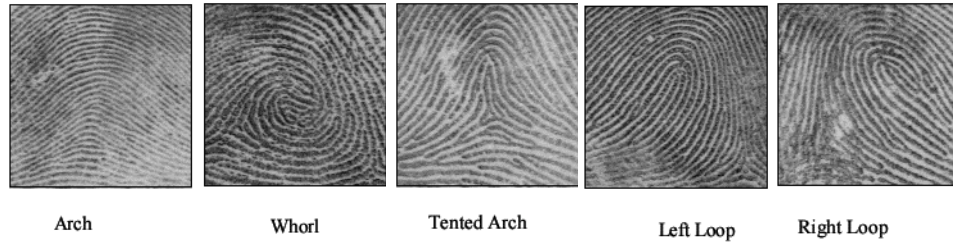
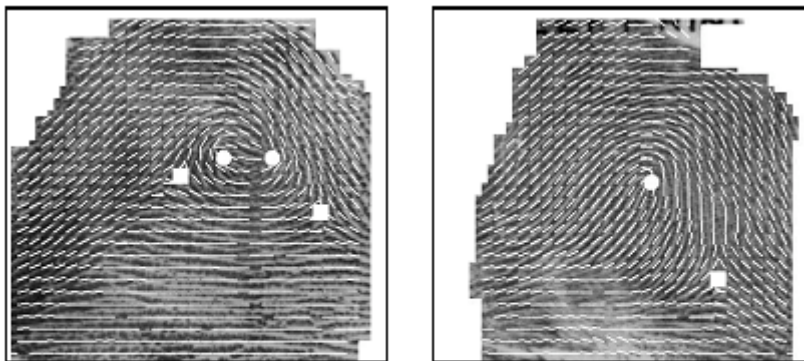


The need for secure biometric devices has been increasing over the past decade. One of the largest challenges that biometric system designers encounter is the lack of computational power for fast processing of biometric inputs. Since the speed of the computers cannot be increased arbitrarily, either the overall speed of the biometric system will suffer, or the systems must implement more efficient algorithms. Doing a complete image match for any given biometric is prohibitively expensive. Therefore, researchers have been working on secure methods to extract key features from biometrics. Performing a comparison of only key features deals with significantly less data and can be done so very quickly. Storing a discrete set of biometric features in a database is also much more secure because the original biometric input cannot be reproduced from the stored features (it is a one way function because data is “lost”). However, the problem then becomes how to quickly extract features from a given biometric input. This paper aims to explain and compare methods of feature extraction based on fingerprint singularities, finger skeletal lines, palm creases, and palm meshes. However, the most accurate results come from parallel processing of multiple biometric inputs using an array of feature extraction techniques.

Fingerprint biometric feature extraction consists of a number of steps. The goal of the feature extraction is to be able to classify the fingerprint into one of the so called “Henry” classes. There are five well known Henry classes: arch, whorl, tented arch, left loop and right loop.



The first step of fingerprint classification is to clean up the image by removing any background image or noise in the image. The second step is to use a method known as orientation field computation to assign arrows to the direction of the line segment of a fingerprint. After this has been performed, the fingerprint singular points must be extracted. There are two types of fingerprint singulars: cores and deltas. A fingerprint core is the top most point on the inner most ridge and it is normally located in the middle of the fingerprint. A fingerprint delta is the point where three “flows” or ridges meet.



**Fig. 4 Singular points found  
(circle as core and square as delta)**

To find and extract the singular points from the fingerprint image, the Poincare index is used. Given a pixel that is enclosed by a given digital curve, it sums up the difference in angle between the given pixel and its neighbor. The nearest neighbor clustering method (single linkage) is used to eliminate false singular points. Single linkage defines the distance between any two clusters as the

minimum distance between them. Once the singular points have been detected, a process known as pseudoridge tracing is applied. Starting at the core point, two lines are traced in opposite directions. When a segmented boundary or a predefined maximum is reached, stop. Next, form two curves from these lines that connect at the core point. After smoothing the curves, use the following classification rules to classify the fingerprint (where  $N_c$  = Number of Cores and  $N_d$  = Number of Deltas):

- If  $N_c = N_d = 0$ , then the print is an arch
- If  $N_c = 2$ , then the print is a whorl
- If  $N_c = 1$ , then trace pseudoridge and analyze
  - If more than 2 turns, then the print is a whorl
  - If start + end are to the left of the turn, then the print is a left loop
  - If start + end are to the right of the turn, then the print is a right loop
  - If start + end are on opposite sides of turn, then the print is a tented arch

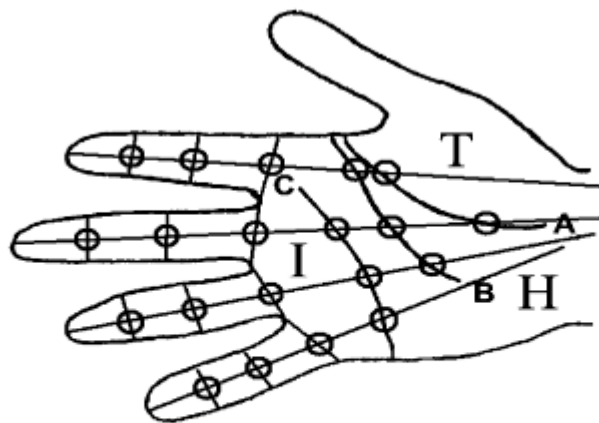
The following is a tabular representation of the classification rules. However due to 1 core and 1 delta mapping to three different pattern types, we must use the more detailed rules above.

<b>Pattern Class</b>	<b>Core</b>	<b>Delta</b>
Arch	0	0
Tented Arch	1	1 (middle)
Left Loop	1	1 (right)
Right Loop	1	1 (left)
Whorl	2	2

Using the aforementioned fingerprint classification technique, researchers at the University of Sydney were able to achieve a correct classification rate of 84% using all five classification types. However, when the tented arch and arch were merged into a single classification type, the success rate rose to 95.3%. The experiments were done using 4000 prints from the NIST database.

Researchers at the Department of Computer Science at the Chiba Institute of Technology in Narashino, Japan have proposed using feature extraction for palmar geometry and palmprint and fusing the results together. Using a single image, they can extract data for both the palmar geometry and the major palm creases. A low resolution video camera is used to capture a nontouching image input of the surface of the hand.

Feature extraction for palmar geometry consists of identifying the intersection points of finger skeletal lines and finger creases. The intersection points of the extended finger skeletal line and the major palmar creases are also feature points of interest.



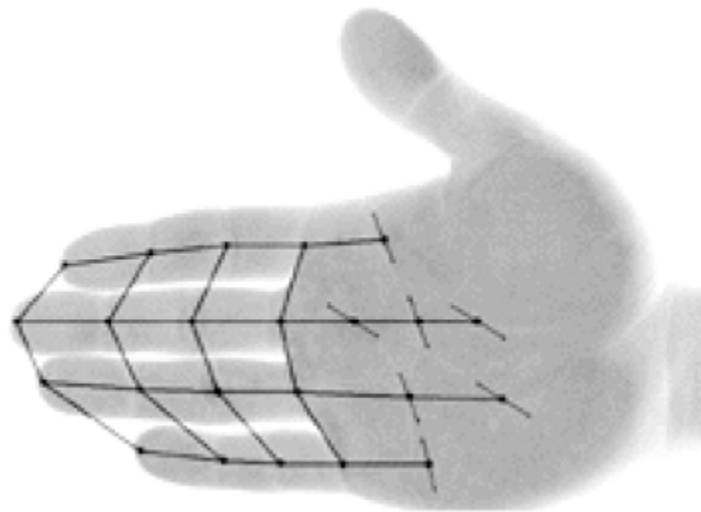
**Fig. 1.** Intersection points with circles. A: Thenar crease (line of life); B: Proximal transverse crease (line of head). C: Distal transverse crease (line of heart); I: Interdigital area; T: Thenar area. H: Hypothenar area.

Three major palmar flexion creases are identified: the thenar crease, the proximal transverse crease, and the distal transverse crease. However, some individuals have more than just three prominent creases. The system analyzes these creases as well and computes the intersections with the finger skeletal lines. The finger skeletal lines are identified by connecting the outer most finger crease (the proximal digital crease) with the inner most finger crease (the palmo-phalangeal crease). Finally, the tangential angles between the palmar creases and the finger skeletal lines are calculated and serve as yet another set of important features.



For repeatability reasons, the hand must be scanned with the fingers together. Most current systems implement a “touching” system in which the user must place his hand onto a plane and align his fingers against special pegs. This system does not need the hand to touch any pegs but the fingers must be touching and the hand must be stretched or straightened out. This technique is much more acceptable to users because they do not have to touch any surface that might be laden with bacteria.

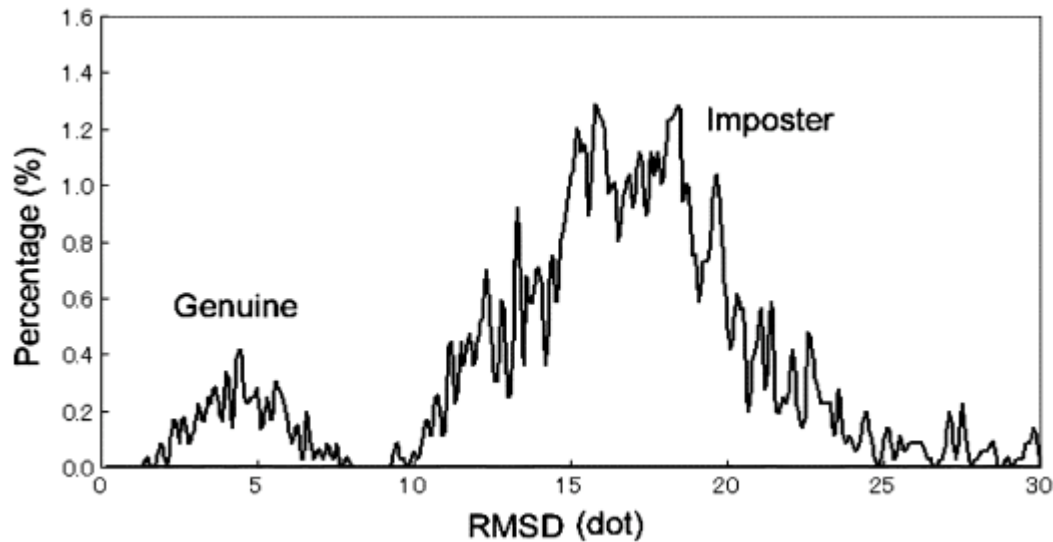
The second biometric feature extraction technique, which is done in parallel with the above method, is the mesh technique. A mesh is constructed by connecting intersection points on the adjacent skeletal lines. This method is combined with the finger skeletal lines and the palmar crease tangential lines. The final feature set consists of all three of these features. This final mesh of features shows very little variation between scans of the same person, regardless of their hand orientation. Any mis-orientation is corrected based off the finger skeletal line of the middle finger (which remains nearly fixed in all situations).



To determine whether two feature sets belong to the same person, the root mean squared deviation (rmsd) value of the two meshes is calculated. It is given by:  $\text{rmsd} = (\sum \delta_i^2 / N)^{1/2}$  where  $\delta_i$  is the positional difference at each mesh point and N is the total number of the mesh points to be compared (usually around 20-30).

The researchers have obtained excellent results through fusion of these two feature extraction methods. The results are perfect (100%) for 500 palm samples from 50 subjects. The processing time of the system is also extremely

low, with most matches being completed in about 0.9 seconds. Another important feature is that the RMSD shows a perfect separation between genuine and imposter attempts which demonstrates the robustness of the system.



The results are achieved by using a multistaged approach. Using the position and orientation of palmar feature points on the middle finger skeletal line is the first stage. The second stage consists of using the four-finger-based procedure (as explained above). If necessary, a third stage is applied in which additional matching parameters are used. These features include the shape of each finger section, the shape of the palm, and the tangential lines between the crease and finger skeletal lines. If after all three stages the margin is small, the system can prompt a user to show their other hand as verification. The team of researchers is also looking into adding facial recognition to the system as well. This would be independent and processed in parallel with the hand scanning. However, even without facial recognition, the system yields excellent results.

## Works Cited

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