

Dermatoglyphic Analysis On The Morphology Of Pores And Its Importance In Forensic Investigation

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Abstract:

Latent fingerprint analysis remains pivotal for forensic investigation in identifying an individual and in criminal profiling. This research investigates the efficiency of Ridgeology and poroscopy, the analysis of the ridge characteristics, and the sweat pores quantitatively as an extension of the Optimal Score Assigned (OSA) framework proposed by Gnanasivam, P., & Vijayarajan, R. (2019). The samples were collected using a stratified method, cohorts (n=500) by age group (C1 to C5), ranging from 15 to 65, and the sexes with a 1:1 ratio. High-fidelity frictional ridge images were acquired using a digital microscope, and studies were conducted using the Proscope software. Ridge count (RC) and fingertip size (FTS) were quantified and found to be efficient in sex determination. However, it was not effective to determine the age of the fingerprint donor. This research focused on the given fragmentary nature of latent prints at crime scenes. Considering the practical application of the OSA method to the crime scene samples, the hypothesis was tested on the ridge thickness (RT) and pore density (PD) along with the traditional ridge density (RD) and the fingertip size (FTS) parameters. The statistical model yielded the gender classification with 88.41% accuracy with RD and FTS factors. However, RT and PD showed a significant difference between the inter-category and intra-category with respect to the age of the fingerprint donor. Identifying value distribution across the PD/RT-modified OSD formula confirmed the metrics' forensic reliability and augmented a classification precision under latent print constraints. This study highlights the importance of the integration of poroscopy into the OSA Model as a methodology for estimating the age of the fingerprint donor, aiding in forensic investigation, personal identification, and criminal profiling.

Keywords: Latent fingerprints; OSA Model; poroscopy; criminal profiling; age estimation; forensic sciences.

Introduction

Forensic science, an amalgamation of various branches of science, has long relied on fingerprint analysis as a key exhibit of personal identification in criminal investigations, as it is one of the major exhibits developed from the scene of the crime that directs the investigators to the criminal(s) and the victim(s) and establishes their link to the weapon of crime and the scene of the crime. Latent print identification has evolved, using various scientific techniques to enhance the evidentiary value of fingerprints while prioritizing the preservation of evidence. (Kaye et al., 2012). Among the various emerging methodologies, poroscopy stands out as a significant tool for the age estimation of latent fingerprint donors, delivering very clear insights that extend far beyond traditional identification methods with the help of non-destructive microscopy techniques. The intersection of forensic science and the legal system has historically encountered challenges, particularly regarding the reliability and adaptability of forensic evidence in the courtroom (Vanter, 2020). As science advances, it becomes very crucial for legal systems to adapt to the innovative practices that align with the evolving nature of forensic evidence, ensuring that methodologies like poroscopy are rigorously examined and integrated for the purpose of criminal investigation and the criminal profiling. Thus,

the importance of poroscopy in age estimation expands the understanding of fingerprint analysis and enhances its application within the justice framework.

Very few studies have been done on poroscopy as an identification tool for the purpose of criminal investigation. Dr. Edmond Locard, the father of poroscopy, in the year 1912, stated that the pores are unique and individualistic, like the ridge characteristics, and hold similar potential in the personal identification process, marking poroscopy as the third level of fingerprint analysis. Initial approaches required meticulous examination and comparison of pore structures, demanding significant time and expertise. With advancements in photographic techniques and the use of higher-resolution microscopes, scientists were able to capture intricate details of pore structures, their dimensions, and their shape, position, and group formations. (Bansal, Sehgal, & Bedi, 2012).

In recent research conducted by Sánchez-Andrés et al., (2018), the scientists displayed that the density of the fingerprint ridges showed a considerable decline and that the ridge density was indirectly proportional to age, but it does not address the older age in which the skin elasticity is noticeably reduced and the skin shrinks, which leads to the increase in the ridge density again after their adult phase. P. Gnanasivam and R. Vijayarajan* conducted an innovative study, and the central idea was to present a method that uses ridge count and fingertip size as fingerprint parameters for gender classification. This technique is named Optimal Score Assignment (OSA), and it has been developed to attribute marks based on different factors, thereby enhancing the accuracy of sex identification. The two key factors that can be used to automatically ascertain the gender using fingerprints are referred to as ridge count (RC) and fingertip size (FTS), and scores are given because numbers of ridge count (RC) values or fingertip size (FTS) occur at different percentages. OSA is a critical component for accurately recognizing gender by analyzing fingerprint parameters, including ridge count and fingertip size. The researchers stated that this method has equal potential in estimating the age of the fingerprint donor, which served as the base for this research. The hypothesis was tested in this research, and the results are stated below.

Materials and Methods:

Instrumentation: (Make: Bodelin; Model: ProScope PS-EDU-100 5Mp digital microscope 10x-300x)

Sample Collection: The subjects were informed of the procedure. Consenting subjects were asked to wash their hands. The inkless inkpad was used to dye their fingertips. The subjects were instructed to roll their fingertips in the designated sections of the ten-digit sheet, and the plain prints were also collected simultaneously.

Sample Condition: The 100 samples were collected under five categories (C1 to C5), age groups ranging from 15 to 25, 26 to 35, 36 to 45, 46 to 55, and 56 to 65, with an equal number of male and female subjects. The samples were collected in a very careful manner to capture the pore details clearly and very precisely.



(Images 1 & 2: Rolled prints of the fingertips captured with precision.)

Data availability: The raw data is very wide, and hence, the summary of the data is added to this paper, and the raw data is available with the principal researcher and is accessible if requested.

Results and Discussion:

The samples were analyzed, and the ridge characteristics and pore characteristics, along with the fingertip sizes, were measured. Further, the OSA formula¹ was applied to the raw data and tested for the positive results of the stated hypothesis of estimating the age of the fingerprint donor from the ridge characteristics.

Application of the formula: The data is separated into different tables based on the category and on the digit number. The higher and lower ranges of ridge density and pore density were selected, and the table has the values from the lower value to the higher value. The frequency of each value is noted as the number of occurrences. Then, the formula (1) is applied to each table to find the occurrence percentage of male and female samples in all five categories.

Occurrence Percentage:
$$\frac{\text{No. of occurrence of Ridge Density} \times 100}{\text{Total number of samples}} \rightarrow (1)$$

Example (from table 5 for the Female : RD: 22) = O.P. = $6/250 \times 100 = 2.4$

From Table No. 5, the RD value of 22 for the female sample would have 2.4 as its occurrence percentage, as its frequency is 6, which is divided by the total number of female samples, 250, and multiplied by 100 to derive the percentage value.

After the occurrence percentage is calculated using the above formula, the OSA (optimum score assigned) value is calculated using the following formula (2) for both male and female samples in all five categories.

¹Gnanasivam, P., & Vijayarajan, R. (2019). Gender classification from fingerprint ridge count and fingertip size using optimal score assignment. *Complex & Intelligent Systems*, 5, 343-352

OSA of RD: Occurrence percentage of the RD $\times 10 \rightarrow (2)$
~~Highest occurrence percentage of the digit~~

Example: OSA of RD (Female: 22) = $2.4/4.8 (\times 10) = 5.0$

From the occurrence percentage, the OSA value is calculated by dividing the occurrence percentage of that particular ridge density among the selected population with the highest occurrence percentage of that data set; i.e., 4.8 in the case of the female sample: 22 RD. Then it is multiplied by 10 as an overall constant value assigned. In the female sample, the OSA value for ridge density 22 is 5.

Then the average OSA value of each category is calculated by the mean formula:

$$\text{Mean} = \sum x / n \rightarrow (3)$$

Followed by the average ridge thickness value of each category, the fingertip sizes are calculated. (Tables 1 and 2)

Female: _AFTS (incm)	1	2	3	4	5	6	7	8	9	10
C-1	2.4	1.6	1.8	1.7	1.2	2.8	1.5	1.8	1.6	1.3
C-2	3.1	2.4	2.5	2.3	2.1	3.2	2.5	2.6	2.5	2
C-3	3.6	2.8	3.0	2.9	2.8	3.6	2.9	3.1	2.9	2.7
C-4	3.4	2.5	2.6	2.4	2.2	3.3	2.6	2.9	2.6	2.4
C-5	3.2	2.3	2.4	2.25	2.175	3.1	2.4	2.5	2.3	2

(Table 1: Average fingertip size of the female samples under different categories of all 10 digits.)

(Table 2: Average fingertip size (_AFTS) of the male samples under different categories of all 10 digits.)

The average fingertip size was also measured with reference to the OSA study formulated by P. Gnanasivam and R. Vijayarajan². This measurement is done on the rolled fingerprints. The OSA study mainly relied on FTS (fingertip size) and RC (ridge count) for the gender analysis and age analysis. Contrastingly, the fingerprints developed from the crime scene are hardly complete enough to measure the actual fingertip size of an individual, and hence, this study mainly focused on RT (ridge thickness) instead of RC (ridge count) for the comparison.

The study estimated the donor's age by analyzing pore density and ridge density, aiming to understand the significance of pores in age estimation and to compare these results with a newly developed method for estimating the donor's age based on latent fingerprints.

Reference tables are shown below:

²Gnanasivam, P., & Vijayarajan, R. (2019). Gender classification from fingerprint ridge count and fingertip size using optimal score assignment. *Complex & Intelligent Systems*, 5, 343-352.

Category 1: RD

Male: Δ FTS (in cm)	1	2	3	4	5	6	7	8	9	10
C-1	2.8	2	2.1	1.9	1.4	2.2	1.9	2.1	1.85	1.5
C-2	3.7	2.8	3	2.9	2.5	3.8	2.9	3.2	3	2.8
C-3	4.3	3.7	3.9	3.8	3.5	4.2	3.8	3.95	3.7	3.5
C-4	4.1	3.5	3.6	3.4	3.1	4	3.4	3.7	3.6	3.2
C-5	3.9	3.2	3.3	3.1	2.9	3.85	3.3	3.45	3.1	3

(Table No. 3: Maximum and minimum Ridge counts of all the digits from category 1 (Age 15-25))

Category 1: PD

(Table No. 4: Maximum and minimum Pore density on all the digits of Category 1 (Age 15-25))

Finger Number	Ridge Count					
	Minimum		Maximum		Most Common	
	Female	Male	Female	Male	Female	Male
1	20	16	28	22	24	19
2	20	16	28	24	23	21
3	18	16	24	24	22	21
4	19	17	24	23	22	21
5	21	17	27	24	25	21
6	16	16	28	21	23	19
7	20	14	27	24	24	22
8	19	16	23	24	21	20
9	18	17	25	24	21	22
10	21	17	28	24	25	21

Finger Number	Pore Count					
	Minimum		Maximum		Most Common	
	Female	Male	Female	Male	Female	Male
1	154	151	212	229	183	186
2	201	143	253	234	213	231
3	180	148	242	236	190	206
4	193	143	237	228	219	203
5	213	141	271	239	253	220
6	213	131	272	223	244	211
7	207	138	247	239	236	216
8	179	162	237	226	220	206
9	194	126	235	231	218	201
10	216	127	270	235	216	207

Similarly, the OSA value was calculated for all the digits under all 5 categories. The method is then simultaneously followed to calculate the pore density and its assigned OSA values. The references are as follows:

RD	Number of Occurrence		Occurrence Percentage		Scores Assigned	
	Female	Male	Female	Male	Female	Male
16	0	1	0	1	0	0.4
17	0	5	0	5	0	2
18	0	9	0	9	0	3.6
19	0	15	0	15*	0	6
20	1	15	0.4	15*	0.833	6
21	1	3	0.4	3	0.833	1.2
22	6	2	2.4	2	5	0.8
23	11	0	4.4	0	9.167	0
24	12	0	4.8*	0	10	0
25	11	0	4.4	0	9.167	0
26	5	0	2	0	4.167	0
27	2	0	0.8	0	1.667	0
28	1	0	0.4	0	0.833	0

PD	Number of Occurrence		Occurrence Percentage		Scores Assigned	
	Female	Male	Female	Male	Female	Male
150-160	1	2	0.4	0.8	0.714	1.429
160-170	8	2	3.2	0.8	5.714	1.429
170-180	14	5	5.6*	2	10.000	3.571
180-190	13	9	5.2	3.6	9.286	6.429
190-200	8	13	3.2	5.2*	5.714	9.286
200-210	4	9	1.6	3.6	2.857	6.429
210-220	1	6	0.4	2.4	0.714	4.286
220-230	0	4	0	1.6	0.000	2.857

(Table No 5: Maximum and minimum ridgedensity of all the digits from category 1: Age 15-25 *highest occurrence percentage.)

(Table No. 6: Optimum Score Assigned for pore density on the Category 1: Right Thumb (RT) *highest occurrence percentage.)

On calculating all the OSA values for all the digits under the 5 age categories, the OSA formula was applied as follows:

In this context, let 'I' represent the identifiable value of the sex and age category, while I_{FS} and I_{MS} denote the identifying values for the female sample and male sample, respectively. The following formulas* (4) and (5) were applied to the samples based on their sex.

$$I_{FS} = A(OSA)RD_F + A(RT)_F \rightarrow (4)$$

$$I_{MS} = A(OSA)RD_M + A(RT)_M \rightarrow (5)$$

For unidentified samples, the following formula can be used:

$$I_{US} = A(OSA)RD_{US} + A(RT)_{US} \rightarrow (6)$$

where:

I_{FS} = Identifying value of the female sample.

I_{MS} = Identifying value of the male sample.

I_{US} = Identifying the value of the unknown sample.

A(OSA)RD_F = average OSA value of the ridge density of the female sample.

A(OSA)RD_M = average OSA value of ridge density of the male sample.

A(OSA)RD_{US} = average OSA value of Ridge Density of the unidentified sample.

A(RT)_F = Average Ridge Thickness of the female sample.

A(RT)_M = Average Ridge Thickness of the male sample.

A(RT)_{US} = Average Ridge Thickness of the unidentified sample.

The following table, No.7, shows the category (n): Identifying values of the samples with respect to the ridge density using the formulas (4) and (5):

Sl. No	C _F : I _{FS}	Value	C _M : I _{MS}	Value
1	C1 _F : I _{FS}	2.937	C1 _M : I _{MS}	3.171
2	C2 _F : I _{FS}	2.855	C2 _M : I _{MS}	2.964
3	C3 _F : I _{FS}	1.920	C3 _M : I _{MS}	2.097
4	C4 _F : I _{FS}	1.961	C4 _M : I _{MS}	2.130
5	5C _F : I _{FS}	1.766	C5 _M : I _{MS}	1.906

(Table No.7 shows the Category (n): Identifying values of the samples with respect to the Ridge Density using the formulas (4) and (5))

Similarly, let 'I' be the identifiable value of the sex and age category. Let I_{FS} and I_{MS} be the identifying values of the female sample and male sample.

The following formulas (4) and (5) were applied to the samples based on their sex.

$$I_{FS} = A(OSA)PD_F + A_{RT_F} \rightarrow (7)$$

$$I_{MS} = A(OSA)PD_M + A_{RT_M} \rightarrow (8)$$

Step 13: For unidentified samples, the following formula can be used:

$$I_{US} = A(OSA)PD_{US} + A_{RT_{US}} \rightarrow (9)$$

where:

I_{FS} = Identifying value of the female sample.

I_{MS} = Identifying value of the male sample.

I_{US} = Identifying the value of the unknown sample.

$A(OSA)PD_F$ = average OSA value of the ridge density of the female sample.

$A(OSA)PD_M$ = average OSA value of ridge density of the male sample.

$A(OSA)PD_{US}$ = average OSA value of Ridge Density of the unidentified sample.

A_{RT_F} = Average Ridge Thickness of the female sample.

A_{RT_M} = Average Ridge Thickness of the male sample.

$A_{RT_{US}}$ = Average Ridge Thickness of the unidentified sample.

The following table, no.8, shows the category (n): Identifying values of the samples with respect to the pore density using the formulas (7) and (8):

Sl. No	C _F : I _{FS}	Value	C _M : I _{MS}	Value
1	C1 _F : I _{FS}	5.413	C1 _M : I _{MS}	2.891
2	C2 _F : I _{FS}	6.025	C2 _M : I _{MS}	3.289
3	C3 _F : I _{FS}	2.035	C3 _M : I _{MS}	2.215
4	C4 _F : I _{FS}	1.752	C4 _M : I _{MS}	1.921
5	C5 _F : I _{FS}	2.165	C5 _M : I _{MS}	2.300

(Table no.8 shows the Category (n): Identifying values of the samples with respect to the Pore Density using the formulas (7) and (8))

The OSA study states that the identifying value of the male samples is higher than the female samples, i.e., $I_{FS} < I_{MS}$, which is true and positive. On the other hand, the age estimation of the donor became inconclusive, as the identifying value of the Category 2 female sample was similar to that of the Category 3 male sample, and the values were inconsistent. Considering the average ridge thickness value, the gender determination is positive, which helps in approximating the age of the donor based on the ridge density.

Contrastingly, the pore density shows very significant and drastic variations with respect to the identifying values of each category in both male and female samples. Hence, the OSA study to estimate the age of the donor is more effective when performed with the

pore density and ridge thickness. The IFS value for category 1 is 5.4, whereas the IMS value for category 1 is 2.891. similar to all the following categories. Hence, the OSA study proved to be effective for the age estimation of the donor from the latent fingerprints when parameters such as pore density with respect to ridge thickness are studied. The identifying value for the unknown samples positively aids in the age estimation of the donor when compared to the nearby values in the table above.

Conclusion:

In this OSA method, scores are assigned for the stated reason that the numbers of Ridge Count (RC) values or Finger Tip Size (FTS) occur at different percentages. There is a noticeable difference between the male and female samples regarding their assigned scores, as observed from the dataset. RC and FTS were used as the parameters to calculate a fingerprint's total score. Therefore, if the total score indicates a greater likelihood of either male or female sex, then such will be classified accordingly. Optimal Score Assignment (OSA) is a crucial element for achieving accurate gender recognition by analyzing fingerprint parameters, including ridge count and fingertip size. By accurately determining the scores assigned to both male and female samples, this approach allows for highly precise gender classification across sexes. It says much about gender identification systems' performance, as it boasts an 88.41% success rate, surpassing other methods looked into during the study. The OSA fingerprint-based gender classification method has a higher success rate than other existing methods tested by these researchers, with 88.41%. Other methods have been found wanting when compared with OSA, proving its effectiveness in the proper estimation of one's biological sex using fingerprint data analysis techniques. This research acknowledged that OSA can be applied in age estimation using latent fingerprints. This hypothesis was tested in this study as a comparison method, and the interpretations displayed that pore density (PD) and ridge thickness (RT) employed in the same formula, instead of RC and FTS factors, showed a higher success rate than the traditional OSA formula in estimating the age of the fingerprint donor. Therefore, the updated OSA technique demonstrates innovation and effectiveness in criminal investigations, facilitating criminal profiling using latent fingerprints gathered from the crime scene.

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