Fingerprint Examination: A Defined Method

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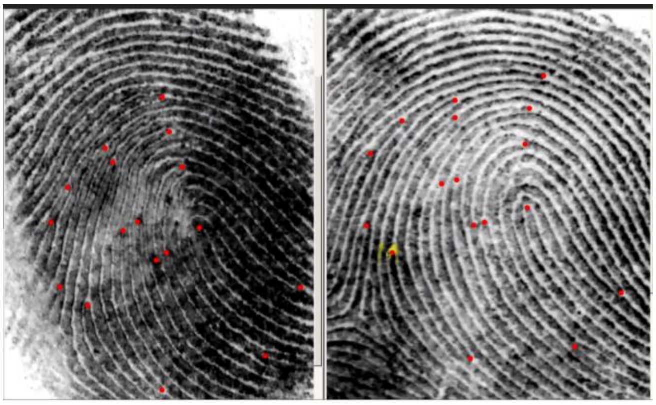
ABSTRACT: Fingerprint comparisons have been performed worldwide for over 100 years. Instructions on how to perform a comparison are limited to very general descriptions; the more intricate guidelines have been handed down through mentorship. This has resulted in a variety of different practices. In an effort to create consistent practices and allow for measurement of results, this paper recommends a defined approach. As with any method, refinement and improvements are continual. The following systematic method converts the factors used during an examination into categorized data which then can be assessed to determine the strength of a conclusion. Once the strength of a conclusion is determined, conclusions can be articulated more transparently. Correctness of a conclusion can be judged by assessing adherence to the rules and thresholds instead of by comparing a conclusion to the opinions of others. This is an advancement that is long overdue.

Fingerprint comparisons are the most widely used form of establishing identity worldwide. They are effective for both confirming identification and assisting in criminal investigation. Fingerprint comparisons are not difficult to perform; the process can be learned by watching a 5-minute YouTube video, https://www.youtube.com/watch?v=IrpTqKkgygA [1]. The process is commonly described as 1) *analyze* the visual features in an impression 2) perform a *comparison* with another impression and 3) *evaluate* the information to arrive at a conclusion; aka ACE. ACE states the broad steps of the process; however, the specific rules used within the ACE process, like which features are allowed to be used, are determined by each agency or practitioner.



For the comparison above, the YouTube lesson states, "The third phase in the comparison process is the evaluation phase. We look at the similarities and any differences that we found during the comparison phase and come to a conclusion of identification, exclusion or inconclusive. For this example, there are enough clear features that share the same orientation and unit relationship in both prints to come to the conclusion of identification that these two prints were made by the same finger". Many people can perform comparisons innately with very little instruction, resulting in a high accuracy rate for discipline. However, comparisons become more complex as features become less clear or limited in number.

As features become ambiguous or limited, one would naturally wonder how much similarity is needed to arrive at an identification. Currently, conclusions are the subjective opinions of the analyst based on individual tolerance levels, a *I know it when I see it* approach. The lack of specific parameters creates two major issues. The first issue is that the more complicated conclusions may only be made by those with superior experience, abilities or perhaps confidence levels; newer practitioners are often told to keep trying and their skills will improve with time. The second issue is that without clear parameters, the accuracy of a specific conclusion can never be known, only assumed. Trusting conclusions due to the reliability of a disciple or due to the credentials of the analyst are extremely concerning considering that people may be found guilty of crimes based on these conclusions. To date, a specific method has not been clearly defined in a way that permits consistent use of practices or measurement of a result. Unstated rules are difficult to teach, difficult to learn, and difficult to enforce; however, this is an obstacle that can easily be overcome. Breaking down the unstated strategies utilized by those with experience creates instructions so that others can learn how to perform complex tasks; complex tasks become easier when rules and parameters are clearly stated. Articulating rules and parameters also diminishes personal thresholds which in turn controls conclusions to prevent those outside a given parameter. More importantly, establishing rules and parameters will give others the ability to assess the strength of each conclusion instead of relying on the past credibility of a discipline.

The following is a four-step method that converts a skill into a structured process. It has been designed to allow for the variety of practices utilized but assesses each practice according to its overall acceptability (i.e., features and practices that are universally used and lead to solid conclusions are considered stronger than features and practices that are seldomly used or have been found to contribute to errors). Each step of this method has parameters that help weigh the risk of error in a conclusion. Step 1 is determining if a fingerprint impression has sufficient data to warrant a comparison to another impression. Step 2 is performing a comparison between two impressions. Step 3 is rating the complexity of a comparison. And step 4 is drafting a conclusion. This method sounds similar to ACE however ACE merely gives broad directions. This method states specific directives and parameters to promote consistency and allow others to assess the strength of conclusions.

The primary philosophies of this method are based on the premises found in the natural or observational sciences, therefore a brief overview of these premises will assist in understanding the overall ideology. Science is not only a body of knowledge but a means of how to best arrive at the body of knowledge. Science is a form of reasoning that relies on evidence instead of relying on human senses; relying on what we know versus what we think we know. Utilizing an outlined approach reduces subjectivity, commonly referred to as human factors.

There is not a solitary method for arriving at scientific knowledge, different methods are useful for different situations. The process of induction is one scientific method where knowledge is gained through an accumulation of data. Induction does not have a numerical requirement for the amount of data that needs to be accumulated before a notion is accepted. It may be tempting to look at low levels of association and jump to a conclusion; however, science warns that “A correlation does not imply causation”. The more data that is accumulated, the stronger a conclusion becomes. Karl Popper brought forward the philosophy that merely collecting information that confirms notions does not provide the best knowledge; rigorously trying to disprove a notion provides stronger knowledge. If robust attempts at falsifying a notion are made, and the notion cannot be disproven, then the notion is accepted, but it is never proven. As a consequence of the induction process, ground truth is never established, resulting conclusions are either accepted to the point of general consensus or disproven. Disproven notions are the only conclusions in science that are definitive and conclusive; once evidence is found that refutes a notion then the notion cannot possibly be found to be true. General consensus may be mistaken as a majority vote; however, in science, general consensus indicates that an idea has been debated and all reasonable doubt has been resolved. This is commonly known as holding up to the scrutiny of others (would others agree or have justification for disagreement). Seeking scrutiny helps improve conclusions, whereas seeking confirmation only serves to show minimal acceptance. Additionally, it is valuable to be reminded that *general* consensus does not mean *universal* consensus.

Step 1: Determining the Value of an Unknown Fingerprint Impression

The Objective of Value Determinations

The first step in the fingerprint examination process is to determine if an unidentified impression has *value*. Value determinations can vary depending on the intended purpose, such as value to preserve and collect an impression, value to perform a comparison, value to exclude an individual from being the source of an impression or value to identify who deposited an impression. An additional approach for value determinations that has rarely been discussed is to assess value as a cost-benefit analysis, which is determining value based on indirect factors such as case type or the amount of work to be performed in a case. With the cost-benefit approach, an analyst may determine an impression has value in one case and conversely determine the same impression has no value in another case. For example, a marginal impression may be deemed to have value if it is the only impression in a homicide case but not deemed to have value if it is the 50th impression in an auto theft case. The differing purposes or uses for value determinations can result in a wide variance of value determinations for the same impression. In the past, variances have been attributed to human subjectivity; however, it seems very plausible that the variation is more likely due to differing objectives [2].

Articulating the purpose of a value determination is essential because the purpose dictates the approach and the procedures needed. The cost-benefit approach appears advantageous; however, it creates false 'no value' conclusions and therefore should not be considered to be a best practice. It is best to state the true value of an impression and later decide whether comparisons to known impressions are useful. *Value for a comparison* allows for additional examination conclusions that are not possible when using the alternative purposes for value determinations. For these reasons, ***value for a comparison*** is the preferred objective. The value determination stage is considered ***a quick triage to decide if a case is potentially workable*.**

Bias / Documentation of the Basis for Value Determinations

It may seem valuable to document the features observed in an unknown impression prior to examining the features in the known impression so that the information in the known impression does not bias the analyst. Bias is only an issue when information is ambiguous or limited therefore it is not valuable to perform comprehensive pre-documentation for every comparison. Bias is addressed in this method by allowing only data and conclusions that can be successfully demonstrated to others who are critically analyzing information, which is different than seeking agreement. This is a form of intersubjective testing designed to weed out personal interpretations in favor of general consensus determinations.

Key Factors and Parameters for Value Decisions

Prior to establishing a threshold for value, it is necessary to define key factors and parameters that are utilized for value determinations. Definitions are necessary to ensure a common understanding since a single word may have several meanings and be used differently. Parameters are necessary because each piece of data does not hold the same weight. Five distinct or important features may hold more significance than fifteen indistinct or unimportant features. The rarity of features may appear to be a key factor; however, rarity is a consideration only when the amount of data is low. Therefore, rarity is not a key factor but rather a sub-factor of the quantity needed and can be integrated into the quantity rating. In this method, key factors are parameterized by how they have been introduced during training and the general acceptance of these factors worldwide. The use of these factors may change as each factor and ranking are shown to be valid or invalid.

a) Feature types that are *available and most likely to be utilized during a comparison*:

Primary features (universally utilized, taught in a rudimentary training program, highly reproducible): Galton points (ending ridges, bifurcations, dots) and intervening ridges

Secondary features (commonly utilized, taught in an advance training program, often reproducible): Incipient ridges, scars and creases

Tertiary features (may be noticed but seldom used as support for a conclusion, not often reproducible): pores, ridge edges

Fig. 1: Example of some features utilized during a fingerprint examination.

b) Quality *of features available*:

Predominantly clear: features that would be labeled the same if assessed by the same person at another time, or by a different person (intra and inter consistent) or features that are easily demonstrable to others

Predominantly ambiguous: features that may be labeled differently if assessed by the same person at another time, or by a different person (intra and inter variable) or features that are not easily demonstrable to others

c) Quantity *of primary and secondary features*:

Abundant: more than needed; analysts could use different Primary or Secondary features to arrive at the same conclusion because the amount is extensive

Limited: analysts would use the same Primary or Secondary features because that is all that exists; another way of stating this is to say that all the data is being consumed, consuming all the data states a measurement regarding the amount of data available

Threshold for Value

Value determinations result in an **impending action that can be taken**; either to attempt a comparison or close out an impression. Therefore, it is more appropriate to refer to the first step as the ***value/comparability decision*** to clearly indicate that it is stating an action of whether or not to proceed. Defining value in this way allows for appropriately utilizing a cost-benefit approach by including the option of stating that a comparison could be performed but was not due to time or staffing constraints.

> **Threshold Guideline for Value/Comparability Decisions**: An impression with a few (3 or 4) clear *primary or secondary* features, or with an abundance of ambiguous *primary or secondary* features, or an abundance of clear tertiary features, that can be compared to another impression to potentially establish similarity in features, regardless of whether that similarity is common or uncommon among a population of individuals.

The above threshold may seem extremely generous and may increase the number of impressions considered comparable. However, it is best to label an impression as comparable rather than erroneously dismiss it as having no value. It may be alledged that establishing similarity with a known impression is not meaningful as it does not convey any useful information to the end user. Under the method described, determining the usefulness of information is left up to the end user to consider the usefulness of information in context with all other information, not assumed by the analyst. This allows results to be reported that may be valuable to an investigation, not simply valuable for prosecuting or defending an accusation (discussed further in the section on Drafting Conclusions).

If an impression shows only a pattern type (e.g., whorl, loop or arch) with no features then the impression cannot reliably be determined to have originated from friction skin, and therefore does not meet the stated threshold for value determinations. The use of simultaneous impressions, i.e., utilizing the combined features from two or more impressions that are assumed to be deposited concurrently, is not directly addressed in this model; however, it can be indirectly addressed on a case by case basis through the *general consensus* threshold described above (i.e., has doubt in the concept been resolved to the satisfaction of others).

Feature Type versus Levels of Detail

Since the 1990's, the attributes of fingerprints have commonly been grouped as 1st, 2nd and 3rd level detail (pattern type, pattern flow and additional attributes) [2]. The categories described in this method of primary, secondary and tertiary features are not the same as the levels of details. Under this method, 1st level detail is not considered as a feature type. 1st level detail may be helpful to determine an area to search but it is not considered a feature within itself. In the levels of detail groupings, 2nd level details include both features that are universally accepted and some that are not, such as incipient ridges or scars. The method described in this paper subdivides features to indicate the acceptability of features. 3rd level details include ridges edges and pores which is the same as tertiary features, however, by labeling them as tertiary features allows these features to be weighted according to their use and acceptability.

A comparison between categorizing features as *levels of detail* and by *primary, secondary and tertiary* is shown below.

FEATURE	CATEGORIZATION by Detail	CATEGORIZATION by usability
Pattern type (ridge flow)	1st Level Detail	
Galton Points (major ridge paths)	2nd Level Detail	Primary (universally accepted)
Incipient Ridges/Creases/Scars	2nd Level Detail	Secondary (commonly accepted)
Pores/Ridge Edges (ridge shape)	3rd Level Detail	Tertiary (uncommonly used as support)

<u>Examples of Value/Comparability Decision – Can a Comparison be Attempted</u>

The following are four examples of assessing the value/comparability decision for different impressions. The examples are in descending order of comparability. The options for documentation in each example are for documenting the value/comparability rating, not for documenting each feature as the basis for each rating.

Documenting the specific basis for each rating is an intricate process that is not addressed within each example because the philosophy of this method is that documentation of the basis is required for complex analyses or if requested by others; it is inefficient to perform such an intricate task unless it is necessary. For straightforward conclusions, the documentation can be performed IF and WHEN it is requested; it does not need to be performed at the time of the value/comparability decision. This is similar to concluding that 3963 ÷ 3 = 1321. Since this division problem is rudimentary and the basis for the conclusion can be easily demonstrated if requested, it is not required that documentation supporting the conclusion be performed and retained for every division problem (except perhaps during training); however, support behind the conclusion does need to be produced and supplied IF requested by others. A reviewer may agree with a conclusion but may note that supporting documentation is needed in certain situations. The desire for a thorough pre-documentation of all information contained in an impression may be a knee jerk reaction to protect against errors; there is no evidence that pre-documentation adds value or is scientifically required.

<u>Example 1 – Value/Comparability Decision – Can a Comparison be Attempted</u>

Fig. 2. Impression from fig. 1 without features labeled.

Fig. 2 can be assessed for a value/comparability decision. There are more than a few clear primary or secondary features to potentially establish similarity with another impression. The decision to label this impression as comparable would hold up to scrutiny to the point of general consensus.

The ratings for value determinations can be documented as deemed necessary by each agency.

Option 1: State the value/comparability determination without stating each rating

Value determination: Comparable

No further documentation is required; however, supporting documentation shall be performed and provided upon request by a verifier, a reviewer, or other, and must hold up to the general consensus threshold.

Option 2: State the value/comparability determination and each rating that supports the determination

Comparable: an abundance of clear primary features.

Option 3: Formally state each rating to support the value/comparability determination

a) Feature types *most likely to be used*: **Primary Features – Galton Points**
b) Quality *of features most likely to be used*: **Predominantly Clear**
c) Quantity *of Primary and Secondary features*: **Abundant**

Value/comparability determination: **Comparable**

Example 2 – Value/Comparability Decision – Can a Comparison be Attempted

Fig. 3: An unknown impression.

Fig. 3 lacks the clarity and amount of information that fig. 2 possesses; however, it does have a few clear primary or secondary features, or an abundance of ambiguous features, to potentially establish similarity in features with another impression.

An option for documentation may be: Comparable, more features than needed to establish correspondence with another impression.

The wording for documentation in this example is different from previous examples (e.g., the word *correspondence* is used instead of the word *similarity*). Wording can be determined by an agency as long as it accurately represents the information to the point of general consensus.

<u>Example 3 – Value/Comparability Decision – Can a Comparison be Attempted</u>

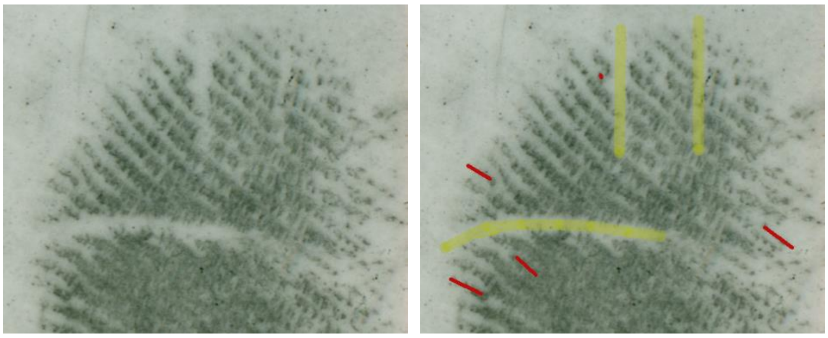


Fig. 4: An unknown impression; the same impression with primary and secondary features marked.

Fig. 4 is comparable because it meets the guideline threshold of having a few (3 or 4) clear primary and secondary features to potentially establish similarity with another impression. Five primary features are marked in red (Galton points) and three secondary features are marked in yellow (creases). Regardless of whether or not this impression can be identified or excluded to a known source, it may be useful to others (investigators or jurors) to know if it is consistent with a known source, similar to knowing if blood at a crime scene was consistent with a suspect's blood type.

An option for documentation: Comparable: limited features, may not be identifiable.

<u>Example 4 – Value/Comparability Decision – Can a Comparison be Attempted</u>

Fig. 5: An unknown impression.

Fig. 5 is not comparable because it does not have the requisite amount of clear primary and secondary features, or an abundance of tertiary features, to potentially establish similarity with another impression.

An option for documentation: Not comparable: The quantity of primary or secondary features is extremely limited and the clarity shows the existence of tertiary features but not specific characteristics of the tertiary features.

Step 2: The Comparison Process

The comparison process involves looking for similarities and dissimilarities between two impressions. Each area of the hands and feet contain very different characteristics which may indicate the area of origin and the orientation of an unknown impression. For example, an unknown impression may contain a delta and the end of the distal transverse crease. These characteristics indicate the hand, area and direction of the unknown impression. Additionally, two impressions from the same source will never be identical due to the elasticity of the skin. Pressure and movement will create slight differences in appearance; however, the features being compared should be in the same spatial relationship relative to one another and have the same number of intervening ridges between features.

The three key factors and ranking parameters defined for value/comparability decisions are utilized as measurements while performing a comparison (feature type, quality and quantity). The area and orientation (A/O) is an additional factor utilized during a comparison because without clues of where to look for similarity, the search phase of the comparison becomes increasingly more challenging. If clues to establish the A/O are unavailable in the unknown impression, then every area in every direction of both hands and feet must be considered and searched. This increases the possibility of not locating similarity due to a lack of information in the unknown impression, which must be accounted for when establishing the end result conclusions. Consider looking for a needle in a haystack, just because a needle is not found does not mean that a needle is not in the haystack.

Parameters for the A/O need to be established to ensure consistency in rating. As with the other factors, training levels can be used to establish parameters for rating the A/O. In rudimentary training courses, the A/O are either given or self-evident (i.e., easily determined by those with very basic knowledge, see fig. 6). Advanced training teaches clues that may be available in an impression that enable the A/O to be determined.

Fig. 6: An example of self-evident; it is obvious to those with very rudimentary training that this is a right hand [3].

While performing a comparison, the feature type and quality of the features *used* are rated since data that is not utilized are irrelevant.

Key Factors and Parameters for Comparison Ratings:

a) **A/O** of the unknown impression:

Self-evident to those with rudimentary training

Not self-evident to those with rudimentary training

b) **Feature types** *used*:

Primary features (universally utilized, taught in a rudimentary training program, highly reproducible): Galton points (ending ridges, bifurcations, dots) and intervening ridges

Secondary features (commonly utilized, taught in an advance training program, often reproducible): Incipient ridges, scars and creases

Tertiary features (may be noticed but seldom used as support for a conclusion, not often reproducible): pores, ridge edges

c) **Quality** *of features used*:

Predominantly clear: features that would be labeled the same if assessed by the same person at another time, or by a different person (intra and inter consistent) or features that are easily demonstrable to others

Predominantly ambiguous: features that may be labeled differently if assessed by the same person at another time, or by a different person (intra and inter variable) or features that are not easily demonstrable to others

d) **Quantity** *of primary and secondary features*:

Abundant: more than needed; analysts could use different Primary or Secondary features to arrive at the same conclusion because the amount is extensive

Limited: analysts would use the same Primary or Secondary features because that is all that exists; another way of stating this is to say that all the data is being consumed, consuming all the data states a measurement regarding the amount of data available

When performing a comparison, similarities and dissimilarities that adhere to the above parameters need to be demonstrable to the satisfaction of others if requested, not necessarily documented for each comparison. There are situations where the quality and quantity may be between two rating options. When this occurs, the higher rating is selected to ensure conservatism.

Example 5 – Value/Comparability Decision and Performing a Comparison

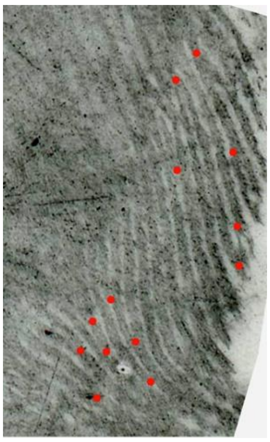


Fig. 7: An unknown impression.

Step 1: The unknown impression in fig. 7 has more than a few clear primary or secondary features to potentially establish similarity in features with another impression, regardless of whether that similarity is common or uncommon among individuals, therefore a comparison can be attempted. This decision would hold up under scrutiny.

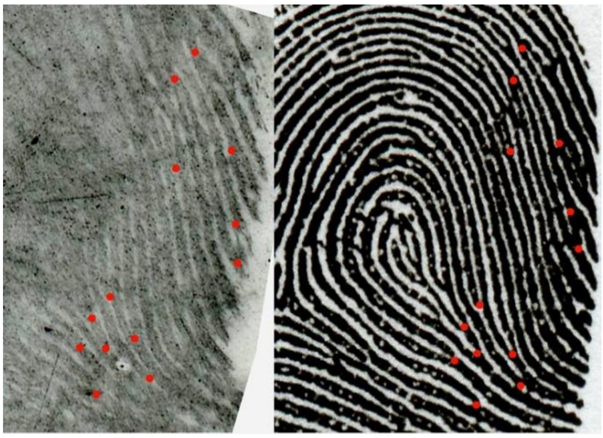


Fig. 8: A comparison between an unknown and known impression.

Step 2: A comparison is performed in fig. 8 and the factors are assessed under the parameters listed.

a) A/O of the unknown impression: **Not Self-evident**
b) Feature types *used*: **Primary Features – Galton Points**
c) Quality *of features used*: **Predominantly Clear**
d) Quantity *of Primary and Secondary features used*: **Limited**

The A/O rating of 'not self-evident' indicates that the A/O cannot be established by with limited training; all areas of friction ridge skin must be searched. If a similar configuration of features is found within a known impression, then the similarities can be noted as above. If a similar configuration of features is not found within a known impression, then it does not indicate that the known impression is not the source. The inability to find similarity when the A/O is not self-evident is due to a lack of information in the unknown impression.

The features used in this example are those that would be utilized and acceptable by any analyst since Galton points are taught in all rudimentary training classes. The quality is predominantly clear, and the quantity is between abundant and limited, therefore this impression would be rated at the more conservative rating of limited.

The comparison phase is completed but more information may be assessed and documented if needed while determining complexity or when drafting a conclusion.

<u>Example 6 – Value/Comparability Decision and Performing a Comparison</u>

During a comparison, the reliability of the features in the unknown impression may differ from the initial assessment since the reliability of features cannot always be determined by viewing the unknown impression in isolation (see fig. 9 and fig. 10). When the features are less reliable than initially assessed due to very subtle indications of distortion, as in fig. 9, a new value decision can be stated as, "following a more thorough examination, the features in the unknown impression are less reliable than initially assessed and therefore further comparisons will not be attempted".

Fig. 9: Unknown impression with initial features marked; known impression; unknown impression with the visual sign of distortion marked (a slight shadow which is usually either referred to as a line of demarcation or a fault line).

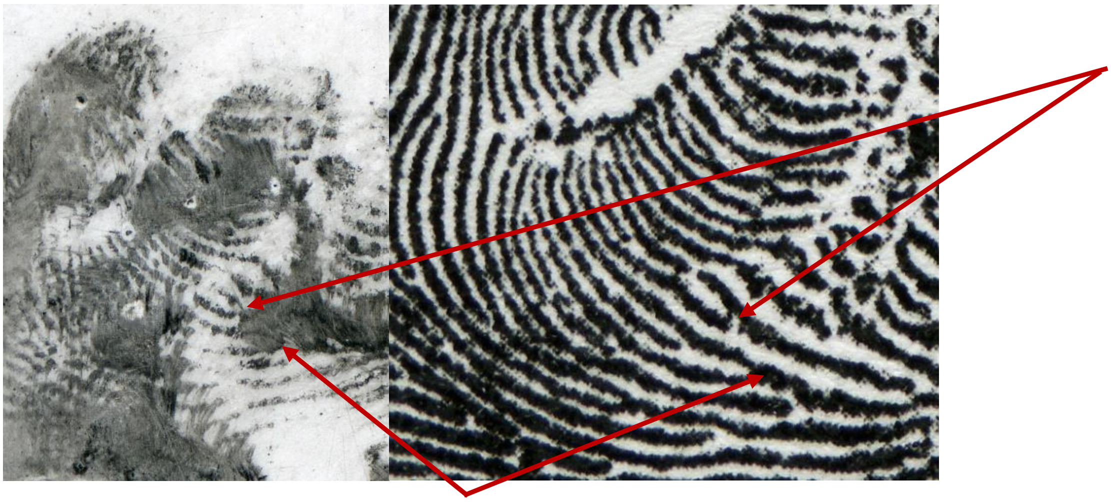


Fig.10: Features that may be more reliable than initially assessed and can be utilized during a comparison.

Step 3: Evaluating the Complexity of a Comparison

Fingerprints are widely diverse. Most errors have been due to misinterpretation of highly subjective data (utilizing data that others cannot see or data that cannot be demonstrated to the satisfaction of others), not because multiple people have the same configuration of features within their fingerprints. An examination method must protect against errors by highlighting when over-interpretation is more likely to occur so that quality assurance measures can be implemented in these situations. This method includes a complexity rating which indicates when over-interpretation is less likely or more likely. This is an essential item needed to determine the strength and reliability of a conclusion.

The categorization of the key factors utilized for comparisons is used to rate the complexity as basic, advanced, or complex [4]. Basic indicates that all factors are optimal. Again, these conditions are utilized in rudimentary fingerprint training courses. Advanced indicates that some factors are not optimal. Non-optimal conditions are taught in advanced fingerprint training courses. Complex indicates that some factors are minimal. Extreme conditions are taught in higher level advanced training courses. As the complexity increases, the risk of error increases. As with the key factors, parameters need to be specified for each complexity level to ensure consistency in complexity ratings.

<u>Parameters of Complexity of a Comparison</u>

Comparisons can range from being based on an abundant amount of clear primary features to being based on a limited amount of ambiguous primary or secondary features. Both basic and complex comparisons may be labeled as identifications; however, the strength of each identification differs considerably. Over-interpretation and errors are more common when features are ambiguous or when the primary and secondary features are limited; therefore, the parameters below label comparisons as complex when these attributes exist (ambiguity or a limited amount of primary or secondary features). The use of tertiary features is considered complex because it indicates that primary or secondary features are limited.

Basic (4 conditions must apply): A/O are self-evident, and an abundant amount of clear primary features are utilized

Advanced (4 conditions are considered): At least one of the requirements for Basic complexity are lacking (may include tonal reversals, e.g., when extreme pressure makes the furrows appear instead of the friction ridges)

Complex (at least 1 of 2 conditions must apply): Either the data is predominantly ambiguous, or the amount of Primary or Secondary features is limited (may include tonal shifts within an impression, e.g., when extreme pressure makes part of an impression tonally reversed)

As the risk increases, additional quality assurance measures need to be implemented to address subjectivity and safeguard against error. A basic comparison may not need any quality assurance measures since the conclusion is easily repeatable by others. An advanced comparison may need minimal documentation to note the A/O, the type of features utilized, the data that is ambiguous, or the limited features. A complex comparison may warrant multiple quality assurance measures. Quality assurance measures, either employed by the user of a method or determined by agency policy, can include full documentation of the similarities and dissimilarities utilized during the comparison, consultation, reviews of the conclusion and the logic supporting the conclusion, and/or group consensus.

The complexity of an unknown impression can be rated in isolation of a comparison; however, the rating may change, once a comparison is performed, (a rating may be different between an impressions and a comparison) making rating an unknown impression unnecessary. The complexity category for a comparison given in this method of Basic, Advanced or Complex correlates to easily repeatable, easily demonstrable and not easily demonstrable (Basic is easily repeatable since all the factors are pristine and Complex is not easily demonstrable since factors are ambiguous or limited).

Example 7 – Evaluating Complexity

Fig. 11: Unknown impression; known impression.

As determined in example 2, the unknown impression in fig. 11 can be compared to a known impression (see fig. 11). The comparison can then be rated for complexity.

A/O: Due to the recurve, the area and orientation of the unknown impression may be considered self-evident, making the complexity level start out as basic. If the determination of A/O being 'self-evident' by those with rudimentary training would not hold up to others, then the complexity level is raised to the advanced level.

<u>Features:</u> Galton Points could be the features utilized during a comparison. If secondary features are utilized, then the complexity level is raised to the advanced level.

<u>Quality (or ambiguity):</u> The features may seem predominantly clear to some; however, that determination would not hold up if this were tested against those with rudimentary training; therefore, the quality is rated as predominantly ambiguous.

<u>Quantity:</u> A person with rudimentary training would need to assess all the similarity and dissimilarity between these impressions, therefore the quantity is rated as limited.

This comparison could be represented as:

a) A/O: **Self-evident**
b) Feature types *used*: **Primary Features**
c) Quality *of features used*: **Predominantly Ambiguous**
d) Quantity *of Primary and Secondary features used*: **Limited**

Rating: **Complex (due to quality and quantity)**

Due to the ambiguity and the limited quantity, this comparison is labeled as complex. Note that complex does not indicate that a conclusion is weak (a conclusion has not been determined yet). 'Complex' indicate that quality assurance measures are warranted since there is ambiguity in the similarity or correlation between the features (what appears as an ending ridge in the latent impression appears to be an ending ridge in the known impression).

If any of the ratings are in doubt by others, then testing can be performed to determine which rating holds up to general consensus. Testing could be performed by asking others to critically scrutinize the initial assessment to determine if each rating is well supported. In lieu of testing, the specific rating in question could be raised to the higher rating.

As an additional consideration, those with advanced training may notice the visual indications of *split ridges* in the latent print (squiggly white lines that appear within a ridge) and determine the unknown impression is possibly tonally reversed (fig. 12). This would be rated as 'predominantly ambiguous' since tonal reversals are not taught in rudimentary training and since there are only two categories for quality ratings. However, special consideration is given for tonal reversals; the quality rating for tonal reversals can be labeled as advanced since one of the requirements for basic complexity is lacking and comparisons of tonal reversals are taught in advanced training. For this specific complexity rating, if the tonal reversal were noticed and the quality rated as advanced, the overall rating may still be complex but only due to the quantity of primary and secondary features.

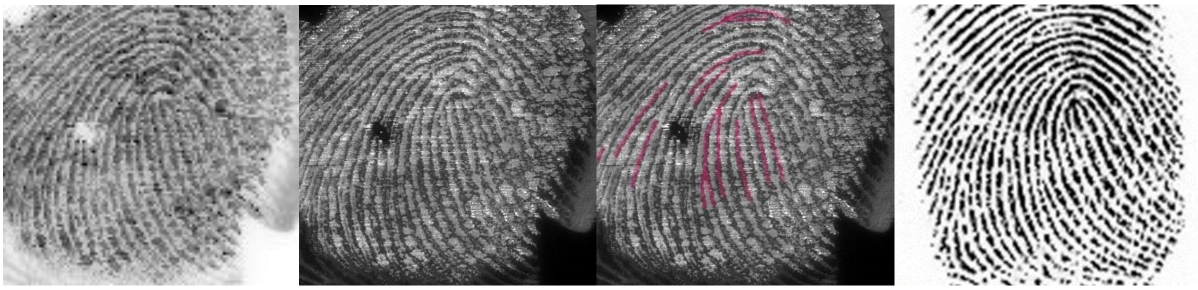


Fig. 12: Unknown impression with visual indications of split ridges; unknown impression tonally reversed; unknown impression tonally reversed and some features marked; a known impression.

Quality assurance measures for this comparison may include documenting the tonal reversal, a chart documenting the similarity and dissimilarity, consultation, extra verification, etc.

Example 8 – Evaluating Complexity

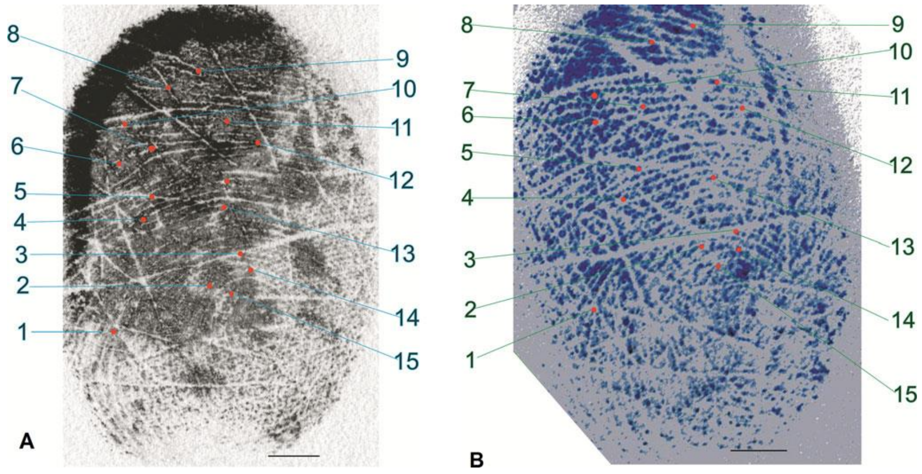


Fig. 13: Published comparison [5].

A comparison can be performed between the impressions in fig. 13 and the factors rated for complexity.

a)	A/O of the unknown impression:	**Self-evident**
b)	Feature types *used*:	**Primary Features**
c)	Quality *of features used*:	**Predominately Ambiguous**
d)	Quantity *of Prim. and Second. features used*:	**Between Abundant and Limited**
	Rating:	**Complex (due to ambiguity)**

The A/O is labeled as self-evident because the shape and pattern type indicate this impression is from a finger. The orientation is that the area above the recurve is the upward position. The A/O could be raised to not self-evident if the A/O determination were in doubt by others (reminder: all decisions/conclusion must hold up to the scrutiny of others to meet the general consensus requirement).

The above comparison utilized highly ambiguous primary features, making the comparison complex. If creases were used to perform the comparison, then the complexity rating would be lowered to advanced due to the use of secondary features that are very clear. Methods that do not allow for the use of creases may be ignoring valuable information and unnecessarily increasing the complexity of a comparison, which in turn increases the risk of error.

Step 4: Drafting Conclusions

Prior to drafting a conclusion, the possible conclusions and thresholds for each level of association must be established. However, the meaning of specific verbiage needs to be discussed first.

Verbiage of Associations

There is a lot of debate about the terms used for conclusions. There is a claim that the words identification and individualized, or any categorical conclusion, are misleading because they imply that source attributions are absolute and conclusive, i.e., facts. Some may even claim that using these terms are scientifically unsupportable. There are several reasons these claims are unjustified.

First, as stated previously, conclusions arrived at by accumulated data offer support for a conclusion. As the amount of support increases, and attempts to falsify the conclusion fail, conclusions become accepted, not proven. Stating that an identification or individualization has been *proven* is scientifically unsupportable; the use of categorical conclusions does not indicate a conclusion is absolute and therefore there is no rationale to support categorical conclusions as being scientifically unsupportable.

Second, in the United States, judges give clear instructions to jurors that they are the sole determinant of the weight of the testimony, indicating that testimony may not be factual.

Third, research has been conducted to determine if layman interpret the term identification to mean 100% certain. The research indicates that all laymen do no interpret expert opinions to be absolute truths [6, 7].

Finally, this debate is inappropriately focusing on the wording used, instead of the method used to arrive at a conclusion. 'Method' in this situation is used to describe a broad method for arriving at any conclusion, not necessarily a specific method used strictly for fingerprint examinations. Conclusions of any type can be based on a variety of properties and the basis for the conclusion is vital in determining the strength or acceptance of a conclusion. For instance, guessing at a conclusion is a method. An incorrect guess may be accepted by others if presented with confidence. It is also possible for a guess to result in an accurate conclusion. Even so, eventually this method will likely fail and therefore knowing that a conclusion was arrived at by guessing dilutes the strength and acceptability of a conclusion. An 'opinion' may simply be based on the belief of a person; based on feelings rather than proper application of a method. Opinions of scientists are not necessarily scientific conclusions. Scientific deductions are based on rules and judged for correctness by the adherence to the rules, and inference are based on reasoning and judged as either well supported or not well supported. The method used to arrive at a conclusion is fundamental in establishing the acceptability of a conclusion. Perhaps this is why the US Federal Rules of Evidence state that the basis for a conclusion may be disclosable, so that the weight of a conclusion can be judged appropriately [8, 9].

Conclusions arrived at by utilizing the method described in this paper are associations established through a combination of inferences and deductions, making it more of an abduction process. Those not understanding the difference between the type of conclusion and the words used to describe the conclusion will continue to state that using the word identification, or individualization, implies the conclusion is a fact even when clearly stated otherwise. In logic, this type of argument is known as a false analogy, i.e., comparing two items that sound the same but are different. Comparing different items will result in different truths and they will always be at odds with each other.

An additional way to articulate associations between unknown and known impressions is to calculate a probability or likelihood ratio of the event. Numerical representations are highly valued; however, prior to accepting any numerical representation, the calculation needs to be tested to ensure the result adequately represents the information.

<u>Conclusions for Non-Comparisons (inferences or deductions): The data indicates or infers</u>

a) Not comparable (final conclusion)
b) Incomplete, need exemplars - Comparable, no comparison attempted, need known prints to perform a comparison (temporary conclusion)
c) Incomplete, comparisons deferred - Comparable, examinations deferred, no comparison attempted due to time or staffing constraints (temporary conclusion)

<u>Fingerprint Comparison Conclusions, Type of Conclusion and the Meaning of the Conclusion:</u>

A) Identification (final conclusion) – A level of association (inductive reasoning: see below for the level of support) that indicates or infers, to the point of general acceptance, that the source of the unknown impression originated from the known impression. Note: General acceptance is expressed as the scientific meaning given earlier in this paper, not a measure of a majority vote
B) Inconclusive (final conclusion) – A level of association (inductive reasoning: see below for the level of support) that is below an amount to establish an identification to the point of general acceptance, or no association found (a lack of a conclusion)
C) Exclusion (final conclusion) – No association exists in ridge features (a conclusive conclusion), or the source has been theoretically excluded due to an identification to another person (a deduction)
D) Incomplete - comparison attempted but need more comprehensive known prints to perform a complete examination (temporary conclusion)

Some fingerprint examination methods incorporate an incomplete comparison into the inconclusive category; however, there is a difference between these two conclusions and therefore it is important to distinguish between the two situations. Inconclusive is when an identification or an exclusion cannot be arrived at due to a lack of data; no additional data is retrievable (e.g., there is similarity to a known impression but not a sufficient amount to infer that the known impression is the source of the unknown impression). Whereas, incomplete is a temporary conclusion; additional analysis can be performed when additional data is retrieved (e.g., obtaining better known impressions).

The threshold for determining the best conclusion from the options below will be the *general consensus* threshold described earlier. Analysts may arrive at different initial conclusions but under this threshold, only one conclusion will hold up after deliberation.

<u>Conclusions with the Strength and Support for Each Conclusion</u>

A) Identifications
    1. Basic Identification: A/O are self-evident, and an abundance of clear primary features are available (an easily repeatable conclusion to those with rudimentary training)
    2. Advanced Identification: A/O are not self-evident, or an abundance of clear Secondary features are utilized (the conclusion may not be independently repeatable by another analyst; however, the conclusion is easily demonstrable)
    3. Complex Identification: Either predominant ambiguity exists or there is a limited amount of Primary or Secondary features (an identification that is not easily demonstrable but is no longer doubted by others)
B) Inconclusives
    1. Inconclusive (inclusive): a large amount of similarity not expected to be seen in others but an identification cannot be demonstrated to the satisfaction of others, may include differences that are not outweighed by the amount of similarity; this information could be useful as an investigative lead in exploring possible suspects involved in a crime; this determination does not imply an identification or that the amount of similarity indicates the known print is likely the source of the impression, the likelihood is not able to be numerically calculated
    2. Inconclusive (inclusive): a marginal amount of similarity, an amount that would be expected in others

    3. Inconclusive (no similarity found): the A/O are not self-evident and therefore an exclusion cannot be conclusive; this determination does not imply the known print is likely excluded as the source of the impression

C) Exclusions
    1. Exclusion (no similarity exists between the unknown impression and the subject being compared): the A/O are self-evident, clear Primary features are utilized
    2. Exclusion: by deduction, due to an identification to another person

Once necessary factors are defined and parameterized, a comparison performed, complexity established and thresholds listed for each possible conclusion, then objective conclusions can be drafted, reported, and articulated.

Inconclusive

Many methods consider only three possible final conclusions (no value, identification or exclusion). Additional conclusions are necessary because the standard three conclusions are not specific enough to convey the intended message or to determine the risk of error with a particular conclusion.

It is common to use the conclusion of inconclusive to indicate incomplete. Not considering the option of inconclusive as *cannot rule out* results in the inability to report out all possibilities and forces analysts to either understate or overstate conclusions by requiring they choose either identification of exclusion. However, it is important to understand that a conclusion of *cannot rule out* does not indicate that a person likely deposited the impression. It may be just as likely that the person did not deposit the impression but there is no mathematical means at this time to determine the likelihood of either situation. It is important to allow, and even promote, all possible conclusions when the lives and liberties of people are affected.

This method creates a larger number of impressions that are considered comparable, which raises the issue of balancing accurate conclusions and practicality. It may not be practical to devote limited staffing resources to all impressions. To balance accurate and transparent conclusions with effectiveness, the option of not performing a comparison on all unknown impressions is allowable depending on administrative needs and resources (option (c) above: Incomplete, comparisons deferred). This option protects against false 'no value' conclusions.

Exclusions

Historically, the term exclusion has been used to indicate two different concepts; either that an area of skin was not the source of the unknown impression or that a specific person was not the source of an unknown impression [2]. Using a single term to indicate two different concepts creates a lot of confusion. Exclusions resulting from this method are to the subject unless otherwise noted. When noting exclusion to an area of skin or to a fingerprint card instead of to a person, it should be clearly stated that a specific person has not been excluded. Simply stating that the impressions on a fingerprint card has been excluded as the source of an unknown impression is not acceptable because those reading this result do not understand the distinction that is being inferred.

As previously stated, identifications are inferences that are accepted due to supporting data, not conclusive facts. Exclusions, on the other hand, are the only conclusive conclusions that science provides. William McComas states, "In actuality, the only truly conclusive knowledge produced by science results when a notion is falsified" [10]. To ensure all conclusions adhere to scientific standards, criterion for exclusions must be unforgiving. Accepting any level of erroneous exclusions indicates a lack of adherence to basic scientific protocols.

The possible conclusions of B3 and C1 above (no similarity found and no similarity exists) have commonly been grouped together and both labeled as exclusions. However, the false exclusion rate has been found to be higher than expected or desired and the reasons behind false exclusions needs to be examined and addressed [11]. As previously stated, just because something is not found does not indicate that it does not exist; therefore, excluding based on a lack of finding similarity is recognized as not a best practice within this method. In order to use these parameters, one must accept the reality that there are times when information is lacking and therefore the most appropriate conclusions is inconclusive (B1, B2 and B3). The supposition that a competent expert should always be able draft a conclusion of identification or exclusion is unrealistic. That would be like assuming that a competent doctor should always be able to diagnose a medical issue even when the symptoms are limited to the point of being common in many illnesses. The exclusion parameters specified in this method increase the accuracy rate of exclusion dramatically by requiring that inconclusive be concluded when no similarly is found.

Conclusion C2, exclusion by deduction, has been questioned due to arriving at a conclusion without performing a direct comparison. Deductive reasoning is considered a valid scientific method; however, the given method can easily be utilized without adherence to C2. In lieu of utilizing exclusions by deduction after an impression has been identified to a source, further comparisons can be performed or conclusion b or c (i.e., incomplete) can be reported when no further comparisons will be performed. Another concern when using exclusion by deduction is that it may imply the identification is absolute or a fact. This can easily be addressed by clearly articulating that this type of exclusion is theoretical and is only as strong as the associated identification.

<u>Example 9 – Drafting a Conclusion</u>

Consider the unknown impression from example 2 determined to be comparable. The comparison shown in example 7 determined this to be a complex comparison. The two best options for conclusions would be A3) Complex Identification: there is a limited amount of data (an identification that is not easily demonstrable but is no longer doubted by others) or B1) Inconclusive (inclusive): a lot of similarity but an identification cannot be demonstrated to the satisfaction of others. Only one conclusion will hold up when tested against general consensus. In this example, the conclusion that holds up under scrutiny is “Complex Identification”. The complexity level does not indicate the conclusion is weak, it conveys that the conclusion is not easily repeatable by others. The conclusion merits questioning as to the reason(s) for the complexity and assurance that adequate quality assurance had been performed. Documenting the results can be done in a variety of ways:

a) Complex Identification
b) Complex Identification due to limited data
c) Complex Identification due to limited data: the data is not abundant but not extremely limited
d) The unknown impression has been attributed to the #3 finger of John Doe. The features used to support the conclusion are primary features (i.e., universally accepted). The quality is rated as advanced due to ambiguity (tonal reversal) and the quantity is rated as complex due to limited data (limited data is a conservative rating, the data is not abundant but not extremely limited). Quality assurance measures include charted documentation and verification to ensure the basis for the conclusion is beyond doubt (i.e., holds up under scrutiny).

Typically, a report would include the short conclusion and case notes would include the more detailed information.

Some may say that a comparison such as this is not difficult and either A1) or A2) is a more appropriate rating. As previously stated, rating the difficulty of a comparison is measuring the analyst's ability, which is different than measuring the complexity of the comparison.

Summary of the Method

The method describes includes four steps; 1) a quick triage to determine if a comparison can be attempted 2) a comparison 3) determining the complexity of the comparison and 4) drafting a conclusion. The ratings in this method may be higher than anticipated; however, the ratings are intentionally increased to promote additional quality assurance measures and to reduce errors by providing the most conservative conclusions. It is possible to subdivide this rating system further, such as saying that the rating is at the low or high end of a range, if that is found to be necessary. Quality assurance measures are determined by the complexity and could be considered to be a fifth step; however, quality assurance measures are designed to be incorporated into each phase as a means of protecting against errors, not used to check for errors after a conclusion is derived.

This approach increases the quality of conclusions by limiting personal interpretation and tolerance levels in favor of categorizing factors by training levels (rudimentary training vs advanced training) and categorizing the complexity of comparisons by basic (easily repeatable), advanced (easily demonstrable) or complex (not easily demonstrable). The general consensus threshold is used in all aspects (the data used, the ranking, and the conclusion) to eliminate personal subjectivity and over-interpretation. Results can then be checked against conformity to rules and criteria, instead of by polling the personal preferences of others. The strength of a conclusion under this method is dependent on adherence to the method and the level of scrutiny the conclusion has been exposed to (i.e., agreement within itself does not indicate a conclusion is accurate or strong). Lastly, each conclusion is specifically defined to provide the result as well as the basis for each result, which is vital in determining the strength of the conclusion.

Trustworthiness

Past trustworthiness in a conclusion has been estimated a variety of ways. Others have attempted to refine the method used to arrive at conclusions to diminish misinterpretation/over-interpretation; however, the intricacies of other methods have not been made public.

Another means of establishing trustworthiness has been to conduct research studies to established error rates. Error rates may show the overall reliability of a discipline; however, overall error rates cannot be extrapolated to indicate the probability of error in a specific conclusion. Additionally, since complexity of comparisons has not been measured in the past, the complexity of the comparisons in these studies cannot be judged to ensure the research included a variety of different situations.

In 2018, The US Department of Justice implemented language to clarify that conclusions are not facts [12]; again, this solution does not indicate the strength or weakness of a specific conclusion.

The US Army Crime Lab has implemented likelihood ratios (LR) to quantify the results of analysts [13]. Although the mathematics behind any LR model may be valid, it is unknown how well the LR approach represents actual conclusions. Many LR approaches currently assess the key factors in a broad sense but may not assess the factors specifically enough to reduce over-interpretation of data or misleading results. Additionally, LRs may be a means of measuring a conclusion after it was arrived at, not a means of arriving at a result [14].

The desire and acceptance of mathematical quantification may be due to the thought that high level mathematics appears more scientific than non-numerically quantified conclusions (sometimes referred to as categorical conclusions). Acceptance of either a numerical or non-numerical method should be in how well the method represent the data and conclusions, not simply judged by the level of mathematics involved.

Trustworthiness has also been established by assessing the credentials of the analyst and their ability to achieve ground truth conclusions on competency, proficiency and certification tests [15]. Proficiency testing is not testing knowledge, logical deduction, or correct application of procedures. Proficiency testing of correct application of procedures cannot be performed prior to establishing rules and procedures. Current testing is assessing personal opinions rather well-founded conclusions. Relying on the past accuracy of an analyst is also problematic because there is a false sense of security in assuming that someone is more likely to arrive at accurate conclusions because they have in the past; and not considering whether sound logic was used to arrive at the conclusion.

A linear approach of documenting features prior to performing a comparison has been suggested as a means of noting the quality and quantity of features. There are some significant limitations with this approach. Pre-documentation may not portray an accurate representation of the information without first standardizing thresholds for what features are usable and how features are to be labeled. This technique is extremely time intensive and therefore it is important to question whether it is valuable for all situations or more useful under certain circumstances. As with value determinations, the usefulness will be determined by the purpose behind the task. Is pre-documentation meant to convey the weight of features, is the purpose to convey the confidence of the analyst in the existence of a feature, or is the purpose to show how much influence viewing the known impression had on drafting a conclusion? Documenting the features prior to performing a comparison may be useful when the practice is better defined to include the purpose, when it is standardized for consistent use, and when it is determined to be valuable.

Rating these four factors as described eliminates the need for a linear approach or pre-documentation, and provides a consistent measure of the relevant data to indicate the risk or trustworthiness in a conclusion without adding much time to the process.

Developing a systematic approach for problem solving not only improves the consistency of conclusions, improves the quality of conclusions, and builds trust, but also makes it possible to test analysts on their proficiency in applying the method. Testing may include proficiency for value/comparability decisions, whether orientation clues can be recognized, whether acceptable data is utilized, whether complexity can be determined, whether definitions such as self-evident, abundant, limited, and tertiary features are understood, or whether conclusions are well supported, not simply testing the ability to arrive at ground truth conclusions [15].

Conclusion

There are many approaches for refining the method used to arrive at fingerprint conclusions, resulting in a variety of methods, not a single technique. Developing a method involves several elements; it needs to be clearly defined, it needs to be tested to ensure effectiveness, practitioners need to receive training in proper use, and be tested to ensure correct application of the method. All these steps need to be completed prior to implementation. To date, these steps have not been performed on most methods and different methods have not been compared to each other to determine the benefits and limitations of each. The method described incorporates the majority of factors utilized during an examination and gives the ability to articulate precise information regarding a conclusion that has not been describable in the past.

The method described intentionally omits many de facto thoughts and practices such as:

- partial prints are inherently weak
- the unknown impression must be analyzed, and observances documented prior to performing a comparison;
- documentation is required;
- dissimilarities must be explained;
- less information is needed when comparing to a victim
- more information is needed when comparing an unknown impression to an impression from a database
- a high number of features is better support than a low number of features
- all conclusions need to be independently repeated by another expert;
- verification is part of the method;
- blind verification is stronger than non-blind verification
- erroneous exclusions are not as significant as erroneous identifications
- embryonic development is not relevant to source attributions, embryonic development research is part of the support behind all fingerprints being accepted as unique

This method considers items like documentation and verification, no matter how they are defined, as quality assurance measures, not as independent stages of a method. The given approach is holistic and puts weight in the ability to demonstrate that the logic behind a conclusion supports the conclusion to the satisfaction of others, instead of putting weight in the beliefs and credentials of the analyst, the repeatability of the conclusion, or in the reliability of a disciple. This method has been tested on thousands of comparisons, from average situations to anomalies, and with past errors [4], and accurately represents each situation. Improvements can be made as vulnerabilities are found.

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