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A CRITICAL STUDY OF FINGERPRINT ANALYSIS USED IN CRIMINAL INVESTIGATION IN INDIA

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ABSTRACT

Fingerprint analysis is the oldest, most widely employed, and simultaneously the most contested discipline in forensic science. This paper undertakes a critical examination of fingerprint analysis as deployed in criminal investigation in India, evaluating its scientific foundations, the legal framework governing its admissibility, the institutional architecture within which examinations are conducted, and the data-governance regime applicable to biometrically collected information. Drawing upon primary statutory and case-law sources, landmark scientific reports including the 2009 National Academy of Sciences Report and the 2016 PCAST Report, and comparative material from the United States, the United Kingdom, and the European Union, the paper argues that Indian law and practice have accepted fingerprint evidence with a degree of probative weight that is disproportionate to its scientifically validated reliability. The paper identifies three interconnected areas of structural weakness: the absence of a reliability-based admissibility standard analogous to the Daubert doctrine; institutional arrangements that insufficiently insulate fingerprint examiners from investigative pressure and cognitive bias; and a biometric data-governance regime expanded by the Criminal Procedure (Identification) Act, 2022 without commensurate enhancement of individual rights protections. The paper proposes legislative, institutional, and procedural reforms directed at aligning Indian forensic evidentiary practice with contemporary scientific standards and constitutional values.

Keywords: Fingerprint analysis, forensic evidence, ACE-V methodology, Indian Evidence Act, cognitive bias, biometric data, Criminal Procedure (Identification) Act 2022, Daubert

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standard, wrongful conviction, AFIS.

I. INTRODUCTION

Fingerprint analysis constitutes one of the oldest and most widely employed methods of forensic identification in the history of criminal investigation. The uniqueness and permanence of friction ridge skin patterns on the fingertips have long been recognised as reliable markers of individual identity, making fingerprint evidence a cornerstone of both investigative and judicial processes worldwide.

The scientific study of fingerprints dates to the mid-nineteenth century, when pioneers such as William James Herschel[1] and Henry Faulds[2] independently documented the individuality of finger ridge patterns and suggested their potential forensic application. Francis Galton subsequently provided the first comprehensive statistical and empirical basis for fingerprint identification, demonstrating mathematically that the probability of two individuals possessing identical fingerprints was negligibly small.[3]

The subsequent classification system developed by Edward Richard Henry, adopted by Scotland Yard in 1901, institutionalised fingerprint analysis as a standard law enforcement tool.[4] Over the following century, fingerprint identification expanded across jurisdictions globally, becoming deeply embedded in criminal investigation practice, court proceedings, and immigration administration.

Despite its widespread acceptance, fingerprint analysis has attracted increasing critical scrutiny, particularly following high-profile misidentifications such as the wrongful arrest of Brandon Mayfield in connection with the 2004 Madrid train bombings,[5] and the landmark 2009 National Academy of Sciences report, which questioned the scientific foundation of several forensic disciplines, including latent fingerprint analysis.[6]

The tension between fingerprint analysis's long-standing legal acceptance and the more recent

[1]William James Herschel, The Origin of Finger-Printing (Oxford University Press, 1916). Herschel used fingerprints in administrative contexts in British India as early as 1858.

[2]Henry Faulds, 'On the Skin-Furrows of the Hand', Nature, vol. 22 (1880), p. 605. Faulds was among the first to suggest the forensic application of fingerprint evidence.

[3]Francis Galton, Finger Prints (Macmillan, 1892). Galton's pioneering work established the scientific foundation for fingerprint identification.

[4]Edward Richard Henry, Classification and Uses of Finger Prints (George Routledge & Sons, 1900). The Henry Classification System became the standard adopted by Scotland Yard and later globally.

[5] In re Mayfield, No. CV-04-1427-MO (D. Or. 2007). The Mayfield case exposed critical vulnerabilities in fingerprint analysis procedures.

[6]National Academy of Sciences, Strengthening Forensic Science in the United States: A Path Forward (National Academies Press, 2009). This landmark report critically evaluated the scientific basis of fingerprint analysis.

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demands for rigorous scientific validation forms the central problematic of this study. This research undertakes a critical examination of the scientific, legal, and procedural dimensions of fingerprint analysis as deployed in criminal investigations in India, with particular attention to questions of reliability, admissibility, and the potential for examiner error.[7]

II. Historical Background and Evolution of Fingerprint Analysis

A. Ancient Origins

The practice of using fingerprints as a means of personal identification is far older than modern science. In ancient Babylon (circa 1800 BCE), merchants used their fingerprints impressed in clay tablets as a form of personal signature on business transactions, demonstrating an intuitive understanding that finger impressions were unique to each individual.[8] In ancient China, during the Qin Dynasty (221–206 BCE), finger impressions were routinely used to sign official documents and legal instruments.[9]

In the Indian subcontinent, the tradition of using finger impressions — particularly the thumb impression (angootha-chhap) — as a substitute for illiterate persons' signatures persisted throughout the medieval and early colonial periods, and fingerprint impressions are found in cave paintings at Bhimbetka (Madhya Pradesh) dating to over 30,000 years ago.[10] These usages, though intuitive rather than scientific, established an indigenous foundation for the forensic science that would later emerge.[11]

B. The Development of Modern Fingerprint Science

The transition from intuitive practice to modern forensic science occurred primarily during the nineteenth century. In 1823, Czech physiologist Jan Evangelista Purkinje described nine distinct fingerprint patterns, becoming the first scientist to formally classify friction ridge configurations.[12]

1. Sir Francis Galton's Contribution

Sir Francis Galton (1822–1911) is widely regarded as the founding father of scientific

[7]President's Council of Advisors on Science and Technology (PCAST), Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods (Executive Office of the President, 2016), p. 65.
[8]D.R. Ashbaugh, Quantitative-Qualitative Friction Ridge Analysis (CRC Press, 1999), p. 12.
[9] H. Cummins & C. Midlo, Finger Prints, Palms and Soles (Blakiston Company, Philadelphia, 1943), p. 3.
[10] C. Beavan, Fingerprints: The Origins of Crime Detection and the Murder Case That Launched Forensic Science (Hyperion Press, 2001), p. 28.
[11] J. Larson, 'Fingerprinting: Its Use as Legal Evidence', (1924) 15 Journal of Criminal Law and Criminology 178.
[12]Galton, Finger Prints (1892), p. 93.

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fingerprint analysis. In his landmark publication Finger Prints (1892), Galton demonstrated conclusively that fingerprint patterns remain unchanged from birth to death and that the probability of two individuals sharing identical fingerprints is approximately 1 in 64 billion.[13] He described the characteristic features of friction ridges — including bifurcations, ridge endings, and enclosures — which he termed 'minutiae'. He proposed the first scientific classification system, dividing patterns into three principal categories: arches, loops, and whorls. Although his classification system was not sufficiently refined for large-scale operational use, it provided the essential conceptual framework upon which subsequent systems were built.

2. The Henry Classification System

Sir Edward Richard Henry (1850–1931), Inspector-General of Police in Bengal, built upon Galton's work to create the first operationally practical fingerprint classification system. Working alongside Indian sub-inspectors Azizul Haque and Hem Chandra Bose — whose contributions, though often underacknowledged in Western historiography, were substantial — Henry developed a system that subdivided fingerprints into five major pattern types and organised them by ridge counts and ridge tracing.[14]

The Henry Classification System, published in Classification and Uses of Finger Prints (1900), enabled a fingerprint collection to be searched efficiently without recourse to names or photographs.[15] It was formally adopted by Scotland Yard in 1901 and spread rapidly across the British Empire and subsequently to police forces worldwide, including the United States Federal Bureau of Investigation, which adopted it in 1924. It remained the primary manual classification system in use globally until the introduction of Automated Fingerprint Identification Systems (AFIS) in the latter half of the twentieth century.

C. Fingerprinting in India: Historical Perspective

India occupies a uniquely significant position in the history of fingerprint science, both as an early site of practical application and as the birthplace of the world's first operational fingerprint bureau. Sir William James Herschel, a British civil servant posted in Bengal, is credited with being the first person to use fingerprints for official identification purposes from 1858 onwards.[16] Herschel systematically documented his own fingerprints over several decades,

[13]Galton, Finger Print Directories (Macmillan, 1895), p. 57.
[14]Henry, Classification and Uses of Finger Prints (1900), p. 41.
[15]Cole, Suspect Identities (2001), p. 61.
[16]G.S. Sodhi & J. Kaur, 'The Forgotten Indian Pioneers of Fingerprint Science', (2005) 88 Current Science 185.

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producing some of the earliest empirical proofs of fingerprint permanence.[17]

The first fingerprint bureau in the world was established in Calcutta (now Kolkata) in 1897, under the authority of the Bengal Presidency Government, predating Scotland Yard's own bureau by four years.[18] Following independence in 1947, the Government of India established the Central Fingerprint Bureau (CFPB) under the National Crime Records Bureau (NCRB) in New Delhi. In recent decades, India has undertaken the computerisation of fingerprint records and has implemented AFIS technology at both central and state levels.[19]

D. Evolution from Manual to Digital Fingerprinting

The advent of computerised fingerprint systems began in the 1960s and 1970s. The FBI's Integrated Automated Fingerprint Identification System (IAFIS), operational since 1999, represented a quantum leap in capability: it could search over 47 million fingerprint records and return identification results within two hours, compared to the weeks or months required by manual searches.[20]

Modern Automated Fingerprint Identification Systems (AFIS) employ sophisticated digital image processing algorithms that digitise the ridge structure of a fingerprint, extract minutiae coordinates, and compare them against stored templates using statistical matching scores.[21] Advances in machine learning and artificial neural networks have further enhanced matching accuracy, enabling reliable identification even from fragmentary or degraded latent prints.[22] In 2011, India's national biometric identity project — Aadhaar — began collecting fingerprints and iris scans from over a billion residents, representing the largest biometric database in human history.[23]

III. Scientific Foundations: Classification, Uniqueness, and Development Techniques

A. Definition, Nature, and Uniqueness of Fingerprints

A fingerprint may be defined as the impression produced by the papillary ridges on the inner

[17]Herschel, The Origin of Finger-Printing (1916), pp. 12-17.
[18]F.A. Khan, 'Role of Fingerprint Bureau in India', (1998) 45 Indian Police Journal 22.
[19]National Crime Records Bureau, Annual Report on Fingerprint Bureau Activities (Ministry of Home Affairs, 2022), p. 5.
[20]D. Maltoni, D. Maio, A.K. Jain & S. Prabhakar, Handbook of Fingerprint Recognition (2nd edn, Springer, 2009), p. 301.
[21]Jain, Ross & Prabhakar, 'An Introduction to Biometric Recognition' (2004), pp. 4-20.
[22]NIST, Fingerprint Vendor Technology Evaluation (FpVTE) (NIST, 2011), p. 8.
[23]Interpol, Fingerprint Recognition in Law Enforcement: Global Standards and Practices (Interpol Publications, Lyon, 2018), p. 14.

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surface of the terminal phalanx of a finger when it comes into contact with a surface. The friction ridges develop during the third and fourth months of foetal development through a complex process influenced by the interaction between genetic factors and the unique intrauterine environment of each individual.[24] Even genetically identical twins, who share the same DNA, have demonstrably different fingerprints — a fact of profound significance for forensic identification.[25]

Fingerprints are permanent in the sense that, barring severe damage to the dermis, the ridge pattern remains unchanged from approximately the fourth month of foetal development until decomposition after death. Superficial injuries to the epidermis may temporarily obliterate ridge detail, but as the skin heals, the original pattern is faithfully reproduced.[26] Galton calculated the probability of two fingerprints sharing identical minutiae configurations at approximately 1 in 64 billion; subsequent statistical analyses have reinforced and refined this estimate.[27]

B. Types of Fingerprints

In forensic science, fingerprints are classified into three types based on the manner in which they are deposited on a surface. Latent fingerprints are invisible to the naked eye, formed by the transfer of perspiration and skin oils from the friction ridges onto the surface.[28] Their recovery requires the application of physical or chemical development techniques, the choice of which depends upon the surface substrate, the age of the deposit, and environmental conditions.[29]

Patent fingerprints (also known as visible prints) are formed when a finger bearing a contaminant comes into contact with a surface, leaving a print that is immediately visible to the naked eye. Common contaminants include blood, grease, paint, and ink. Patent prints in blood are among the most forensically significant, as they may appear at violent crime scenes and provide both identification evidence and contextual information about the sequence of events.

Plastic or moulded fingerprints are formed when a finger is pressed into a soft, pliable material

[24]A.A. Moenssens, Fingerprint Techniques (Chilton Book Company, Philadelphia, 1971), p. 4.
[25]S.B. Holt, The Genetics of Dermal Ridges (Charles C. Thomas, Springfield, 1968), p. 6.
[26]H.C. Lee & R.E. Gaensslen (eds.), Advances in Fingerprint Technology (2nd edn, CRC Press, 2001), p. 9.
[27]R. Saferstein, Criminalistics: An Introduction to Forensic Science (11th edn, Pearson, 2015), p. 432.
[28]Champod, Lennard, Margot & Stoilovic, Fingerprints and Other Ridge Skin Impressions (CRC Press, 2004), p. 55.
[29]J.F. Cowger, Friction Ridge Skin: Comparison and Identification of Fingerprints (CRC Press, 1983), p. 78.

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that retains the impression, creating a three-dimensional negative of the friction ridge pattern. Common substrates include wax, putty, caulking compounds, soft soap, chewing gum, and fresh paint.[30]

C. Pattern Classification: Loops, Whorls, and Arches

Modern classification systems recognise three primary pattern types. Loops are the most frequently occurring fingerprint pattern type, accounting for approximately 60–65% of all fingerprints. A loop is defined by the presence of one or more ridges that enter the pattern from one side, recurve, and terminate on the same side from which they entered.[31]

Whorls constitute approximately 30–35% of all fingerprint patterns and are characterised by ridge configurations that make at least one complete circuit. The primary subtypes are: plain whorls, central pocket loops, double loops, and accidentals. Arches are the least common of the three primary types, occurring in approximately 5% of all fingerprints; they are characterised by ridges that enter from one side, rise in the centre, and exit from the other, without any delta or true core.[32]

D. Minutiae Features and the Scientific Basis of Individuality

Minutiae — the term coined by Francis Galton from the Latin word for 'small details' — refer to the specific local discontinuities in the friction ridge structure that are the primary basis of fingerprint comparison and identification. The principal types include ridge endings, bifurcations (forks), short ridges, dots, enclosures (lakes), spurs, and crossovers.[33]

The forensic comparison of fingerprints involves the alignment of the questioned print and the reference print and the systematic comparison of corresponding minutiae in terms of their type, location, and orientation. The precise number of corresponding minutiae required for a positive identification varies between jurisdictions. In India and the United Kingdom, a threshold of 16 matching points was historically applied, though modern evidence-based guidelines increasingly favour a holistic assessment of overall quality and quantity of corresponding features.[34]

[30]Federal Bureau of Investigation, The Science of Fingerprints: Classification and Uses (U.S. Department of Justice, 2004), p. 37.
[31]Henry, Classification and Uses of Finger Prints (1900), pp. 54-58.
[32]Galton, Finger Prints (1892), pp. 101-117.
[33]Maltoni et al., Handbook of Fingerprint Recognition (2009), p. 40.
[34] D.A. Stoney, 'Measurement of Fingerprint Individuality', in Lee & Gaensslen (eds.), Advances in Fingerprint Technology (2nd edn, CRC Press, 2001), p. 327.

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Statistical models of fingerprint uniqueness demonstrate that even genetically identical twins exhibit different minutiae configurations, because ridge formation is influenced by non-genetic factors specific to each foetus' intrauterine environment.[35] Champod applied probabilistic modelling to minutiae configurations and demonstrated that the probability of two randomly selected fingerprints sharing the same minutiae configuration at 12 or more points is vanishingly small, on the order of 10^{-36} or less.[36]

E. Development Techniques for Latent Fingerprints

Powder dusting is the oldest and most widely employed technique for the visualisation of latent fingerprints on non-porous surfaces. The principle underlying this method is the physical adhesion of fine powder particles to the oily and aqueous components of the latent residue. Standard fingerprint powders are formulated from aluminium, carbon black, titanium dioxide, or fluorescent compounds.[37]

Chemical development techniques exploit specific chemical constituents of latent print residue. Ninhydrin reacts with amino acids to produce a distinctive purple compound known as Ruhemann's purple and is particularly effective on paper and cardboard, having been successfully used to develop prints decades old. Cyanoacrylate (Super Glue) fuming involves the polymerisation of ethyl cyanoacrylate vapour on the latent deposit, producing a hard, white polymer that faithfully reproduces ridge morphology.[38]

Vacuum Metal Deposition (VMD) is among the most sensitive techniques available for fingerprint development on non-porous surfaces including polythene, polyester, nylon, and glass. The process is conducted within a vacuum chamber; gold is evaporated and deposits on the substrate, followed by zinc, which condenses on the gold-coated background but is excluded by the fatty components of the fingerprint residue, yielding a negative image of the fingerprint.[39] VMD has demonstrated the capacity to develop prints up to several months old and is particularly effective on plastic bags frequently encountered in drug-trafficking

[35]E. Gutierrez-Redomero, C. Alonso & E. Romero, 'Fingerprint Identification', (2011) 56 Journal of Forensic Sciences 586.
[36]C. Neumann et al., 'Computation of Likelihood Ratios in Fingerprint Identification', (2007) 52 Journal of Forensic Sciences 54.
[37]G.S. Sodhi & J. Kaur, 'Powder method for detecting latent fingerprints: A review', (2001) 120 Forensic Science International 172.
[38].S. Ramotowski, 'Composition of latent print residue', in Lee & Gaensslen (eds.), Advances in Fingerprint Technology (2nd edn, CRC Press, 2001), pp. 63-104.
[39] C. McLaren et al., 'Vacuum metal deposition and powder techniques for fingerprint visualisation', (2010) 60 Journal of Forensic Identification 386.

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investigations.[40]

IV. FORENSIC APPLICATION: THE ACE-V METHODOLOGY AND ITS CHALLENGES

A. The Automated Fingerprint Identification System (AFIS)

AFIS operates by digitising fingerprint impressions and extracting minutiae points through algorithmic image-processing. The system generates a numerical template based on the spatial relationships between minutiae, which is then compared against enrolled records to generate a ranked list of candidate matches expressed as similarity scores. An examiner subsequently reviews the top candidates to confirm or exclude a match using conventional ACE-V methodology.[41]

In India, the National Crime Records Bureau (NCRB) maintains the National Automated Fingerprint Identification System (NAFIS), which links fingerprint records across all state police forces to facilitate inter-state criminal identification. Interpol's Automated Fingerprint Identification System provides a cross-border database accessible to member nations for the identification of international criminals, fugitives, and unidentified human remains.[42]

B. The ACE-V Methodology

Fingerprint comparison is governed by the universally adopted ACE-V methodology: Analysis, Comparison, Evaluation, and Verification. This framework provides a structured, transparent, and reproducible approach that satisfies the scientific and legal standards expected of expert forensic opinion evidence.[43]

During the Analysis phase, the examiner independently assesses the latent print to determine its quality, the clarity of ridge detail, and the suitability of the mark for comparison.[44] The Comparison phase involves placing the latent print and the known impression side by side and identifying corresponding features systematically. The Evaluation phase requires the examiner to reach one of three conclusions: Individualisation (identification), Exclusion, or Inconclusive. Verification is then carried out independently by a second qualified examiner who repeats the

[40]A. Becue et al., 'Fingermark visualisation using nanoparticles', (2011) 30 Trends in Analytical Chemistry 380.
[41]National Crime Records Bureau, Annual Report on Crime in India 2022 (Ministry of Home Affairs, 2023), p. 88.
[42]Interpol, Fingerprint Reference Guide (Interpol General Secretariat, Lyon, 2021), p. 22.
[43]Galton, Finger Prints (1892), pp. 111-115.
[44]SWGFAST, Standard for the Documentation of Analysis, Comparison, Evaluation and Verification (ACE-V), Version 2.0 (2013).

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ACE process without knowledge of the first examiner's conclusions, thereby providing a quality assurance safeguard against bias and error.[45]

C. Common Challenges and Errors in Analysis

The landmark 2009 National Academy of Sciences Report identified significant weaknesses in the empirical foundations of friction ridge analysis, noting the absence of validated error rates, insufficient standardisation, and the potential for cognitive bias among examiners.[46]

Contextual bias poses a significant and empirically documented threat to the reliability of fingerprint examination. Research by Dror and colleagues demonstrated that qualified fingerprint examiners altered previously made identifications when provided with contextual information suggesting a different outcome, highlighting the susceptibility of holistic expert judgement to confirmation and expectation bias.[47] This finding has prompted recommendations for linear sequential unmasking protocols, wherein examiners analyse the latent mark independently before exposure to contextual case information.

D. Notable Case Studies

1. State of Tamil Nadu v. Murugan @ Kasi Viswanathan

In State of Tamil Nadu v. Murugan @ Kasi Viswanathan, the Supreme Court of India upheld a conviction in which fingerprint evidence formed part of the incriminating material. Fingerprints lifted from the scene of crime were matched against those of the accused by a qualified state fingerprint expert. The judgment affirmed several foundational principles: that the opinion of a fingerprint expert is admissible under Section 45 of the Indian Evidence Act, 1872; that the court is not bound to accept such opinion but may weigh it against other evidence; and that where the expert's methodology is sound, fingerprint evidence may corroborate or independently sustain a conviction.[48]

2. The Mayfield Misidentification

Perhaps the most consequential misidentification case in the modern history of forensic fingerprinting is the erroneous identification of Brandon Mayfield in connection with the 2004 Madrid train bombings. The FBI's Latent Print Unit identified Mayfield, an Oregon attorney,

[45]I.W. Evett & R.L. Williams, 'A review of the sixteen points fingerprint standard in England and Wales', (1996) 46 Journal of Forensic Identification 49.
[46]National Academy of Sciences, Strengthening Forensic Science in the United States (2009), pp. 136-145.
[47]B.T. Ulery et al., 'Repeatability and reproducibility of decisions by latent fingerprint examiners', (2011) 6 PLoS ONE e19884.
[48]State of Tamil Nadu v. Murugan @ Kasi Viswanathan, (2002) 7 SCC 609.

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as the source of a fingerprint found on a bag of detonators near the bombing site. The identification was made on the basis of AFIS-generated candidates and confirmed by three experienced examiners. Spanish authorities subsequently identified the correct donor, and an independent review established that the examiners had succumbed to confirmation bias exacerbated by contextual information.[49]

The Mayfield case prompted fundamental reforms in FBI fingerprint examination protocols, including the implementation of blind verification procedures, documentation requirements for the analysis phase, and mandatory reporting of discrepancies identified during verification. It catalysed the National Academy of Sciences' critical 2009 review of forensic science disciplines and remains a canonical illustration of how procedural safeguards and scientific humility are indispensable counterweights to overconfidence in forensic identification.

V. LEGAL FRAMEWORK GOVERNING FINGERPRINT EVIDENCE IN INDIA

A. Constitutional Provisions

The Constitution of India furnishes the foundational guarantees within which all evidentiary collection must operate. Article 20(3) embodies the privilege against self-incrimination, declaring that no person accused of any offence shall be compelled to be a witness against himself.[50] The precise ambit of this guarantee in the context of fingerprinting was authoritatively resolved by the Supreme Court in State of Bombay v. Kathi Kalu Oghad (AIR 1961 SC 1808), where an eleven-judge Bench held that the production of physical evidence — including fingerprints — does not constitute 'being a witness' within the meaning of Art. 20(3), because such evidence is not testimonial or communicative in nature.[51]

Article 21 guarantees the right to life and personal liberty.[52] The Supreme Court's watershed ruling in K.S. Puttaswamy v. Union of India (2017) 10 SCC 1 elevated the right to privacy to the status of a fundamental right under Art. 21.[53] This recognition carries direct implications for biometric data collection: any statutory scheme that mandates the taking of fingerprints must satisfy the twin requirements of legality and proportionality.

[49]Mayfield v. United States, 504 F. Supp. 2d 1023 (D. Or. 2007).
[50]Constitution of India, 1950, Art. 20(3).
[51]State of Bombay v. Kathi Kalu Oghad, AIR 1961 SC 1808 (Eleven-Judge Bench).
[52]Constitution of India, 1950, Art. 21.
[53]K.S. Puttaswamy v. Union of India, (2017) 10 SCC 1 (Nine-Judge Bench).

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B. The Indian Evidence Act, 1872: Sections 45 and 73

Section 45 of the Indian Evidence Act, 1872 renders relevant the opinions of persons 'specially skilled' in, inter alia, questions relating to the identity of finger impressions.[54] By explicitly mentioning 'finger impressions' in its text, Parliament acknowledged that fingerprint examination is a specialised discipline whose conclusions are properly within the domain of expert opinion. The Supreme Court reaffirmed in Bhagwan Dass v. State (Delhi Administration) (AIR 1985 SC 1050) that the evidence of a fingerprint expert is relevant under s. 45 and may be acted upon by the court if it is reasoned and credible.[55]

Section 73 confers a supplementary power: it empowers the court to compare disputed fingerprints with specimens admitted or proved to have been made by the person in question, and to form its own opinion on the question of identity.[56] In Mobarik Ali Ahmed v. State of Bombay (AIR 1957 SC 857), the Supreme Court held that s. 73 entitles the court to make an independent comparison without the mediation of an expert, although in practice judges rarely exercise this power without expert assistance.[57]

C. Statutory Framework: From the Identification of Prisoners Act, 1920 to the Criminal Procedure (Identification) Act, 2022

The Identification of Prisoners Act, 1920 (IPA) was the oldest dedicated legislative framework for the collection of fingerprints in India. Section 3 empowered a Magistrate to direct any person arrested in connection with an offence punishable with rigorous imprisonment of one year or more to allow the taking of his 'measurements', a term defined to include finger and palm impressions.[58] Section 4 permitted police officers of the rank of Sub-Inspector or above to take the measurements of any convicted person without a Magistrate's order.[59]

The Criminal Procedure (Identification) Act, 2022 (CPIA 2022) supersedes the IPA and substantially broadens the state's power to collect, store, and use biometric data. The Act defines 'measurements' expansively to include finger-impressions, palm-print impressions, footprint impressions, photographs, iris and retina scans, biological samples and their analysis, and behavioural attributes.[60] Section 3 extends the authority to collect measurements to persons

[54]Indian Evidence Act, 1872, s. 45.
[55]Bhagwan Dass v. State (Delhi Administration), AIR 1985 SC 1050.
[56]Indian Evidence Act, 1872, s. 73.
[57]Mobarik Ali Ahmed v. State of Bombay, AIR 1957 SC 857.
[58]Identification of Prisoners Act, 1920, s. 3.
[59]Identification of Prisoners Act, 1920, s. 4.
[60]Criminal Procedure (Identification) Act, 2022, s. 2(1)(b).

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arrested for any cognisable offence. The Act mandates centralised storage at the NCRB for a period of 75 years, with a provision for destruction of records in respect of persons acquitted or discharged on a final order.[61]

The constitutionality of the CPIA 2022 has been challenged before the Supreme Court, with petitioners contending that its broad data collection powers and extended retention periods violate the fundamental right to privacy recognised in Puttaswamy, the privilege against self-incrimination under Art. 20(3), and the guarantee of personal liberty under Art. 21.[62]

D. Key Supreme Court Pronouncements

1. Pritam Singh v. State of Punjab, AIR 1956 SC 415

In Pritam Singh v. State of Punjab, the Supreme Court sustained a conviction that rested substantially on fingerprint evidence. The Court held that a court of fact is entitled to act upon the opinion of a fingerprint expert if that opinion is well-reasoned and has not been discredited in cross-examination. The decision authoritatively laid down that fingerprint evidence is not inherently inferior to other categories of evidence, and that a court is not required to seek corroboration before basing a conviction upon it.[63]

2. Jaspal Singh v. State of Punjab (1979) 4 SCC 40

In Jaspal Singh v. State of Punjab, the Supreme Court undertook a detailed examination of the principles governing fingerprint comparison and held that fingerprint comparison by a trained expert is admissible, and that if the expert's credentials are established and his methodology is sound, his testimony is entitled to significant weight. The decision further indicated that the court may legitimately examine the fingerprint exhibits itself for the purpose of reaching its own conclusion under s. 73 of the IEA, particularly where the expert's evidence is contested.[64]

E. Comparative Legal Framework

In the United States, the admissibility of expert scientific testimony is governed by Rule 702 of the Federal Rules of Evidence as interpreted through Daubert v. Merrell Dow Pharmaceuticals, Inc. (1993).[65] Under Daubert, a trial judge must assess whether the expert's methodology is scientifically valid, whether it has been peer-reviewed, and whether its known

[61]Criminal Procedure (Identification) Act, 2022, s. 4.
[62]People's Union for Civil Liberties v. Union of India, WP (Civil) No. 829 of 2022 (pending before the Supreme Court of India).
[63]Pritam Singh v. State of Punjab, AIR 1956 SC 415.
[64]Jaspal Singh v. State of Punjab, (1979) 4 SCC 40.
[65]Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S. 579 (1993).

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error rate is acceptable. The PCAST Report of 2016 subjected latent fingerprint examination to sustained scientific scrutiny and called for mandatory error-rate studies, sparking renewed debate about the validity of fingerprint identification in American courts.[66]

In the United Kingdom, following the Scottish case of McKie v. HM Advocate (2011), in which a fingerprint expert's identification was found to be erroneous, British practice has moved towards greater standardisation and the adoption of a quality assurance framework for fingerprint laboratories.[67] The Court of Appeal's decision in R v. Buckley (1999) confirmed that fingerprint evidence does not require a minimum number of matching characteristics in order to be placed before a jury.[68] The House of Lords Science and Technology Committee's 2019 report called for a statutory forensic science regulator to be given binding powers, a recommendation that has since been partly implemented.[69]

Within the European Union, the General Data Protection Regulation (GDPR) and the Law Enforcement Directive (LED) treat fingerprint data as biometric data constituting a 'special category' of personal data subject to heightened protection.[70] Article 10 of the LED permits law-enforcement authorities to process biometric data only where it is strictly necessary, where appropriate safeguards are in place, and where national law so authorises.[71]

F. Privacy Concerns and Biometric Data Protection

The collection, storage, and use of fingerprint data by the state engages fundamental rights of privacy and dignity. As fingerprints are uniquely identifying, irrevocable, and incapable of being changed, any compromise of a biometric database entails irreversible consequences for the individual. India's existing data-protection architecture does not yet provide comprehensive protection for biometric data. The Information Technology (Reasonable Security Practices) Rules, 2011 list biometric data as sensitive personal data and impose obligations on body corporates to maintain reasonable security practices[72]; however, the Rules were designed primarily for the private sector and do not bind law-enforcement agencies. The Digital Personal Data Protection Act, 2023 establishes a general framework for personal data processing, but

[66]PCAST, Forensic Science in Criminal Courts (2016), pp. 65-87.
[67]McKie v. HM Advocate [2011] HCJAC 53 (Scotland).
[68]R v. Buckley (1999) 163 JP 561 (CA).
[69]House of Lords Science and Technology Committee, 'Forensic Science and the Criminal Justice System: A Blueprint for Change' (3rd Report, Session 2018-19, HL Paper 333), para. 118.
[70]Regulation (EU) 2016/679 (General Data Protection Regulation), Art. 9(1).
[71]Directive (EU) 2016/680 (Law Enforcement Directive), Art. 10.
[72]Information Technology (Reasonable Security Practices) Rules, 2011, r. 3(v).

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the categorisation of specific classes of sensitive data has been deferred to subordinate legislation.[73]

VI. CONCLUSION AND RECOMMENDATIONS FOR REFORM

A. Summary of Findings

This research has undertaken a critical examination of fingerprint analysis as deployed in criminal investigation in India, evaluating its scientific foundations, its legal framework, and the institutional and data-governance vulnerabilities that may compromise its reliability. The findings confirm all four hypotheses advanced in the introduction.

First, the legal acceptance of fingerprint analysis is disproportionate to its scientifically validated reliability. The 2009 NAS Report[74] and the 2016 PCAST Report[75] have authoritatively identified the absence of validated error rates, objective standards, and reproducibility testing as fundamental deficiencies in latent fingerprint analysis. Second, the ACE-V methodology remains susceptible to cognitive bias. The empirical research of Dror and Charlton[76] has shown that trained examiners may alter prior conclusions when exposed to contextual case information. Third, existing legal and procedural frameworks are inadequate. The CPIA 2022 has significantly expanded the state's biometric collection powers without commensurate enhancement of individual rights protections or judicial oversight mechanisms.[77] The absence of a reliability standard analogous to the Daubert framework[78] leaves Indian courts without the tools needed to perform effective scientific gatekeeping. Fourth, while AFIS and digital fingerprint analysis have transformed investigative capability, they introduce distinct risks including algorithmic bias and the aggregation of biometric data in under-regulated national databases.

B. Critical Analysis of Structural Weaknesses

1. The Evidentiary Standard

Section 45 of the Indian Evidence Act, 1872 renders relevant the opinion of a person 'specially skilled' in the identity of finger impressions[79], but provides no criteria for determining what

[73]Digital Personal Data Protection Act, 2023, s. 2(t).
[74]NAS Report (2009), pp. 87-99.
[75]PCAST Report (2016), pp. 65-87.
[76]Dror & Charlton, 'Why Experts Make Errors' (2006), p. 600.
[77]Criminal Procedure (Identification) Act, 2022, ss. 3 and 4.
[78]Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S. 579 (1993).
[79]Indian Evidence Act, 1872, s. 45.

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constitutes 'special skill', no minimum methodological standards, and no requirement of disclosure of error rates or uncertainty. Courts have — through Jaspal Singh[80], Pritam Singh[81], and Bhagwan Dass[82] — consistently affirmed the admissibility of fingerprint evidence and treated well-reasoned expert opinion as potentially sufficient for conviction. Yet these decisions have not grappled with the deeper scientific critique that post-dates their pronouncement. The court's retention of the ultimate fact-finding function[83] is formally sound but practically hollow where the court lacks the scientific tools necessary to critically evaluate contested expert opinion.

2. Institutional Architecture

State Fingerprint Bureaus operate within the organisational hierarchy of State Police, and the Central Fingerprint Bureau functions under the NCRB, itself within the Ministry of Home Affairs.[84] Fingerprint examiners are therefore employees of the same organisation that investigates crime and secures prosecutions — a structural conflict of interest that generates the very conditions for contextual bias identified by research as a primary source of error. The absence of an independent statutory forensic science regulator — comparable to the proposed regulator in the United Kingdom[85] — means that there is no external authority capable of mandating quality standards, conducting periodic audits, or investigating complaints.

3. Data Governance and Privacy

The CPIA 2022's provision for 75-year retention of fingerprint data — effectively lifelong retention — for all persons arrested for cognisable offences, including those ultimately acquitted or discharged, fails to satisfy the proportionality requirement identified in Puttaswamy[86] as a constitutional constraint on state action affecting the right to privacy. The constitutional validity of this provision is currently being litigated.[87]

C. Legislative Reform Proposals

1. Amendment of the Bharatiya Sakshya Adhiniyam

Section 45 of the Indian Evidence Act, 1872 (now incorporated in the Bharatiya Sakshya

[80]Jaspal Singh v. State of Punjab, (1979) 4 SCC 40.
[81]Pritam Singh v. State of Punjab, AIR 1956 SC 415.
[82]Bhagwan Dass v. State (Delhi Administration), AIR 1985 SC 1050.
[83]Dalip Singh v. State of Punjab, AIR 1953 SC 364.
[84]NCRB, Annual Report on Crime in India 2022 (Ministry of Home Affairs, 2023), pp. 88-95.
[85]House of Lords Science and Technology Committee, HL Paper 333 (2018-19), paras. 95-120.
[86]K.S. Puttaswamy v. Union of India, (2017) 10 SCC 1.
[87]PUCL v. Union of India, WP (Civil) No. 829 of 2022 (pending).

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Adhiniyam, 2023) should be amended to introduce a reliability criterion for forensic expert testimony, requiring that expert opinion in forensic science disciplines be based upon a methodology that has been: (i) subjected to peer review and publication; (ii) tested empirically, with known or estimated error rates; and (iii) generally accepted within the relevant scientific community. This tripartite reliability test, modelled on the Daubert standard, should be a condition of admissibility rather than merely a factor going to weight. The Bharatiya Sakshya Adhiniyam, 2023, which has replaced the Indian Evidence Act without substantively altering the provisions on expert opinion, represents a missed legislative opportunity that must be addressed in subsequent amendment.[88]

2. Amendment of the Criminal Procedure (Identification) Act, 2022

The CPIA 2022 should be substantially amended to bring it into conformity with the constitutional right to privacy as articulated in Puttaswamy and with international data-protection norms. The retention period of 75 years should be replaced by a tiered retention regime; data of persons acquitted, discharged, or released without charge should be automatically expunged within 12 months. The scope of compulsory collection should be limited to offences of a gravity proportionate to the intrusion involved, and the Act should expressly incorporate a purpose-limitation principle ensuring that data collected for criminal investigation is not repurposed for immigration, employment, or civil administrative uses.

3. Enactment of a Biometric Data Protection Statute

India lacks a sector-specific statute governing the collection, storage, use, and transfer of biometric data by law-enforcement agencies. Drawing upon the European Union's Law Enforcement Directive[89] and the principles elaborated in Puttaswamy, Parliament should enact a Biometric Data Protection (Criminal Justice) Act that: (i) provides a clear and accessible legal basis for biometric data collection; (ii) mandates purpose limitation and data minimisation; (iii) requires regular independent audits of biometric databases; (iv) establishes enforceable data security standards; and (v) provides effective judicial remedies for unlawful collection or retention.

D. Institutional Reform Proposals

The most consequential institutional reform proposed is the establishment of an independent National Forensic Science Regulatory Authority (NFSRA) with statutory functions analogous

[88]Law Commission of India, 185th Report on the Review of the Indian Evidence Act 1872 (2003), pp. 101-109.
[89]Regulation (EU) 2016/679 (GDPR), Art. 9; Directive (EU) 2016/680 (Law Enforcement Directive), Art. 10.

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to those recommended by the House of Lords Science and Technology Committee in the United Kingdom. Its mandate should encompass: (i) the accreditation of all forensic science laboratories and fingerprint bureaus in India; (ii) the promulgation of binding minimum standards for the ACE-V methodology[90]; (iii) the regular publication of national error-rate data for fingerprint examination[91]; (iv) the investigation of complaints of examiner misconduct; and (v) the development of national training and competency assessment standards. Unaccredited bureaus should not be permitted to tender expert opinion evidence in criminal proceedings.

State Fingerprint Bureaus and the CFPB should be progressively reorganised as independent forensic units, administratively separated from investigating police. Until full structural separation can be achieved, interim measures should include: (i) mandatory blind verification procedures; (ii) linear sequential unmasking protocols ensuring examiners analyse the latent print independently before exposure to any case context[92]; and (iii) mandatory documentation of analysis phase conclusions before comparison is undertaken. The trend towards probabilistic reporting using likelihood ratios[93] should be actively explored through pilot studies conducted by the CFPB.[94]

Research has demonstrated that fact-finders tend to give disproportionate weight to fingerprint evidence and to be insufficiently critical of examiner methodology.[95] The National Judicial Academy and State Judicial Academies should therefore develop and deliver mandatory continuing legal education programmes for judges at all levels, covering the scientific principles of fingerprint analysis, the ACE-V methodology, and the limitations identified by the NAS and PCAST Reports.

E. Concluding Remarks

Fingerprint analysis occupies a unique and paradoxical position in the administration of criminal justice. It is, simultaneously, one of the oldest, most widely accepted, and most scientifically contested of the forensic identification disciplines. This study has argued — and

[90]SWGFAST, Standard for the Documentation of ACE-V, Version 2.0 (2013).
[91]B.T. Ulery et al., 'Accuracy and Reliability of Forensic Latent Fingerprint Decisions', (2011) 108 Proceedings of the National Academy of Sciences 7733.
[92]Dror, Charlton & Peron, 'Contextual Information Renders Experts Vulnerable to Making Erroneous Identifications', (2006) 156 Forensic Science International 74.
[93]Champod et al., Fingerprints and Other Ridge Skin Impressions (CRC Press, 2nd edn, 2016), pp. 312-330.
[94]Neumann et al., 'Computation of Likelihood Ratios in Fingerprint Identification', (2007) 52 Journal of Forensic Sciences 54.
[95]Garrett & Mitchell, 'How Jurors Evaluate Fingerprint Evidence', (2013) 10 Journal of Empirical Legal Studies 484, pp. 484-511.

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the evidence strongly supports the argument — that Indian law and practice have, on balance, accepted the infallibility narrative too uncritically and for too long. The result is a legal framework that extends to fingerprint evidence a degree of probative weight not fully justified by its validated scientific reliability; institutional arrangements that insufficiently insulate examiners from investigative bias; and a data-governance regime that has expanded the state's biometric collection powers without commensurate enhancement of individual rights protections.

This critique does not argue for the abolition or wholesale discrediting of fingerprint evidence. The biological foundations of fingerprint uniqueness and permanence, while not mathematically proven as an absolute truth, are well-supported empirical propositions with substantial evidentiary value.[96] The concern is not with the technique as such, but with its application in an institutional and legal environment that does not incorporate adequate safeguards against the minority of cases where the technique fails — and where the consequences of failure may be the wrongful deprivation of a person's liberty.

The reforms proposed in this study — legislative modernisation of the evidentiary standard and the biometric data-governance framework; institutional separation of forensic science from law enforcement; the establishment of an independent regulatory authority; enhanced judicial education; and the introduction of probabilistic reporting — are realisable, evidence-based reforms that draw directly upon the experience of comparable jurisdictions and upon the recommendations of authoritative scientific bodies.

India stands at a critical juncture. The enactment of the CPIA 2022, the replacement of the Indian Evidence Act by the Bharatiya Sakshya Adhiniyam, and the ongoing Puttaswamy-derived litigation against biometric data collection laws together constitute a moment of profound legislative and judicial reconsideration of the state's relationship to its citizens' biological identities. This study is offered as a contribution to that engagement, in the hope that it will stimulate further research, critical commentary, and — most importantly — the concrete legislative and institutional reforms necessary to ensure that fingerprint evidence in India is used justly, scientifically, and with full respect for the rights of all persons who come within the reach of the criminal justice system.

[96]Wertheim & Maceo, 'The Critical Stage of Friction Ridge and Pattern Formation', (2002) 52 Journal of Forensic Identification 35.