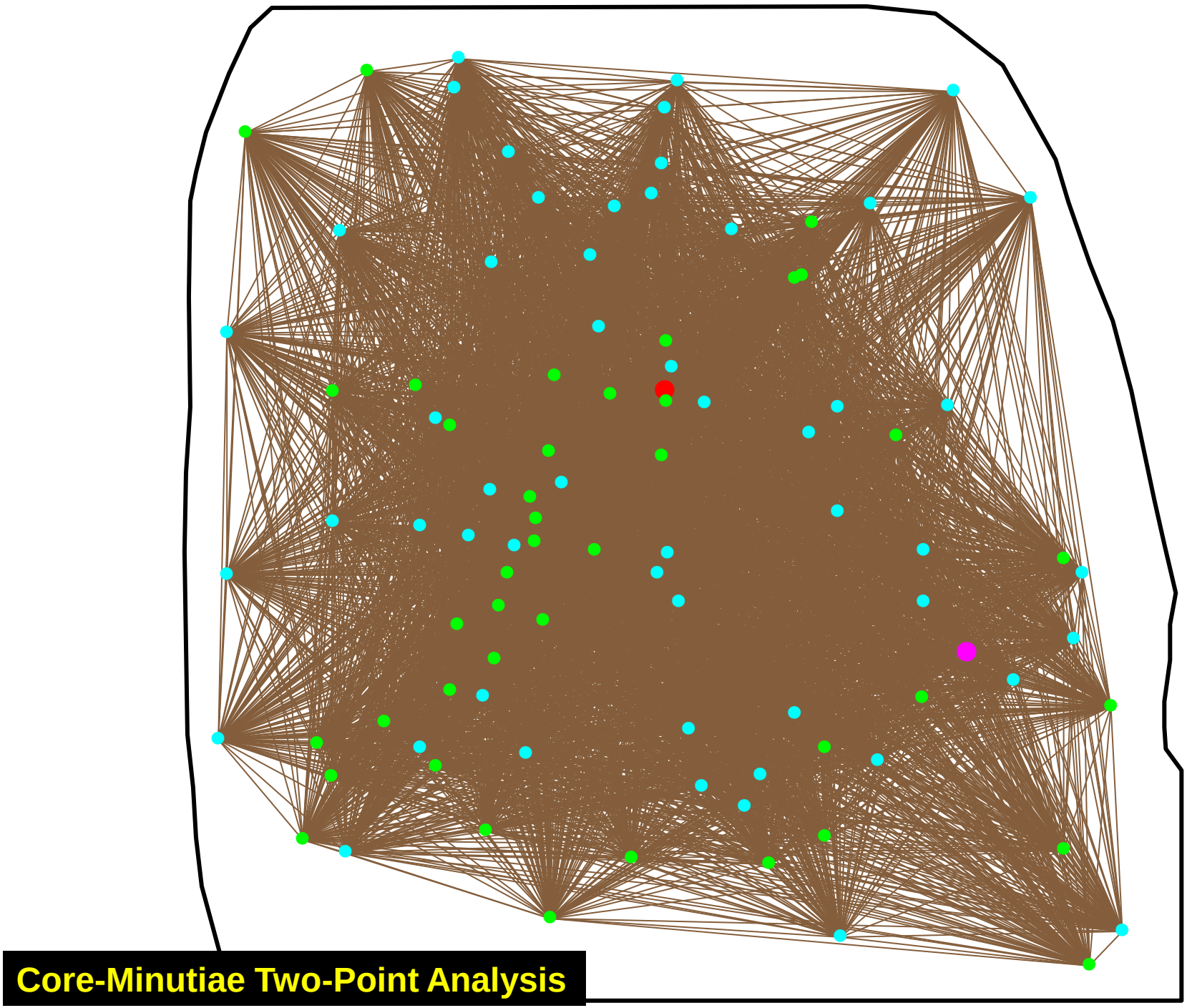


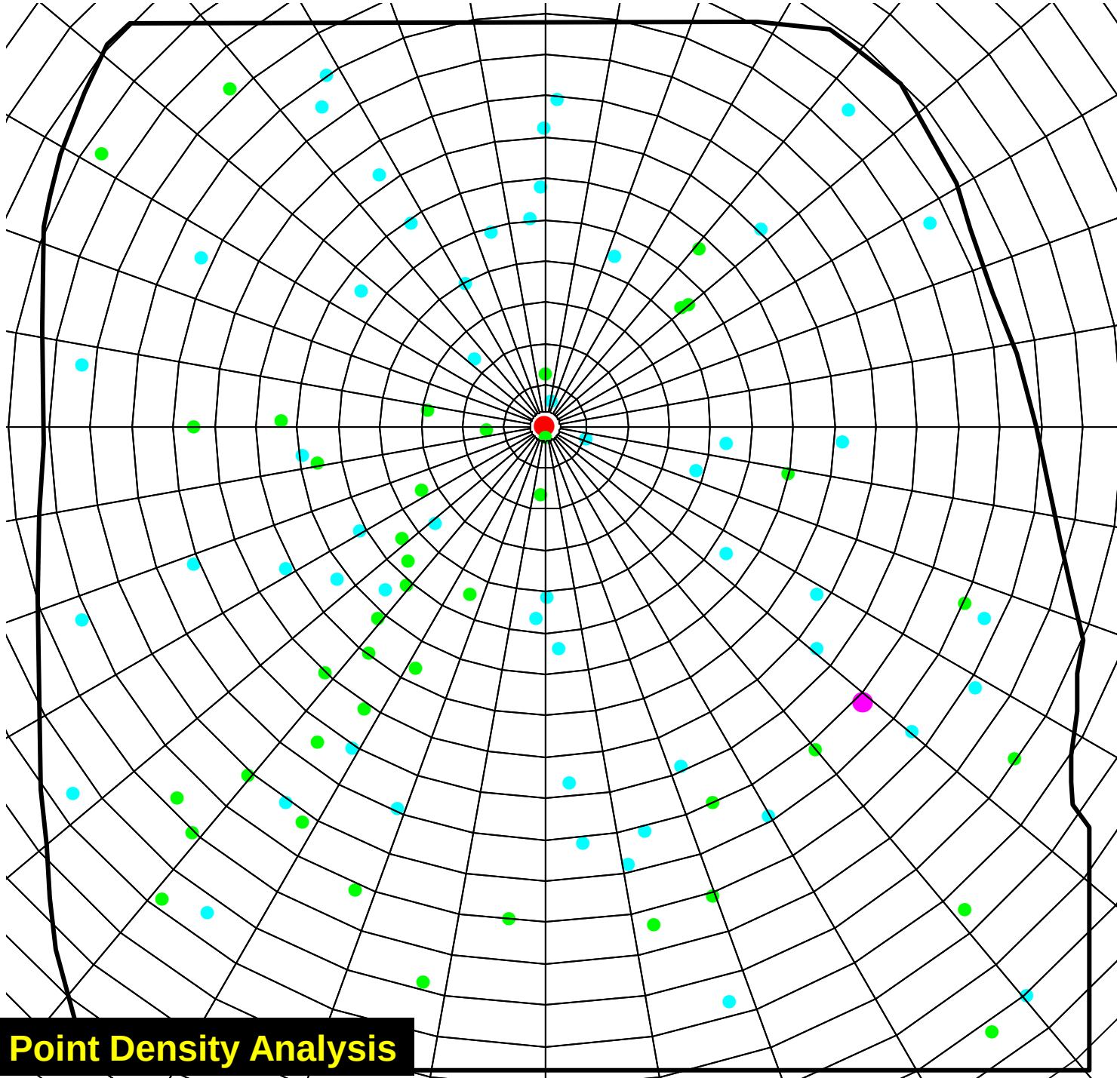
Core-Minutiae Distance-Directional Analysis


Core-Minutiae Distance-Directional Analysis

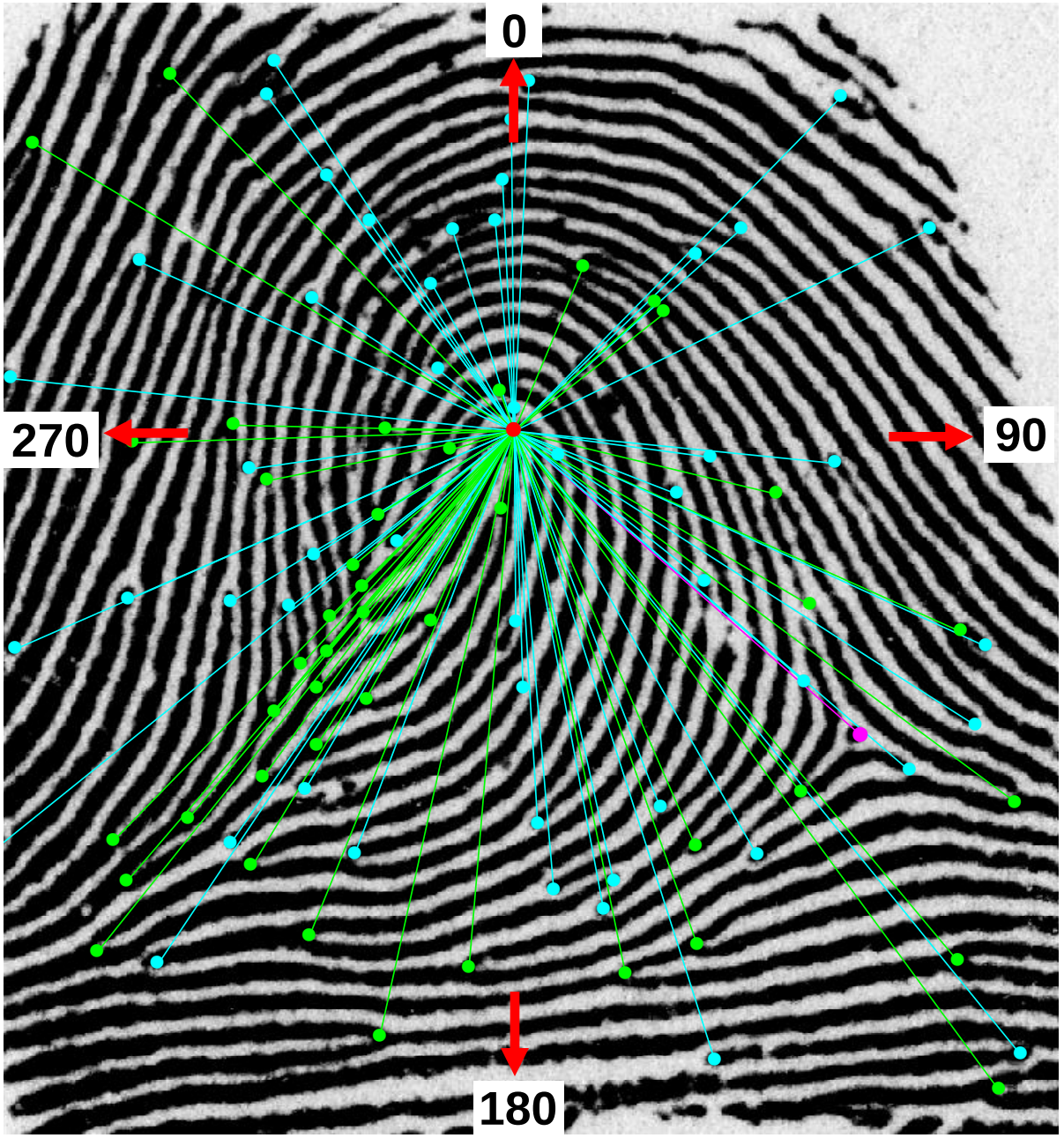


GIS-Based Fingerprint Mapping


Core-Minutiae Two-Point Analysis


Quadrat Point Density Analysis

Analytical Concept 1: Minutiae Distance and Core Azimuth Measurements

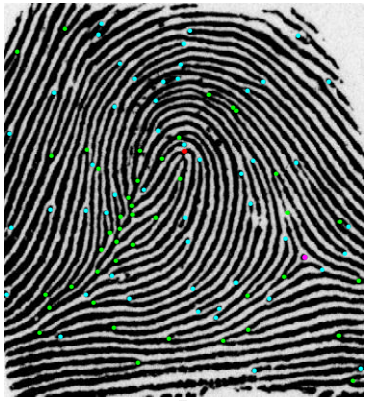


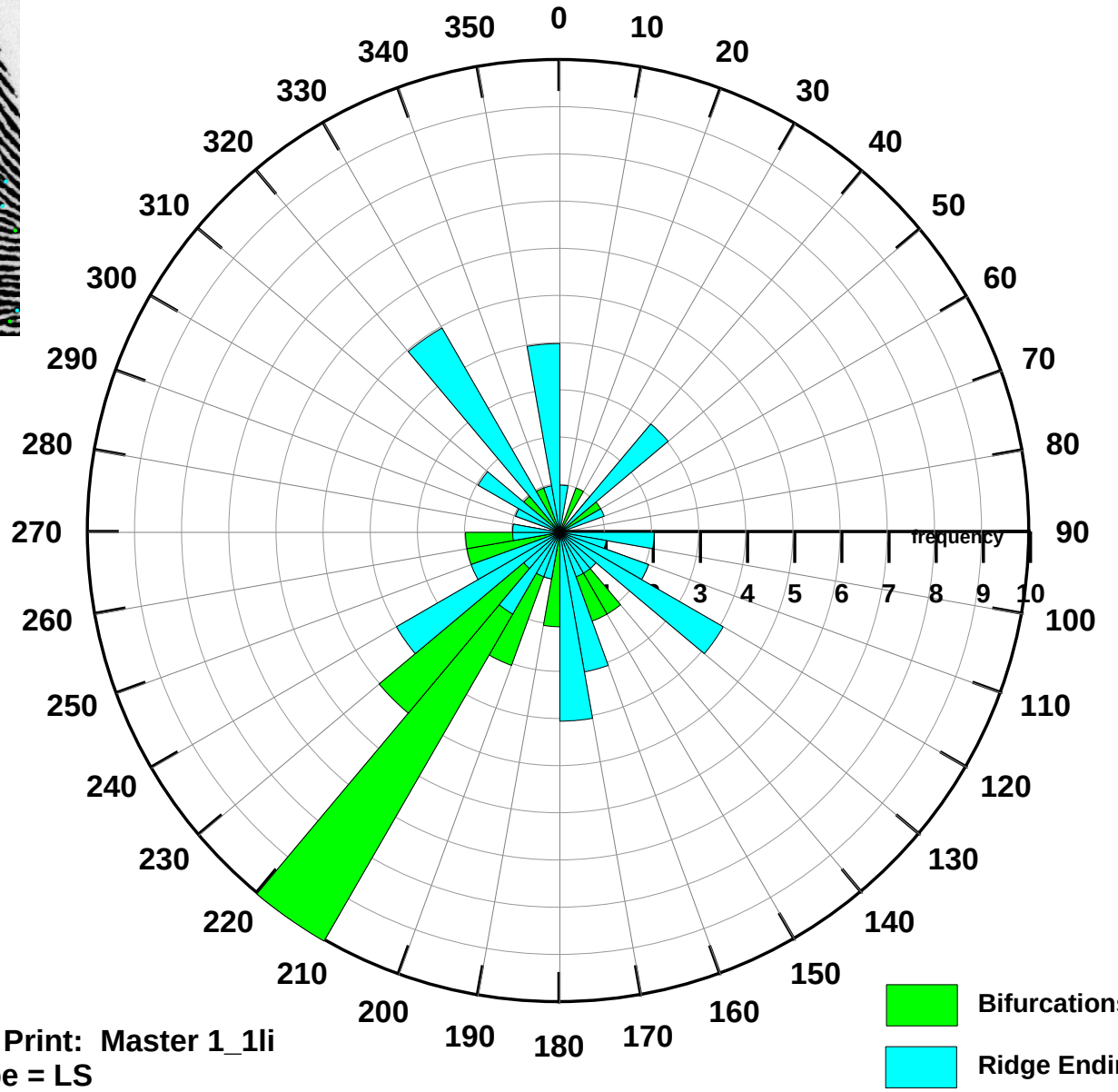
- Core
- Delta
- Ridge Ending
- Bifurcation

Print Type = LS

Master 1_1li

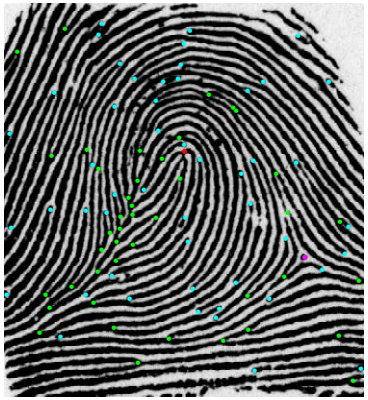
Example Azimuthal Frequency (Rose) Diagram Showing Spatial Orientation of Minutiae Relative to Core

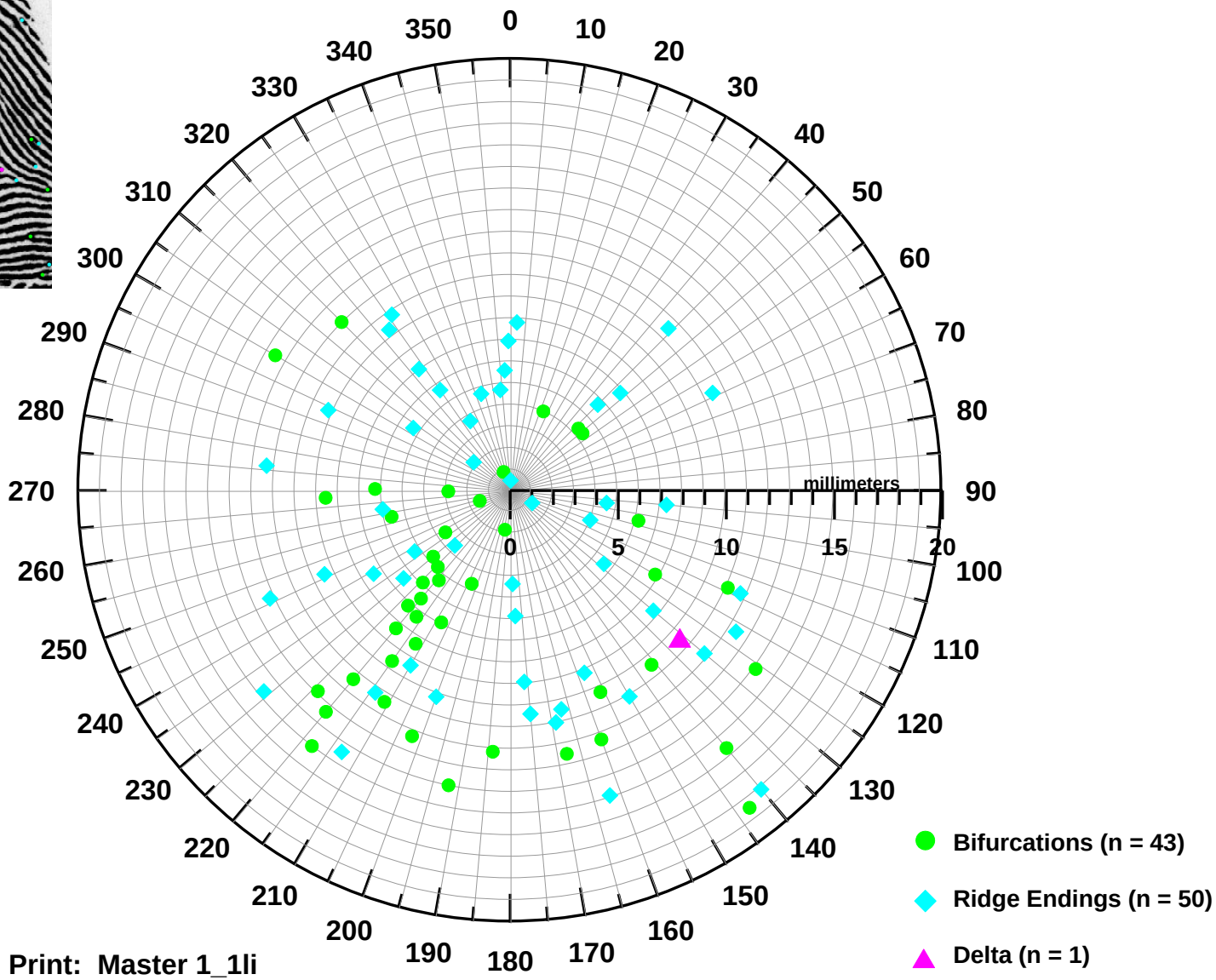




Example Print: Master 1_1li
Print Type = LS

Example Polar Diagram Showing Radial Distance (mm) and Azimuth Orientation of Minutiae Relative to Core

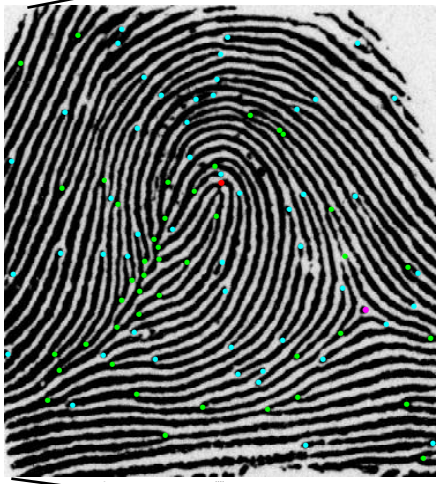


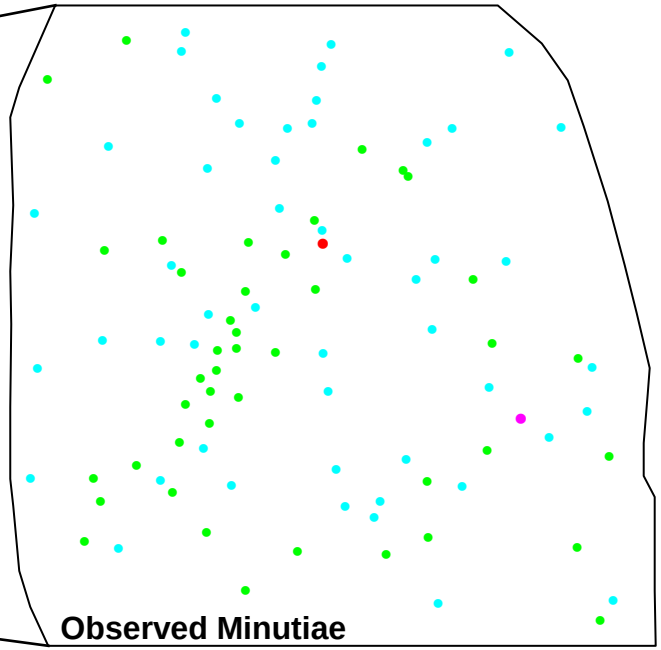


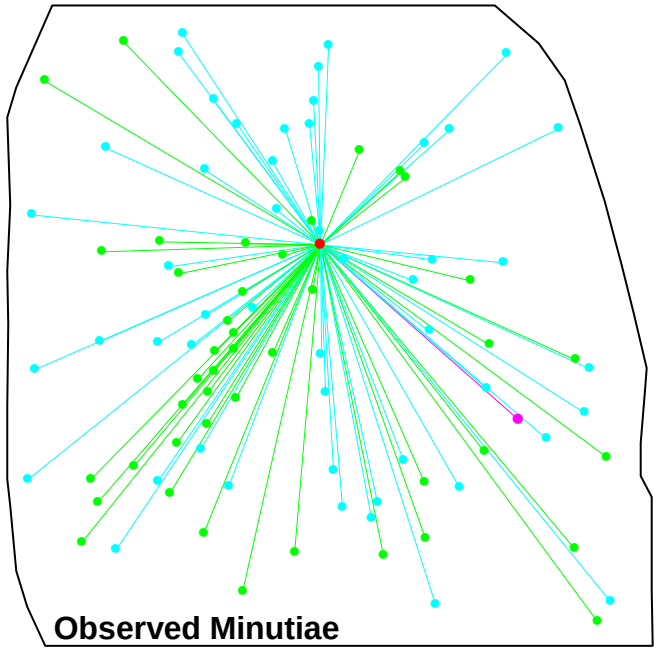
Example Print: Master 1_1li
Print Type = LS

Analytical Concept 2: Monte Carlo Simulations and Randomization

Master 1_1li

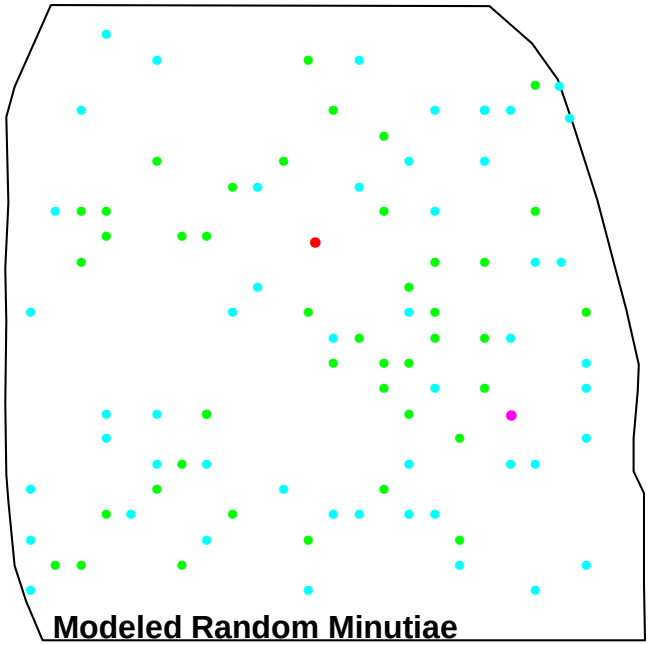


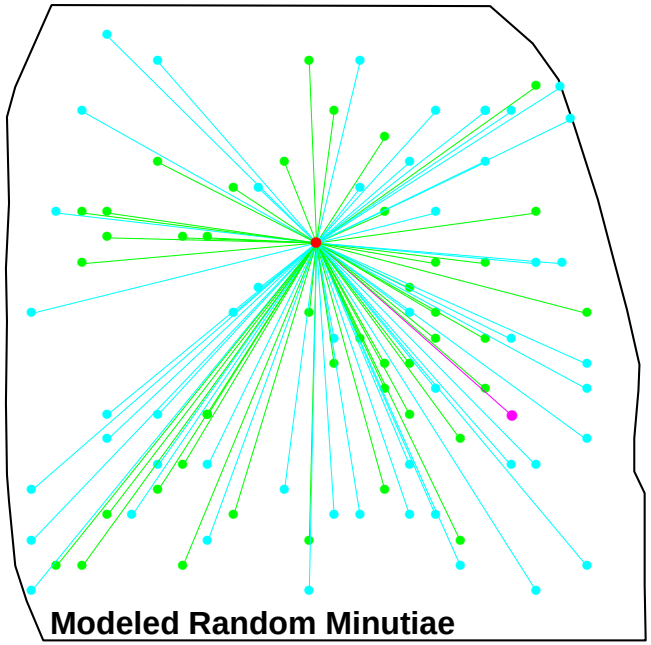




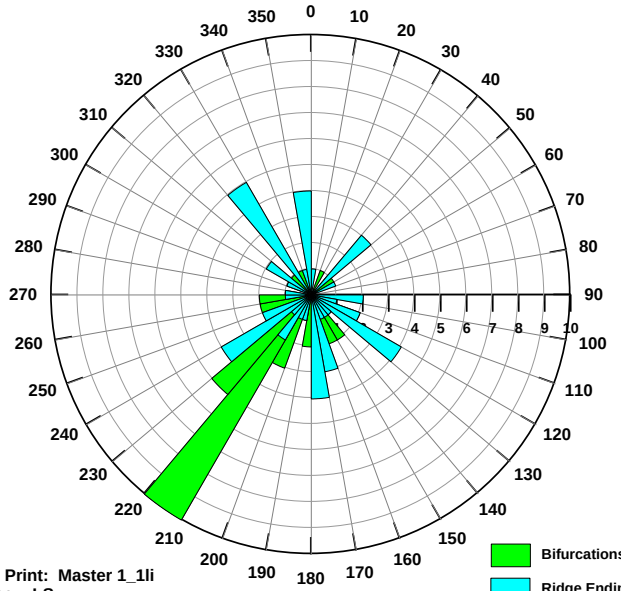
- Core
- Delta
- Ridge Ending
- Bifurcation

Print Type = LS

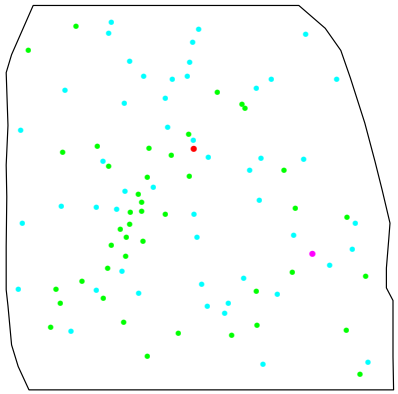




Example Azimuthal Frequency (Rose) Diagram Showing Spatial Orientation of Minutiae Relative to Core

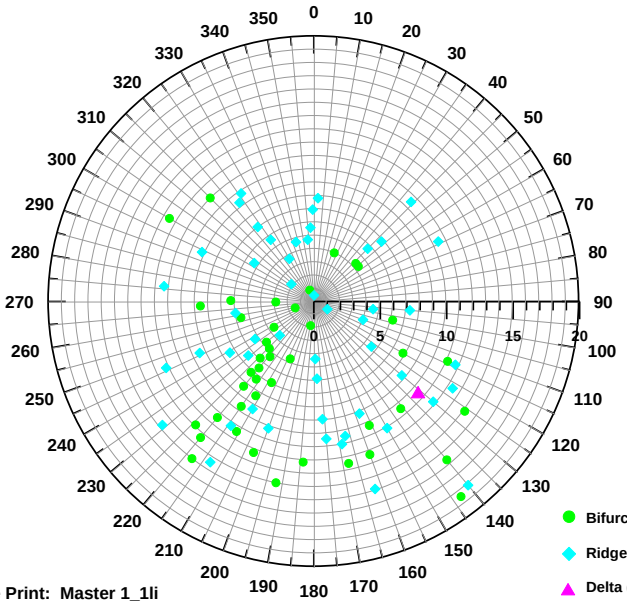


Example Print: Master 1_1li
Print Type = LS



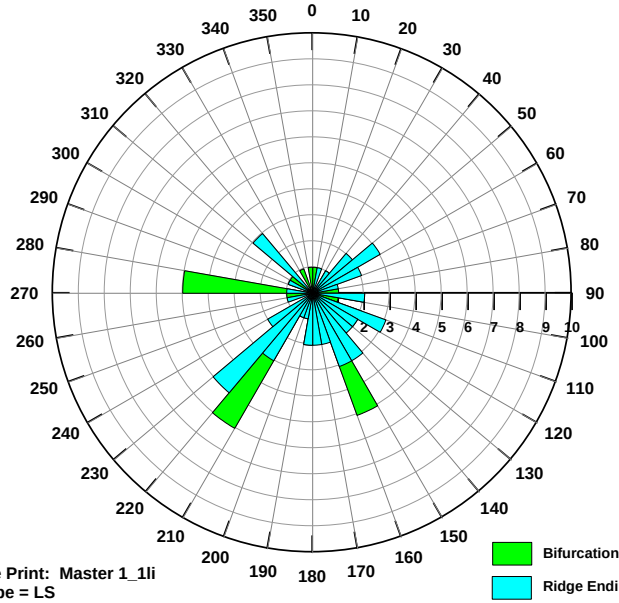
Observed Minutiae

Example Polar Diagram Showing Radial Distance (mm) and Azimuth Orientation of Minutiae Relative to Core

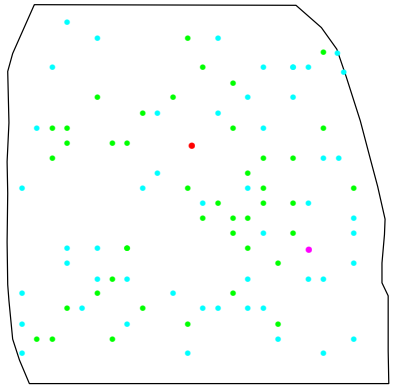


Example Print: Master 1_1li
Print Type = LS

Example Azimuthal Frequency (Rose) Diagram Showing Spatial Orientation of Modeled Random Minutiae Relative to Core

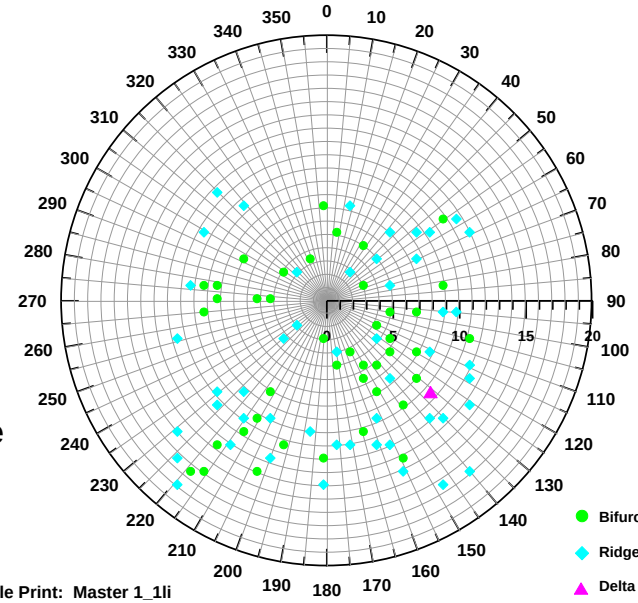


Example Print: Master 1_1li
Print Type = LS



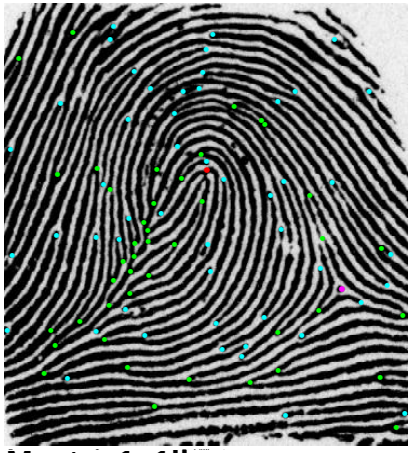
Modeled Random Minutiae

Example Polar Diagram Showing Radial Distance (mm) and Azimuth Orientation of Modeled Random Minutiae Relative to Core

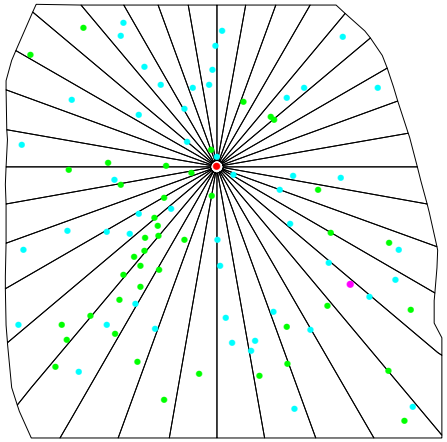


Example Print: Master 1_1li
Print Type = LS

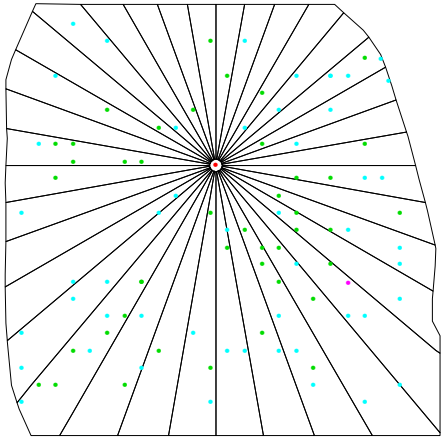
Radial Quadrat Analysis of Minutiae Frequency Relative to Core Azimuth



Master 1_1li

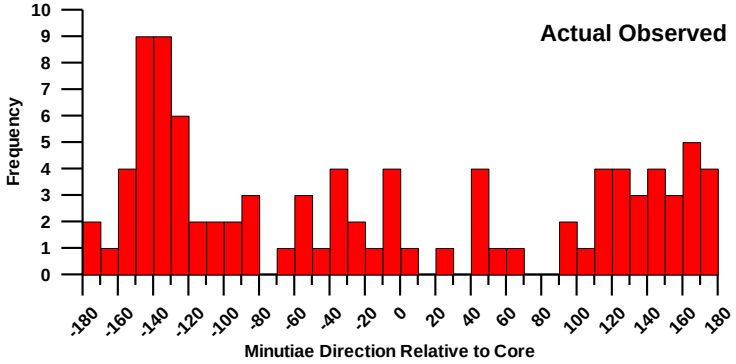


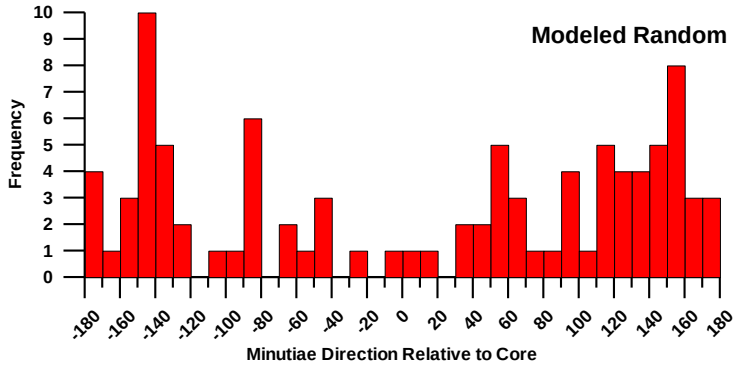
Observed Minutiae



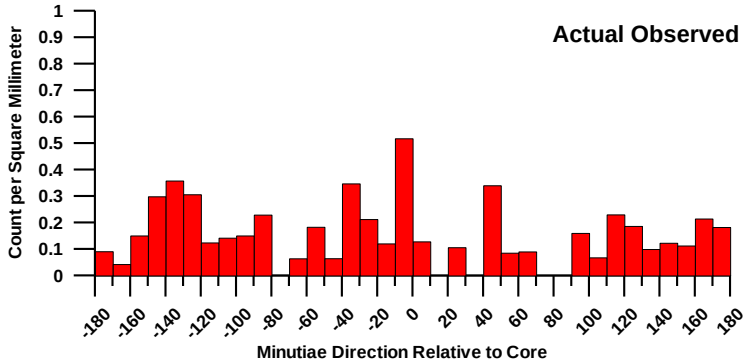
Modeled Random Minutiae

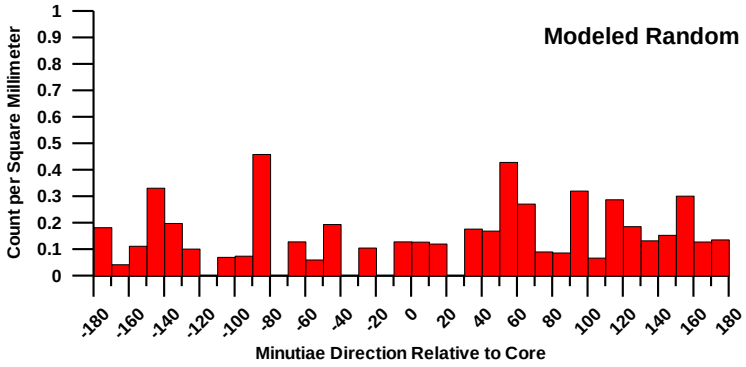
Frequency Analysis of Minutiae Occurrence Relative to Direction from Core





Minutiae Point Density Relative to Direction from Core





Project Status – Ongoing Year 2

- **Two-year, NIJ-funded forensics grant hosted by Natural Sciences faculty at Western Oregon University.**
- **Interdisciplinary team approach includes applications in biometrics, morphometrics, Geographic Information Systems, spatial analysis, and principles of bio- and geo-statistics.**
- **Project objectives: Evaluate fingerprint characteristics and derive probabilistic models for predicting uniqueness and establish certainty levels for latent print identifications.**
- **Status: 7 months of earnest time into project; staffing, data collection, management and analysis systems in place.**
- **Next steps: Continue data collection; develop statistical methodology and protocols**