Forensic Individualisation from Biometric Data

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This paper deals with the question of inference of identity of source in forensic science and focuses on the individualisation process of human beings from biometric data. Its goal is to explicitly describe the logical mechanisms that underpin the inference of identity of source in forensic science and to propose a concrete methodology for the forensic individualisation from biometric data. It also analyses the limits of several biometric modalities (fingerprint, face, voice) used for forensic individualisation.
Firstly, the concept of identity and its application in forensic science is described. Secondly, the confusion between numerical and qualitative identity is addressed. Thirdly, the hypothetical-deductive method is described as a logical approach for forensic individualisation and the likelihood ratio approach premised on the Bayes Theorem is proposed as a concrete methodology to infer identity of human beings from biometric data in forensic science. Finally a concrete framework is proposed, which includes hypotheses definition, sources and databases selection, analysis and comparison of biometric data and their interpretation.

Este trabajo trata sobre el tema de la inferencia de identidad de una fuente en ciencia forense y se concentra en el proceso de individualización de seres humanos a partir de datos biométricos. Su meta es describir explícitamente los mecanismos lógicos que subrayan la inferencia de identidad en ciencia forense y proponer una metodología concreta para la individualización forense a partir de datos biométricos. También analiza los límites de algunas modalidades biométricas (huellas dactilares, rostro, voz) usadas para la individualización forense.

In dieser Abhandlung wird die Frage der Quellen-Identitätsinferenz untersucht mit Konzentration auf den Identifizierungsprozess von Menschen mittels biometrischer Daten. Das Ziel ist eine detaillierte Beschreibung der logischen Abläufe, welche die Identitätsinferenz der Quellen in der Forensik stützen und eine konkrete Methodik für die forensische Identifizierung aus biometrischen Daten aufzustellen. Außerdem werden die Grenzen verschiedener biometrischer Modalitäten (Fingerabdruck, Gesicht, Stimme) für die forensische Identifizierung analysiert.
Zunächst wird beschrieben, was man in der Forensik unter Identität und deren Anwendung versteht. Zweitens wird die Verwechslung zwischen numerischer und qualitativer Identität besprochen. Drittens wird die hypothetisch deduktive Methode als logischer Ansatz bei der forensischen Identifizierung angesprochen sowie die Theorie der Wahrscheinlichkeitsquote basierend auf dem Bayes Theorem als konkrete Methodik zur Ableitung der menschlichen Identität aus biometrischen Daten in der Forensik vorgeschlagen. Schließlich wird ein konkreter Rahmen aufgestellt einschließlich der Definition der Hypothese, Auswahl der Quellen und Datenbanken, Analyse und Vergleich biometrischer Daten sowie deren Interpretation.

Cet article traite de la question de l'inférence de l'identité de la source en sciences forensiques et se focalise sur le processus d'individualisation de personnes à partir de données biométriques. Son but est de décrire les mécanismes qui sous-tendent l'inférence de l'identité de la source en sciences forensiques et de proposer une méthodologie concrète l'individualisation forensique à partir de données biométriques. Il analyse également les limites de plusieurs modalités biométriques (traces digitales, vocales et faciales) utilisées pour l'individualisation forensique.
Premièrement le concept d'identité et son application en sciences forensiques est décrit. Deuxièmement la confusion entre identité numérique et qualitative est traitée. Troisièmement la méthode hypothético-déductive est décrite comme une approche logique pour l'individualisation forensique et l'approche du rapport de vraisemblance base sur le théorème de Bayes est proposé comme une méthodologie concrète pour inférer l'identité de personnes à partir des données biométriques en sciences forensiques. Finalement, un cadre concret est proposé, incluant la définition des hypothèses, la sélection des sources et des bases de données, l'analyse et la comparaison de données biométriques et l'interprétation des résultats.

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Introduction

'On May 6, federal prosecutors strode into a courthouse in Portland, Oregon, and claimed the FBI had made a "100 percent positive identification" linking a local lawyer to a fingerprint found on a bag connected to terrorist bombings in Madrid. Within weeks, the same prosecutors were forced to return to the courtroom and admit an international humiliation: the fingerprint analysis that led to the arrest of Brandon Mayfield was wrong. But the FBI didn't realize it until Spanish authorities linked the fingerprint to an Algerian man, Ouhnane Daoud. Not just one but three FBI analysts, all seasoned veterans, had made the same mistake. A fourth expert independently appointed by the judge erred as well when he determined Mayfield's prints were a match' [1]. This "erroneous fingerprint individualisation in the Madrid Train bombing case" [2] indicates the necessity to revisit the forensic methodology for the individualisation of human beings from biometric data collected on crime scenes, and particularly the fingermarks.

The study of fingerprints as a means of positive identification by outstanding scientists like Sir William Herschel, Dr Henry Faulds, Sir Francis Galton, Sir Edward Richard Henry and Dr Edmond Locard, was the starting point of the science of individualisation, termed by some criminalistics, by others forensic science [3].

The first part of this paper is dedicated to the concept of identity and to its application in forensic science. The content of this theoretical basis is a brief summary of the unique research effort on this particular topic, the brilliant but sadly underrated PhD dissertation of Dr Quon Yin Kwan entitled "Inference of identity of source" [4]. The second part of this paper illustrates the confusion associated with the notion of identity when used for forensic individualisation from biometric data. The third part is devoted to the description of the forensic individualisation process based on the hypothetical-deductive method, while the last part proposes a concrete framework to design a computer-based approach for forensic individualisation from biometric data.

Identity

Definition

> "En police scientifique et en droit, l'identité est l'ensemble des caractères par lesquels un homme définit sa personnalité propre et se distingue de tout autre. Dans ce dernier ordre d'idées, établir l'identité d'un individu est l'opération policière ou médico-légale appelée identification. Un homme peut être semblable à plusieurs autres, ou à un autre, au point d'amener des erreurs; il n'est jamais identique qu'à un seul, à lui-même. C'est à discriminer avec soin les éléments de ressemblance des éléments d'identité que consiste le problème de l'identification"[1] [5].

Ambiguity

The term "identity" has a dual character and this duality gives rise to ambiguity. When the concept of source is used with reference to an object of interest to signify a class of individual entities from which this object could originate, it refers to qualitative identity. This is due to the fact that a class is defined by an identity of the properties of its members. The operation in which a class is determined to be the source is termed "classification" or "identification" in science. When the concept of source is used to signify one particular individual entity from which an object originates, it refers to numerical identity. The operation in which a particular individual entity is determined to be the source of an object is termed "individualisation" in science, but is often wrongly named "identification" in forensic science.

Confusion surrounds the terms "identity", "identify" and "identification" in forensic science. This is clearly demonstrated in popular practice, when the perpetrator of an infringement is said to be "identified from her/his fingerprints". The perpetrator is not identified, but individualised. What is proved by the fingerprints is individuality [6, 9]. Kirk emphasizes this confusion as well in [3], but concludes:

> "The real aim of all forensic science is to establish individuality or to approach it as closely as the present state of science allows. Criminalistics is the science of individualisation. The criminalist is not ultimately interested in the similarity of two objects but in their source" [3].

Therefore, to individualise a human being on the basis of biometric data in forensic science ultimately consists in determining if an individual is the source of the biometric data considered as forensic traces/marks.

Identity in forensic science

> According to Kwan, " what is meant by identity of source is relative to what source signifies. When source refers to class, identity is akin to qualitative identity and when source refers to an individual, identity of source is akin to numerical identity. This distinction made between the two kinds of identity is consistent with the classical forms of identity distinguished by philosophers over the ages. The reason for the approach from a philosophical perspective is that the central problem of identity of source comes to be known" [4].

Distinguishing numerical from qualitative identity

Qualitative identity is established when a set of properties agrees in two objects. Numerical identity is demonstrated by

1. Freely translated from the original French citation: "In forensic science and law, identity is the set of characteristics in terms of which a human being defines its own personality and distinguishes itself from all others. In this context, establishing the identity of an individual is the forensic activity called identification. A human being may be similar to several others or to one other person to the extent that it causes errors; but it can only be identical to one person, himself/herself. The challenge of identification lies in the careful discrimination of elements of similarity from elements of true identity.

establishing continuity in time. A well-known example of numerical identity in forensic science is the chain of evidence, or chain of custody. To be maintained, the chain of evidence requires proof that the item is the same individual entity, from the time of collection on the crime scene to the time of presentation in court. Because qualitative identity is not determined by this criterion of continuity, it is relative. The relativity of qualitative identity is with respect to the observer, especially with respect to his choice of properties to characterize objects [4].

The principal distinguishing characteristic between numerical and qualitative identity is time. Time makes identity of objects absurd since no two objects can be one object simultaneously. Identity of source is a relationship that involves time because of the need to establish the continuity of objects from one source in time. Qualitative identity, on the other hand, is independent of time. Time implies that numerical identity is compatible with change whereas qualitative identity is not.

> "A thing can be identical only with itself, never with any other object, since objects in the universe are unique. If this were not true, there could be no identification in the sense used by the criminalist" [3].

To convince yourself that numerical identity is compatible with change, take your ten-year-old identity document, compare your face with the passport photo of this identity document and observe the changes. This shows that two objects with different qualities, existing at different times, can be numerically identical. This finding illustrates that numerical identity does not entail qualitative identity and, vice versa, qualitative identity does not entail numerical identity. It demonstrates the absence of a logical relationship between numerical and qualitative identity.
Forensic individualisation is not a deduction

The discussion on the relationship between qualitative and numerical identity provides different perspectives on identity. In his work, Leibniz never explicitly stated a law relating qualitative and numerical identity, but two different interpretations of his position on identity have created considerable confusion. Leibniz's position on identity is expressed in two formal maxims: the Law of Identicals and the Law of Identity of Indistinguishables. The former says that what is featured in one thing is featured in another when the two are numerically identical simultaneously. There is no problem with this interpretation although, according to Wittgenstein, it is a tautology [4]. The latter simply equates qualitative identity with numerical identity, which is not a valid relationship, as explained supra. In spite of the questionable validity of this second interpretation, it has become a fundamental principle for forensic science.

General principle of uniqueness

Dogma…

The idea that identity of source can be deduced on the basis of qualitative identity and on the assumption of uniqueness of the source is still widely supported by the forensic community [6]. In fact, in forensic science the individualisation process is most often perceived as a process of rigorous deductive reasoning [7], as a syllogism constituted of a major premise, a minor premise and a conclusion[2]. The major premise is the general principle of uniqueness applied to the properties of a source and to the properties of the object generated by this source, the trace/mark, the minor premise is the observation of the correspondence of the observed properties between the source and the trace/mark and the conclusion is that the source and the trace/mark have a common origin because of the correspondence of the observed properties.

… but shortcomings

However, the general principle of uniqueness assumed in forensic science must be qualified as a dogma because this "principle of forensic identification" is based on inductive reasoning. It is founded on a line of reasoning that proceeds from particular statements (based on observation or experience) to universal laws or theories [8-10]. Both Locard [11] and Eco [12] are conscious of this misuse of inductive reasoning in forensic science, when they invoke the eighth rule of syllogism according to Aristotle: "nihil sequitur geminis ex particularibus unquam"[3]. This logical statement was first developed by Sextus Empiricus (AD 150–230) and David Hume (1711–1776) adapted this criticism of the application of induction to the notion of causality.

Therefore, induction cannot be considered as rigorous reasoning for individualisation in forensic science because what is true for the particular is not necessarily true for the whole. The misuse of induction provides the illusion that science substantiates categorical conclusions of identification or exclusion [8].

The criterion of empirical falsifiability

Popper uses the argumentation of Hume but argues that complete verification of any scientific statement is impossible; therefore, the complete verification of the general principle of uniqueness applied to forensic science is not possible. Popper refutes the criterion of scientific verifiability but proposes the criterion of empirical falsifiability as demarcation criterion.

The reasoning process of Popper is based on a fundamental logical consideration: to prove the hypothesis of a general principle from particular or singular statements is impossible, but it is possible to falsify it. Falsifying a hypothesis amounts to proving that the hypothesis of a general principle is false because one or more cases contradict it: what is false to the particular is false to the whole. To fail in the attempt to falsify the hypothesis of uniqueness will never prove that the principle is true but, in

2 Following the first rule of syllogism according to Aristotle "Terminus esto triplex: medius, majorque, minorque", a syllogism should be composed, to be valid, of a general principle, named major premise, a particular observation, called minor premise and a deduction, called medium term or conclusion.

3 "No deduction can follow two minor premises".

standing the tests, the hypothesis can reach a sufficient degree of corroboration to be used as a basis for practical application, described as the degree of "verisimilitude" by Popper [13].

Principle of uniqueness applied to individualisation from biometric data

Dogma…

The uniqueness of the properties used for individualisation from biometric data is in general assumed without debate, both in forensic and commercial applications of biometrics [14]. Moreover, in forensic science the principle of uniqueness assumed for the properties of the source is often extended to the properties of the trace/mark without question. For example, the uniqueness is assumed for the fingerprint (source) and the fingermark (mark), for the face (source) and the still or the live picture of the face (trace) as well as for the voice (source) and the speech audio recording (trace).

… but shortcomings

The demarcation criterion of empirical falsifiability developed by Popper in most cases conflicts with the hypothesis of uniqueness of the properties used for individualisation from biometric data. The different extent to which various biometric characteristics are able to meet the demarcation criterion of falsifiability is experienced in everyday life as well as in forensic practice, as shown in the following examples.

Assumption of uniqueness for complete rolled inked fingerprints

Automatic fingerprint identification systems (AFIS) have been used for 30 years, collecting databases of convicted people and of asylum seekers in order to detect repeat offenders and prevent multiple asylum applications. In these two situations, a ten-print sheet from a suspected person or from an asylum seeker is made, and two fingers, generally the right index and middle finger, are searched against the main fingerprint collection. The eight other fingers are generally not used for the automatic research, but when a candidate is proposed by the system, they can be used by the fingerprint examiner to falsify the hypothesis of identity based on the automatic comparison of the two first fingers. As far as we know, this procedure of individualisation based on the comparison of ten inked fingerprints (considered as secondary sources, the primary sources being the real fingers) is extremely difficult to falsify. Of course this consideration only takes in account the output of the automatic process and not the output of the entire process including human interaction with the AFIS, even though human errors, due to clerical mistakes or others are intrinsic to any human activity.

From our point of view, the assumption of uniqueness of the fingerprint first formulated by Herschel and Galton [15] reaches a sufficient level of "verisimilitude" and therefore renders very valid the assumption that the complete rolled inked fingerprint as a reliable enough representation of the real finger for human individualisation.

Assumption of uniqueness of the fingermark

In contrast, forensic practice is punctuated with several cases of false individualisation of defendants on the basis of the comparison of fingermarks with inked fingerprints by fingerprint examiners. Apart from the Mayfield case [1], one can quote the Scottish case of H.M. Advocate v. Shirley McKie; for the first time since the adoption of the 16-minutiæ standard, a full identification of a latent mark has been challenged in a court of law in the UK, and that challenge was upheld by a unanimous verdict [16]. Therefore, from our point of view, the assumption of uniqueness of the fingermark does not reach a sufficient level of "verisimilitude".

Assumption of uniqueness of the properties of the face and voice

The uniqueness of properties of the human face is also questionable, as no idiosyncratic property is known or can be assumed for this biometric modality. For the voice as well, the hypothesis that no two humans speak exactly alike is plausible, but to date no large-scale demonstration of the extent of idiosyncrasy in a homogeneous community of speakers has been adduced in support of this hypothesis [17]. Therefore, the assumption of uniqueness does not reach a sufficient level of "verisimilitude" for the human face and voice.

Assumption of uniqueness of the properties of face and the voice traces

The consideration mentioned supra is also true for the properties of the face and voice traces. Experiences of everyday life as well as the findings of applied psychology and artificial perception confirm the limitations of human beings and machines in their capacity for human individualisation based on face recognition, speaker recognition or on those two combined [18, 19]. This situation is particularly relevant in forensic science, where the trace is normally of limited quality for voice and face, for instance a telephone quality audio recording, a CCTV video recording or a passport photo.

Discussion

This assessment does not mean that fingermarks, face traces and voice traces cannot be used or are not suitable for individualisation from biometric data in forensic science, but it clearly lays down limits on the certainty that can be expected, depending on the quality of the trace/mark and on the method chosen for the individualisation process. The lack of constancy in the face and the voice, as well as in the fingermark, highlights the existence of a within-source variability besides the between-source variability, which should also be considered in the forensic individualisation process.

Since the forensic individualisation process cannot be seen as a deduction based on qualitative identity and on the general principle of uniqueness, another approach must be considered to infer the identity of source.

Forensic individualisation remains an inference

When the concept of source refers to a class of entities from which an object could originate, the question of how the source is identified is merely an epistemological question of how qualitative identity comes to be known, i.e., through a set of characteristics, as explained *supra*. When the concept of source signifies a particular individual entity from which an object originates, the question of how the source is identified is a much more complex problem. The general rule to demonstrate numerical identity is by establishing continuity. But this answer is impracticable for the forensic scientist, who almost never knows a priori the actual source nor have seen the source. As there is no one to ensure unbroken continuity between the source and the object of interest since the creation of this object, there is no way of knowing the numerical identity of source [4]. By essence, the identity of source remains an inference in forensic science.

The hypothetical-deductive method

Principle

The notion of proof is not subordinated by essence to the concept of deduction [20]. The hypothetical-deductive method, already described by the ancient Greek philosopher Parmenides, seems to be a much more practicable approach for inferring identity of source in forensic science. It can be described as a process of hypothesizing and testing; a set of hypotheses is formulated which is tested and modified in a cyclic fashion until a modified hypothesis is arrived at which is not rejected.

> "In using the hypothetical-deductive method, one commences by posing several hypotheses that could explain a phenomenon which has just been observed. Hypotheses are generally posed after taking into account what is generally known about the properties of the class of phenomena of interest – prior knowledge. One then proceeds to determine which one hypothesis from the set of all plausible hypotheses best explains the phenomenon. Deductions are made from the posed hypotheses and these serve as bases for proposing experiments. That is, if one can make predictions from these hypotheses, one can devise experiments to test the predictions. This is the most valuable congruent of the hypothetical-deductive method. If a hypothesis either does not agree with the body of prior knowledge or if its predictions are falsified by experimentation, it is rejected. This is done successively until a single hypothesis remains that explains the phenomenon which no alternative hypothesis does" [4].

The hypothetical-deductive method was already considered a relevant reasoning process by Edgar Allan Poe, when he described the adventures of the detective Dupin, in his Tales stories. As pointed out by Locard, Poe requires the ideal detective to combine the imagination of the poet (to generate the hypotheses) with the method of the mathematician (to test these hypotheses) [11]. Even Sherlock Holmes repeats often: "The old axiom that when all other contingencies fail, whatever remains, however improbable, must be the truth" [21].

Although the analytical process described *supra* is first of all an exercise of logic which is not directly related to reality, the hypothetical-deductive method requires an empirical validation of the resulting hypotheses [22].

It is worthwhile emphasizing that to generate hypotheses is a necessary but not sufficient condition for the reasoning from hypotheses. In fact, as a hypothesis is intrinsically not demonstrable, it is necessary to distinguish the plausible alternative hypotheses from the fanciful ones. It is now acknowledged that it is impossible to derive criteria to define *ex nihilo* the notion of plausible hypothesis, because these criteria depend dramatically on the problem analysed [20].

For the questions related to the inference of identity of source of a trace/mark, it is possible to define two mutually exclusive alternative hypotheses: the prosecution hypothesis (Hp) and the defence hypothesis (Hd). A hypothesis can be considered as plausible when it is accepted as a possible explanation by the fact-finder.

Methods of statistical inference

Methods of statistical inference supplement the hypothetical-deductive method by assigning weight to predictions of hypotheses facilitating the selection of the hypothesis that best explains the source of the trace/mark. But statistics will not lead to an objective process of absolute identification [23]. One important assumption that must be heeded is that every quantitative method chosen for the inference of identity of source is based upon the premise of qualitative identity. It means that the features used to characterize an object must be selected on the criteria of distinguishability, ratio between the within-source and the between-source variability, stability in time, standardization and independence [4]. Among the methods of statistical inference, the likelihood ratio approach premised on the Bayes Theorem is currently considered as the most logical framework for the inference of identity of source in forensic science. This choice was acknowledged as early as the beginning of the twentieth century in the Dreyfus case [24] and publications of the past fifteen years illustrate this trend for the interpretation of many kinds of forensic evidence (e.g. fingermark, DNA, speaker recognition or earmark) [9, 25-28].

The likelihood ratio approach premised on the Bayes Theorem

Definition of the hypotheses

The background information (I) on the case and the preliminary observation of the trace/mark are the necessary information to define the set of all the plausible sources of the trace/mark, named the potential population. The background information also determines which particular source of the potential population can be focused on and selected as the putative source of the trace/mark.

The prosecution hypothesis Hp is the one according to which the putative source is truly the source of the trace/mark. The defence hypothesis Hd is the one according to which an alternative plausible source is truly the source of the trace/mark. A logical constraint necessitates that the two hypotheses are mutually exclusive, but not necessarily exhaustive.

Test of the hypotheses

The likelihood ratio approach shows how an a priori probability ratio of the two competitive hypotheses Hp and Hd can evolve to an a posteriori probability ratio, considering the background information and the result of comparison of the putative source with the trace/mark, named the evidence (E). The likelihood of the evidence is evaluated when the hypothesis Hp is true on the one hand, and when the hypothesis Hd is true on the other hand. The ratio between these two likelihood values, the likelihood ratio (LR), is defined as the numerical value that allows for revision of the a priori probability ratio (prior odds), based on the new information E, to give the a posteriori probability ratio (posterior odds) of the two hypotheses Hp and Hd:

$$\frac{p(H_p|E,I)}{p(H_d|E,I)} = \frac{p(E|H_p,I)}{p(E|H_d,I)} \times \frac{p(H_p,I)}{p(H_d,I)}$$

$$\begin{array}{ccccc} \text{a posteriori} & & & & \text{a priori} \\ \text{probability ratio} & = & \text{likelihood ratio} & \times & \text{probability ratio} \\ \text{posterior odds} & & & & \text{prior odds} \end{array}$$

Framework for forensic individualisation from biometric data

This section presents a concrete framework based on the hypothetical-deductive method for the forensic individualisation from biometric data. This framework, summarized in the scheme presented in Table 1, includes the definition of the alternative hypotheses, the selection of the sources and databases, the analysis and comparison of the biometric properties, and the interpretation of the evidence using the likelihood ratio approach.

The trace/mark (X) considered for forensic individualisation from biometric data can be a fingermark, a photo or a video recording of a face or a speech audio recording. The set of all the plausible sources of the trace/mark is defined on the basis of the background information (I) and on the preliminary observation of this trace/mark. The background information also determines which of the plausible sources can be focused on and selected as the putative source (Y).

The prosecution hypothesis is the hypothesis that the putative source (Y) is the source of the trace/mark (X). For the clarity of the scheme, the subset of all the other plausible sources is considered as one generic alternative source. The defence hypothesis Hd is the hypothesis that an alternative source is the source of the trace/mark (X). In reality however, the background information about the different other plausible sources can vary, and if so, a distinct defence hypothesis should be considered for each other plausible source.

Selection of the databases

When applied to forensic individualisation from biometric data, the likelihood ratio approach needs biometric data to estimate the within-source variability of the putative source and the between-source variability of the trace/mark. The data has been structured in three databases: the potential population database (P), the putative source reference database (R) and the putative source control database (C). The content and use of each of these databases is detailed infra.

Analysis and comparison

Extraction of the characteristics

The importance of selecting characteristics judiciously cannot be overemphasized. If the characteristics are poorly chosen, no amount of mathematics can salvage an individualisation scheme [29]. For the fingerprint, the information is known and structured in three levels of characteristics: the first level is the pattern type of the fingerprint (arch, loop and whorl), the minutiæ or Galton points (ridge ending, bifurcation and dot) form the second level and the pores and ridge edges constitute the third one. The current AFIS systems use mainly the position and angle of the minutiæ as well as the skeleton for the analysis, but the use of other characteristics such as the probability for minutiæ configuration on the surface of the finger would contribute to developing a probabilistic assessment of fingermarks based on statistics [26]. For face and voice, the knowledge of the existence of idiosyncratic characteristics is hampered by the difficulty to provide a symbolic description for this information. In such cases, the individualisation process is supported by the recognition of the information containing source-dependent characteristics, the information itself remaining impossible to define [30].

Estimation of the value of the evidence

The evidence is the result of the comparative analysis of the characteristics (x) extracted from the trace/mark X, with the characteristics (y) extracted from the putative source Y. In a computer-based approach of individualisation from biometric data, the result of the comparison of x and y leads to a unidimensional or multidimensional numerical value which estimates the “distance” or the “proximity index” between them; this information represents the evidence E.

Interpretation of the evidence using the likelihood ratio approach

Estimation of the between-source variability and calculation of the denominator of the LR

The potential population database (P) is a large-scale database used to estimate the variability of the sources from the potential population. Ideally, P is made up of information that contains the exhaustive characteristics of interest of the alternative sources from the potential population. For individualisation from biometric data, this database can be made up of rolled inked fingerprint pictures, 2D or 3D pictures of the face or spontaneous speech audio recordings of the alternative sources from the potential population.

The characteristics concerning the relevant alternative sources are extracted and compared to the characteristics of the trace/mark. The result of this comparative analysis is a set of distance measures (B) used to estimate the between-source variability given the trace/mark. This amounts to estimating the distribution of the distance measures that can be obtained when the trace/mark is compared to the alternative sources of the potential population database. The between-source variability matches the relative frequency of the evidence in the potential population, in the limit of the P database in which it is observed approaching that of the full population. The calculated between-source variability is then used to estimate the denominator of the likelihood ratio P (E | Hd).

Estimation of the within-source variability and calculation of the numerator of the LR

The putative source reference database (R) is made up of information that ideally contains the exhaustive characteristics of interest of the putative source. For individualisation from biometric data this database can be made up of rolled inked fingerprints pictures, 2D or 3D pictures of the face or spontaneous speech audio recordings. The characteristics (y) extracted from the putative source Y serves to calculate the evidence (E) when they are compared to the characteristics of the trace/mark (x).

The putative source control database (C) is made up of information that is ideally of the same quality as the trace/mark, but originated from the putative source. For individualisation from biometric data, it can be fingermarks of the putative source detected on the same surface as the trace/mark, pictures of the face of the putative source taken in similar conditions as the trace/mark or speech audio utterances of the putative source recorded in similar conditions as the trace/mark. These pseudo-marks are used to evaluate the within-source variability of the putative source when the characteristics of the samples of the C database are compared to the characteristics of the putative source.

The result of this comparative analysis is a set of distance measures (W) used to estimate the within-source variability of the putative source. It involves estimating the distribution of the distance measures that can be obtained when the putative source and a pseudo-trace/mark of the same origin are compared. This

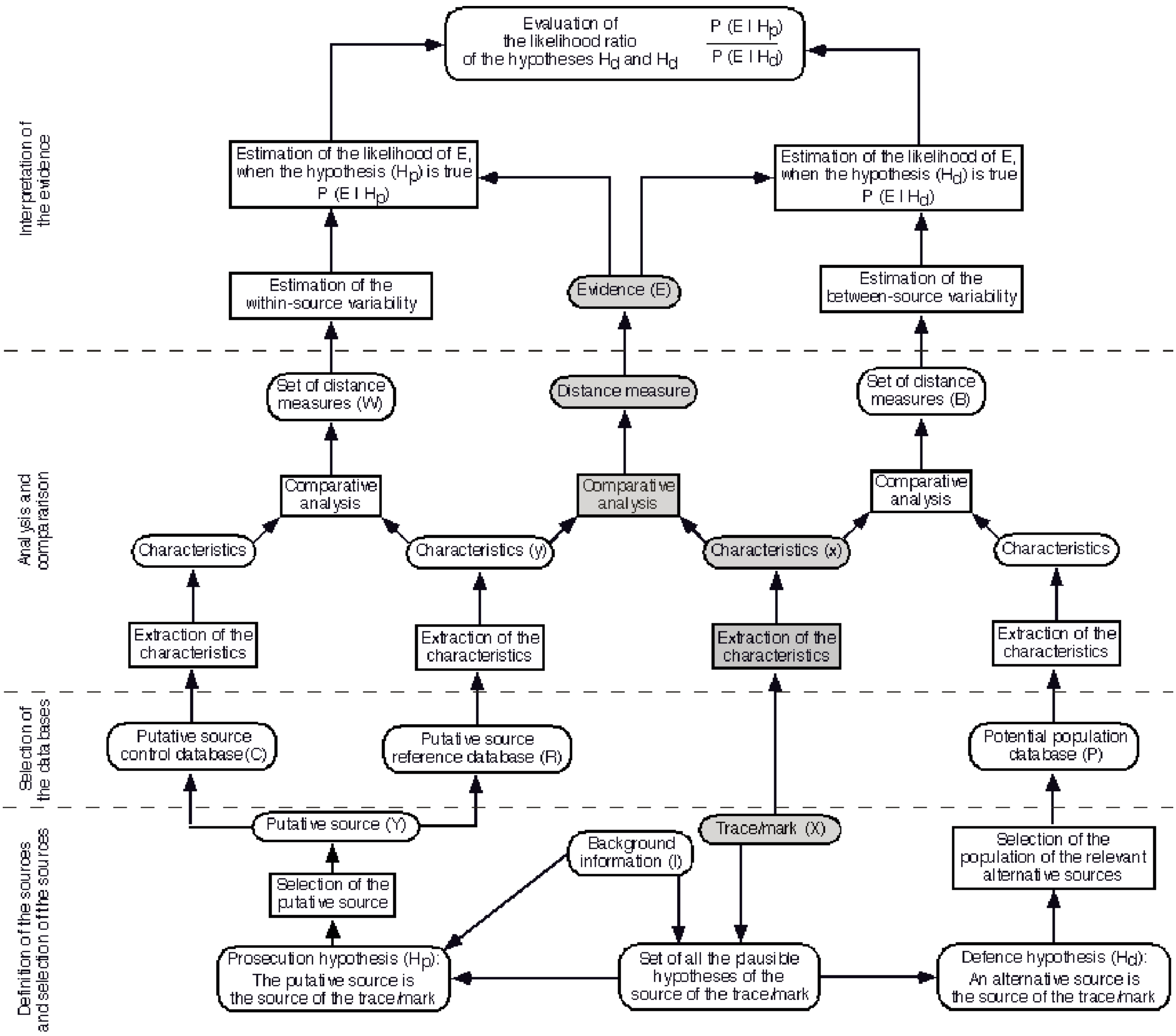

Table 1 Framework for forensic individualisation from biometric data

distribution matches the within-source variability of the putative source, in the limit of the C and R databases in which it is observed, approaching the real variability of the putative source. This calculated within-source variability is then used to estimate the numerator of the likelihood ratio P (E | Hp).

Evaluation of the strength of the evidence
The evaluation of the likelihood ratio of the two hypotheses results from the calculation of P (E | Hp) / P (E | Hd). The strength of evidence can be expressed by numerical values, but it can also be expressed by linguistic qualifiers, which report the amount of support of the evidence E for the hypothesis Hp against the hypothesis Hd, following a qualitative scale of verbal equivalents corresponding to values of likelihood ratios [25].

Conclusion

In forensic science, the concept of identity is related to the identity of source. Establishing the identity of a source refers to an individualisation process, which consists of determining if a particular individual entity is the source of a trace/mark. As the continuity in time of a source and a trace cannot be proved in forensic science, the identity of source is not absolute and can only be inferred.

The assumption of uniqueness, often considered as a principle in forensic science, is not satisfied for the traces/marks and some of the sources considered for forensic individualisation from biometric data. This assessment does not mean that fingermarks, face traces and voice traces are not usable for forensic individualisation from biometric data, but it clearly lays down limits in the certainty that can be expected, depending on the nature of the source, on the quality of the trace/mark and on the method chosen for the analysis. One, in general, cannot deduce the source of a trace.

The logical consequence is that the individualisation process used for forensic individualisation from biometric data cannot be simply considered as a comparative analysis of the characteristics of a source and a trace/mark followed by a binary decision of identification. It should be considered according to the hypothetical-deductive method, whose highlights are its taking into account of prior knowledge, its requirement to consider all plausible hypotheses to explain the source of a trace/mark and its power to test them. The framework proposed to design a computer-based system for forensic individualisation from biometric data gives a possible framework to apply the hypothetical-deductive method.

In practice, probabilistic statements about identity, that can be substantiated by forensic science, must be distinguished from categorical statements about identity that can be substantiated at best by a combination of forensic science and opinion. Unfortunately the belief that forensic individualisation rests on a deductive reasoning is still present in the forensic community, where the misleading terminologies of fingerprint (instead of fingermark), voiceprint or faceprint are still commonly used.

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