Palmprints: An Introduction

9

Ashish Badiye, Archana Kamble, and Neeti Kapoor

Abstract

Palmprints are the prints formed due to the friction ridges in the middle portion of the ventral part of the hand. These are equally important as fingerprints because of their uniqueness and persistence. However, as the palmprints have a larger surface area, they can provide more number of ridge details than fingerprints. Palmprints are often found at the crime scenes like sexual offences, burglary, kidnapping, murder, rape, theft, and forgery. Apart from normal ridge details, palmprints also have unique characteristic features, including principal lines, tri-radii, and vestiges; some ridge characteristics are specific to a particular palm region. This chapter presents various aspects and classifications of the palmprint. Considering the actual scene of crime, the investigating officer may not get a complete palmprint; thus, in such cases, the unique ridge details and the palmprint classification system may serve the purpose of comparing and identifying the unknown print with the suspect's palmprint.

Keywords

Hand prints · Palm prints · Palmprint classification · Interdigital · Thenar · Hypothenar

A. Badiye · N. Kapoor (✉)
Department of Forensic Science, Government Institute of Forensic Science, Nagpur, Maharashtra, India
e-mail: ashishbadiye@ifscnagpur.in; neetikapoor@ifscnagpur.in

A. Kamble
Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu, India

P. Shrivastava et al. (eds.), *Textbook of Forensic Science*,
https://doi.org/10.1007/978-981-99-1377-0_9

9.1 Introduction

'Palm' refers to the inner surface of the hand, and 'palmprints' are the prints formed by the inner surface of the hand. The terms 'palmprint' and 'handprint' cannot be used interchangeably as the handprint includes the print of the whole hand, including the print of the fingers and thumb phalanges, while the palmprint is a portion of the ventral part of the hand (Gopal et al. 2016). Handprints and palmprints are often encountered at the crime scene. Handprints can provide information such as the stature of the person (Krishan et al. 2015), sex (Kapoor and Badiye 2015a; Jerković et al. 2021; Dayarathne et al. 2021), determination of hand (Kapoor and Badiye 2015b; Kapoor et al. 2020), and personal identification. Palmprints can also play a significant role in differentiation between left and right hands, determination of sex (Badiye et al. 2019), personal identification, and presence of any abnormalities in the palm. Handprints and palmprints can be encountered in crimes like burglary, theft, kidnapping, sexual assaults, etc., on various surfaces. Just like fingerprints, palmprints can be used for the identification of suspects, as palmprints are also unique and persistent (Fig. 9.1).

Generally, the palmprint is divided into three groups: interdigital area (area below the fingers), thenar area (area near thumb), and hypothenar area (area near little finger). Palmprints have some characteristic features; thus, even when partial prints are collected from the crime scene, they may provide helpful information (Fig. 9.2).

Fig. 9.1 Inked handprints of left and right hand

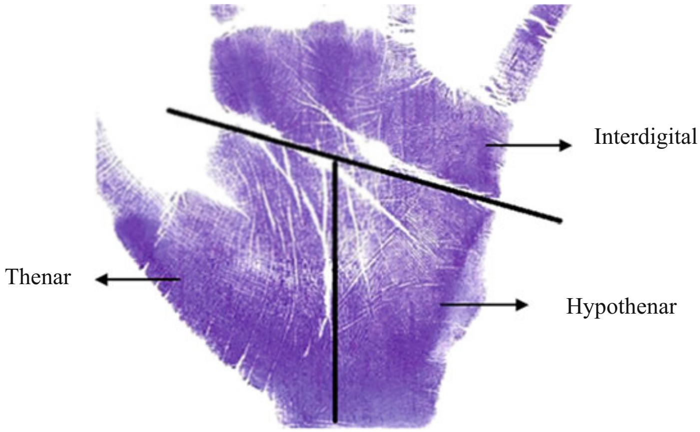


Fig. 9.2 Three palmar regions: interdigital, hypothenar, and thenar

9.2 The Emphasis on Palmprints over Fingerprints

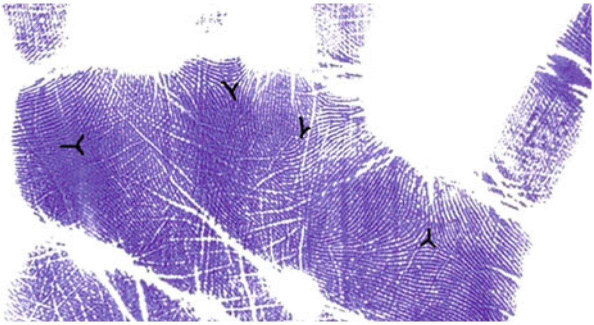
Palmprints are similar to fingerprints as they are unique for every individual; even monozygotic twin does not have the same palmprints. They are persistent throughout human life and have ridge details similar to fingerprints. Fingerprints are smaller in size and thus may have more probability of getting smudged prints. However, palmprints have a larger surface area than fingerprints; thus, the ridge details are better appreciated. Palmprint also has unique characteristics like principal lines, tri-radii, etc., which can be used for classification and identification purposes.

9.3 Regions of Palm

- Interdigital Region
  The interdigital region shows many ridge details. The primary ridge flow starts from the bottom of the index or middle finger, runs in the interdigital region, and exits the palm from the ulnar side. This characteristic feature is called a "waterfall" (Fig. 9.3). Usually, the interdigital areas have four deltas located below each finger. However, palmprints may have less or more than four deltas (Maceo et al. 2013). The delta below the index finger is termed "clean delta," the delta below the middle finger is termed "snow cone delta," the delta below the ring finger is called "double snow cone right/left," and the delta below the little finger is known as "side cone" (Horton 2018). The most common patterns found in the interdigital region are loop and whorl; other than that, patterns like column and tented arch are also observed (Horton 2018). The interdigital region can be divided into VP regions: the region between the index and middle fingers, the region between the middle and ring fingers, and the region between the ring and little fingers as II, III, and IV, respectively (Maceo et al. 2013) (Fig. 9.4).

Fig. 9.3 Waterfall region of interdigital region of left and right hand

Fig. 9.4 Interdigital region of right palm showing the index (I), middle (M), ring (R), and little (L) deltas



- Thenar
  The thenar region is the area below the thumb of the palm. The thenar region has two characteristic features, namely, half-moon and vestiges. The ridges entering the palm through the middle of the index finger and the thumb and leaving from the bottom of the print give rise to a semi-circle formation around the thumb and is called a "half-moon." Another characteristic feature of the thenar area is the vestige. The vestiges run perpendicular to the pattern's normal ridge flow and are usually found at the base of the thumb. Vestiges are only found in thenar region; thus, it can be very helpful in partial palmprint examination to understand the orientation of the hand as well as differentiation between right and left hand. Vestiges are also called "thenar area clues" (Horton 2018). Vestiges may be small and independent. However, this region may also show patterns such as loop, column, and whorl (Maceo et al. 2013). Another region called the flip area is located in the web area. These ridges change the flow direction as they flip up, thus termed as "flip area" (Horton 2018) (Fig. 9.5).

Fig. 9.5 Thenar area of right hand

- Hypothenar Region
  The hypothenar area covers the most significant part of the palm, and thus, it is primarily present in most partial palmprints. The ridges show a downward movement and exit from the side of the hand. The portion of the ridges in the hypothenar region tends to converge and appears as a funnel, thus termed as "funnel area." "Belly out" regions are at the bottom of the hypothenar area, where the ridges running down the pattern make a turn and exit the palm through the side of the hypothenar region. The ridges flowing in the vertical direction form a delta at the lower portion of the palm. It is termed the "carpal delta" and is mainly formed between the thenar and hypothenar regions. A slight arch below the carpel delta is called a "hump." The most common pattern found in the hypothenar region is a loop. The loop pointing towards the outer edge of the palm is called the "ulnar loop," while the "radial loop" points towards the center of the palm. The loop pointing toward the bottom of the palm is called a "proximal loop" (Maceo et al. 2013; Horton 2018) (Figs. 9.6, 9.7, and 9.8).

Fig. 9.6 Funnel area of the right hand

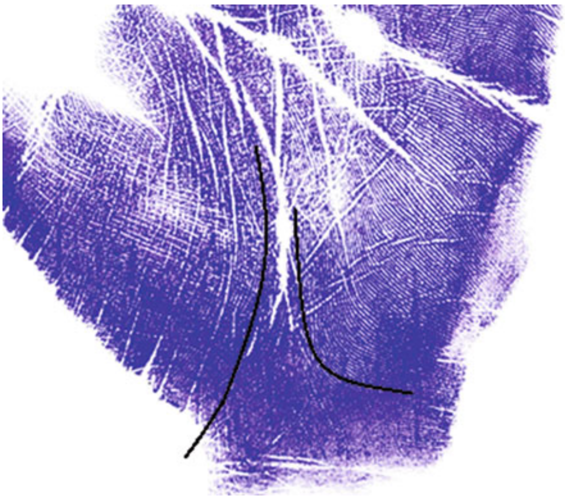


Fig. 9.7 Outline of the belly out portion of the right hand

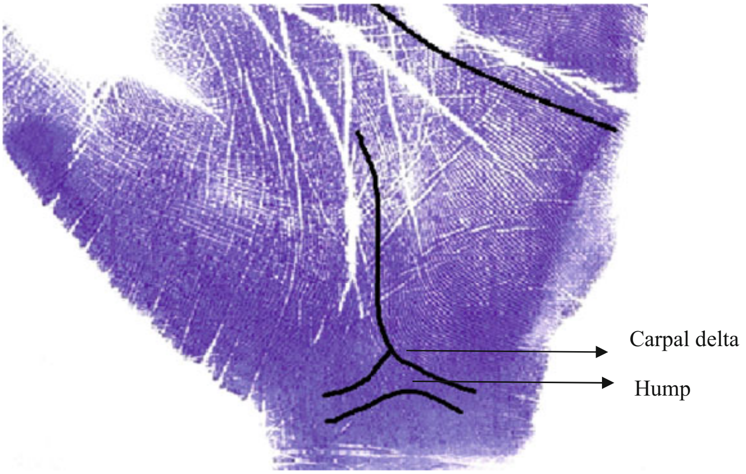


Fig. 9.8 The carpal delta and hump areas of the palm of the right hand

9.4 Classification of Palmprints

Classification of palmprints is very helpful for documenting and comparing complete and partial prints. Some palmprint classification systems are given below.

9.4.1 Western Australian Palmprint Classification

- Primary Classification
  The primary classification is based upon the ridge flow in the palm's three regions, i.e., interdigital, thenar, and hypothenar regions. The values assented to the areas are similar to the Henry classification, but this classification provides numerical values irrespective of the type of pattern present. Furthermore, in the end, one is added to the total score (Table 9.1).
- Secondary Classification
  The secondary classification has two divisions. The first division is based on the patterns present in the thenar and hypothenar areas. And the values are expressed in the form of fractions with thenar values in the numerator and hypothenar values in the denominator. The second division (secondary subclassification) deals with

Table 9.1 Primary value determination (Baird 1959, pp 21–24)

Area of consideration		Value
Interdigital	Delta near fifth finger	1
	Delta between third and fourth finger	2
	Delta between third finger to radial edge	4
Thenar		8
Hypothenar		16
No pattern in the area		0

the area between the thumb, index finger, and interdigital area (Holder et al. 2011). Therefore, the classification formula becomes

$$(\text{primary}) = (\text{thenar})\ (\text{thumb to index area})/(\text{hypothenar})\ (\text{interdigital}).$$

9.4.2 Liverpool Palmprint Classification System

The Liverpool classification system is based on three divisions of palm, similar to the Western Australian Palmprint Classification system; however, the Liverpool classification system has four parts and is represented in alpha numeric symbols.

1. Primary Division
   The primary division has three parts thenar, hypothenar, and interdigital. In cases when more than one pattern is present in the palmer area, it is considered as one pattern. While in cases when the patterns are present in different palmer areas, all the values are added together. Value pattern indications are represented in Table 9.2.
2. Secondary Division
   The secondary classification is based upon the ridge patterns present in the hypothenar region of the palm. Table 9.3 represents the symbols for each pattern observed in the hypothenar region. In the secondary subclassification, the ridge characteristics are recorded when a single loop is present in the hypothenar area. And in case of absence of any pattern, type of delta is recorded.
3. Tertiary Division
   Tertiary division is considered for the patterns in the thenar area. If two patterns are present in the thenar region, the coding box is divided into two parts by a diagonal line from the lower-left corner to the upper right corner of the box. Moreover, the pattern present near the interdigital area is represented by an alphabetical symbol in the upper left triangle. The pattern near the thenar region is represented by an alphabetical symbol in the lower-left triangular box of the coding box.

Table 9.2 Pattern indication from primary value

Primary	Value pattern indication
1	None
2	Thenar only
3	Interdigital only
4	Hypothenar only
5	Thenar and interdigital only
6	Thenar and hypothenar only
7	Interdigital and hypothenar only
9	Patterns in all three areas

Table 9.3 Symbols used in the secondary classification in the Liverpool Palmprint Classification System

Pattern	Symbol
Whorl A (circular)	A
Whorl B (elliptical)	B
Twinned loop	TL
Lateral pocket loop	LP
Central pocket loop	CP
Accidental/composite	ACC
Tented arch	T
Loop core inward	I
Loop core outward	O
Loop core downward	D
Loop core upward	U
Loop core nutant	K
Nondescript	N
Plain arch	N
No pattern	
High carpal delta	H
Low carpal delta	L

Table 9.4 Pattern value for part 2 of the quaternary division

Position of pattern	Value
Under index finger	8
Under middle finger	4
Under ring finger	2
Under little finger	1

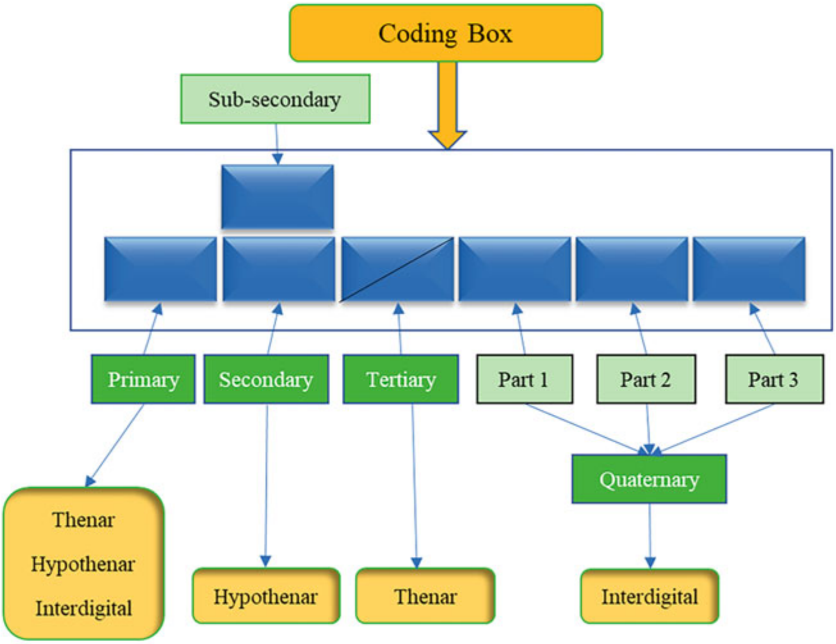
4. Quaternary Division
   The quaternary division is based on the patterns observed in the interdigital region of the palm. It sub-divided into three parts. Part 1 represents the pattern present in the interdigital area. Part 2 provides a numerical value to the pattern in relation to the fingers (Table 9.4). Part 3 involves recording the ridge count for arch and loop patterns.

The complete classification system of the Liverpool palmprint classification is represented within a coding box, and the patterns are mentioned in the coding box as alphanumeric symbols (Table 9.5).

9.4.3 The Brogger Moller Palmprint Classification System

The Brogger Moller Palmprint Classification System employs a special measuring glass with four separate measuring areas. Each area has three concentric circles with 2, 4, and 6 cm radii. This classification system involved patterns present in three regions of palm and primary, secondary, and tertiary values (Tables 9.6, 9.7, and 9.8). And the measuring glass was used to determine some values as represented in the table below (Holder et al. 2011).

Table 9.5 Coding box for Liverpool Palmprint Classification System



9.4.4 Palmprint Classification Using Principal Lines

The principal lines have been used to classify a palmprint. The print can be classified into six categories based on the principal lines and intersections. To classify the print, the principal lines are defined, and the number of principal lines and intersections are counted (Wu et al. 2004) (Table 9.9).

9.4.5 Automated Palmprint Classification Systems

Some authors have worked in the area of automated palmprint identification systems (Chen et al. 2001; Duta et al. 2002; Funada et al. 1998; Li et al. 2002; Sowmiya Manoj and Arulselvi 2021; Wu et al. 2002; Zhang and Shu 1999). Sakdanupab and Covavisaruch (2008) provided an automated palmprint classification system based on extraction of the heart line, head line, and life line. Scanned palmprints were overlaid in the computer system and compared by automated tools (Connie et al. 2005). The FBI has initiated a process to collect and convert into digital format to maintain a digital library (Holder et al. 2011).

Table 9.6 Classification for the hypothenar (Moenssens 1971, pp 200–205)

Ridge pattern	Primary	Secondary	Tertiary
No design (carpal delta only)	1	Using circle measurement, dot at carpal delta and read circle where the lowest ridge of the carpal area falls	None
Distal loop opening toward interdigital, with core pointing to ulnar side	2	Using 0–9 scale, measure the distance between the carpal delta and core of the loop	8 = only when the core has a distinct inclination toward the carpal/radial area
Outward loop opening toward ulnar side, with core pointing toward thenar	3	Using a 0–9 scale, measure the distance between the carpal delta and core of the loop	None
Whorls	4	Using a 0–9 scale, measure the distance between carpal delta and core (for double whorls, using core closest to carpal delta)	None
Double loops	5	Using a 0–9 scale, measure the distance between two cores	None
Arches	6	1 = arches	None
		2 = tented arches	
Loops opening toward the wrist, with the core pointing toward the ulnar side of the palm	7	Using a 0–9 scale, measure the distance between core and delta above it	None
Composite patterns (any pattern not conforming to the above patterns)	8	None	None

Case Study: Automated systems aid in comparing the unknown print with the database and finding the matching print. AFIS has helped in solving many crimes. A case was reported of a break-in into a business, and lateral palmprints were found on the entrance lock. The prints were developed using magnetic powder, and a scanned copy was run in the AFIS to find the match. However, no result was found. A few months later, fingerprints and palmprints of a suspect were collected and compared with the unknown lateral palmprint, and it was found to be a positive match. It was found that the suspect's record already exists but due to lack of sufficient amount of ridge details of lateral palmprints, it was not detected (Hefetz et al. 2021).

Table 9.7 Classification for the interdigital (Moenssens, pp 206–207)

Ridge pattern	Primary	Secondary	Tertiary
One loop in the base area	1	2 = if the loop is between index and middle fingers 3 = if loop is between middle and ring fingers 4 = if the loop is between the ring and little fingers	Using 1–6 scale, measure the height of the loop (from deltas to core)
Tented arch	2	1 = arch below index finger 2 = arch below middle finger 3 = arch below ring finger 4 = arch below little finger	Using a 1–6 scale, measure height of the arch (from the base of the arch to the summit)
Double loops	3	2 = if the loop is between the index and middle fingers 3 = if a loop is between middle and ring fingers 4 = if a loop is between the ring and little fingers	Using 1–6 scale, measure the height of the ulnar loop (from deltas to core)
Two loops in the same interdigital area and tented arches and loops in other areas	4	2 = if a two-loop combination is between the index and middle fingers 3 = if a two-loop combination is between the middle and ring fingers 4 = if a two-loop combination is between the ring and little fingers	None
Plain arches	5	None	None
One loop and one tented arch	6	2 = if a loop is between the index and middle fingers 3 = if a loop is between middle and ring fingers 4 = if a loop is between the ring and little finger	Using 1–6 scale, measure the height of loop (from deltas to core)
Three loops or combinations of three loops and tented arches	7	Three loops = height of loop between the ring and middle fingers. Combination of three loops and tented arches = height of pattern located next to the ulnar side of palm	None 2
Long transversal loop below one or several digital deltas	8	None	None
One or several whorls appear alone or in combinations with loops and tented arches	9	2 = if whorl is between the index and middle fingers 3 = if whorl is between middle and ring fingers 4 = if whorl is between the ring and little fingers	None

Table 9.8 Classification for the thenar (Moenssens, pp 207–209)

Ridge pattern	Primary	Secondary	Tertiary
No pattern (or plain arch)	1	None	None
Various patterns	2	1 = one proximal loop opens toward the radial side with the core pointing to the web of the thumb or center of the palm	Using a 0–9 scale, measure distance between the core and the nearest delta
		2 = one proximal loop and one distal loop	Using a 0–9 scale, measure the distance between the core of the proximal loop and nearest delta
		3 = one proximal loop and one whorl	None
		4 = one proximal loop and one double loop	None
Patterns with peculiar ridge formations	3	None	None
One distal loop opening toward the web of the thumb with the core pointing downward	4	Using a 0–9 scale, measure the distance between core and delta (not carpal delta)	None
Three different patterns	5	1 = one single whorl	None
		2 = one whorl and one distal loop	None
		3 = two whorls	None
Four different patterns	6	1 = one double loop	None
		2 = one double loop and one distal loop	None
		3 = one double loop and one whorl	None
		4 = two double loops	None
Two collateral distal loops both opening toward the web of the thumb	7	None	None
Two proximal loops, either both opening toward the carpal area or one toward the radial area and one toward the carpal area	8	None	None
Any pattern not discussed	9	None	None

Table 9.9 Palmprint classification system based on principal lines and intersections

Category	Number of principal lines	Number intersections	Symbol
1	1	0	(a)
2	2	0	(b)
3	2	1	(c)
4	3	0	(d)
5	3	1	(e)
6	3	>1	(f)

9.5 Conclusion

The study of palmprints holds immense potential in identifying individuals and assisting in criminal investigations. Palmprints, with their intricate patterns and distinctive features, offer a wealth of information for forensic analysis. The subsequent exploration of the regions of the palm highlights the complex nature of palmprints. The various parts, including the thenar, hypothenar, and interdigital areas, each possess distinct characteristics that contribute to the overall identification process. Understanding these regions' specific details and patterns is vital for accurate palmprint analysis.

Overall, the chapter emphasizes the unique nature of palmprints as a valuable forensic tool. Forensic experts can extract crucial information for individual identification and crime scene analysis by examining the handprints' regions and employing classification systems. As technology advances, palmprint analysis promises to play an increasingly integral role in forensic investigations, enhancing our ability to solve complex cases and bring justice to those affected.

References

Badiye A, Kapoor N, Mishra SD (2019) A novel approach for sex determination using palmar tri-radii: a pilot study. J Forensic Leg Med 65:22–26. https://doi.org/10.1016/j.jflm.2019.04.005

Baird AJ (1959) System used by the Western Australian police force for the classification and filing of palmprints (unpublished)

Chen J, Zhang C, Rong G (2001) Palmprint recognition using crease. In: Proceedings 2001 international conference on image processing (Cat. No. 01CH37205), vol 3, pp 234–237

Connie T, Jin ATB, Ong MGK, Ling DNC (2005) An automated palmprint recognition system. Image Vis Comput 23(5):501–515. https://doi.org/10.1016/j.imavis.2005.01.002

Dayarathne S, Nawarathna LS, Nanayakkara D (2021) Determination gender using foot, footprint, hand and hand print measurements in a Sinhalese population in Sri Lanka using supervised learning techniques. Comput Methods Programs Biomed 1:100017. https://doi.org/10.1016/j.cmpbup.2021.100017

Duta N, Jain AK, Mardia KV (2002) Matching of palmprints. Pattern Recogn Lett 23(4):477–485

Funada J, Ohta N, Mizoguchi M, Temma T, Nakanishi K, Murai A, Sugiuchi T, Wakabayashi T, Yamada Y (1998) Feature extraction method for palmprint considering elimination of creases. In: Proceedings. Fourteenth international conference on pattern recognition (Cat. No. 98EX170), vol 2, pp 1849–1854

Gopal, Srivastava S, Bhardwaj S, Bhargava S (2016) Fusion of palm-phalanges print with palmprint and dorsal hand vein. Appl Soft Comput 47:12–20. https://doi.org/10.1016/j.asoc.2016.05.039

Hefetz I, Liptz Y, Oz K (2021) The benefit of AFIS searches of lateral palm and non-distal phalanges prints in criminal investigation. Forensic Sci Int 328:111024. https://doi.org/10.1016/j.forsciint.2021.111024

Holder EH, Robinson LO, Laub JH (2011) The fingerprint sourcebook. U.S. Dept. of Justice, Office of Justice Programs, National Institute of Justice

Horton A (2018) Using pattern area ridge flow in the three areas of the palm to determine classification trends. The University of Southern Mississippi

Jerković I, Kolić A, Kružić I, Anđelinović Š, Bašić Ž (2021) Adjusted binary classification (ABC) model in forensic science: an example on sex classification from handprint dimensions. Forensic Sci Int 320:110709. https://doi.org/10.1016/j.forsciint.2021.110709

Kapoor N, Badiye A (2015a) Sex differences in the thumbprint ridge density in a central Indian population. Egypt J Forensic Sci 5(1):23–29. https://doi.org/10.1016/j.ejfs.2014.05.001

Kapoor N, Badiye A (2015b) An analysis of whorl patterns for determination of hand. J Forensic Leg Med 32:42–46. https://doi.org/10.1016/j.jflm.2015.02.015

Kapoor N, Badiye A, Mishra SD (2020) Fingerprint analysis for the determination of hand origin (right/left) using the axis slant in whorl patterns. Forensic Sci Res 7(2):285–289. https://doi.org/10.1080/20961790.2020.1794362

Krishan K, Kanchan T, Kharoshah MA (2015) Estimation of stature from handprint dimensions – positional variations in real crime scene situations. Egypt J Forensic Sci 5(4):129–131. https://doi.org/10.1016/j.ejfs.2015.10.002

Li W, Zhang D, Xu Z (2002) Palmprint identification by Fourier transform. Int J Pattern Recogn Artif Intell 16(04):417–432

Maceo A, Carter M, Stromback B, Vegas L, Police M, Vegas L (2013) Palm prints. In: Encyclopedia of forensic sciences, vol 4, 2nd edn. Elsevier, Amsterdam. https://doi.org/10.1016/B978-0-12-382165-2.00277-4

Moenssens AA (1971) Fingerprint techniques. Chilton Book

Sakdanupab M, Covavisaruch N (2008) An efficient approach for automatic palmprint classification. In: 2008 IEEE International conference on signal image technology and internet based systems, pp 229–234. https://doi.org/10.1109/SITIS.2008.22

Sowmiya Manoj M, Arulselvi S (2021) Palm print identification and classification using KNN algorithm. Materials Today Proc. https://doi.org/10.1016/j.matpr.2021.01.804

Wu X, Wang K, Zhang D (2002) Fuzzy directional element energy feature (FDEEF) based palmprint identification. In: 2002 International conference on pattern recognition, vol 1, pp 95–98

Wu X, Zhang D, Wang K, Huang B (2004) Palmprint classification using principal lines. Pattern Recognit 37(10):1987–1998. https://doi.org/10.1016/j.patcog.2004.02.015

Zhang D, Shu W (1999) Two novel characteristics in palmprint verification: datum point invariance and line feature matching. Pattern Recogn 32(4):691–702