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Detection of Ridge Damages in Fingerprint Recognition Caused by Skin Diseases

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Abstract

This article describes research on the topic of the influence of skin diseases on fingerprint recognition, particularly the actual detection of fingerprint areas negatively influenced by skin diseases. It introduces a number of skin diseases, describes their influence on fingerprint images according to a diseased fingerprint database, explains methods used for the detection and finally presents results of this research.

Keywords: *fingerprint recognition, skin disease, image processing, histogram*

1. Introduction

Nowadays, as people's need for a higher security is increasing, fingerprint recognition is still the most widely used type of a biometric system. We now encounter fingerprint recognition on a regular basis: biometric access systems, fingerprint access to our computers, biometric passports and other security features.

However, as fingerprint recognition systems count heavily on the structure and uniqueness of an individual's fingertip papillary line (ridge) patterns that positively determines physical identity of a person, people affected by various skin diseases, disorders or other negative influence might be discriminated. Their papillary line patterns have been impaired and they are therefore not capable of using the fingerprint recognition systems without more or less serious problems.

There is a significant number of patients suffering from skin diseases who have their fingertips affected as well. Thus, it is important not to underestimate this factor and it is necessary to develop algorithms for fingerprint image analysis, detection of skin disease influences and, if possible, their algorithmic removal, so that the aforesaid situations could be eliminated as much as possible and the lives of persons with skin diseases could be facilitated.

In this text, results of an analysis of a diseased fingerprint database are presented, followed by classification of particular diseases. Then, an approach towards detection of damaged areas in a fingerprint image is introduced and individual methods are explained and experimental results are presented.

2. Previous work

There is a very little research on the topic of the influence of skin diseases on fingerprint recognition. Some literature mentions skin diseases' negative influence on the quality of fingerprint images but there is no other research exclusively focused on skin diseases in fingerprint recognition.

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The only known diseased fingerprint database has been created by the Faculty of Information Technology at Brno University of Technology, where this research is being conducted, in corporation with dermatologists from the Czech Republic and Germany [1]. The fingerprints have been acquired from 44 patients with 12 different skin diseases in total. Numbers of fingerprints from female and male patients are balanced (50.04% from women and 49.96% from men) and the age distribution is between 19 and 84 years. [1]

More than 50% of acquired fingerprints were affected by some kind of *hand eczema* and the second most frequent disease was *psoriasis vulgaris*. The rest of the fingerprints came from patients suffering from *dishydrosis*, *hyperkeratotic eczema*, *verruca vulgaris*, *scleroderma*, *acrodermatitis continua*, *colagenosis*, and *Raynaud's phenomenon*. Some fingerprints were affected by effusion of fingers, cut wound or an "unknown" disease. [1] [2] [3] [4] For exact numbers, see the next chapter Diseased Fingerprint Database Analysis.

After the database has been considered large enough for experiments, the development of a set of methods for disease-affected fingerprint image enhancement has started, along with the analysis of the acquired database and classification of diseases present in the DB.

3. Diseased Fingerprint Database Analysis

The raw diseased fingerprint database was first analyzed in order to provide a solid foundation for future research. For every particular disease, common signs among all fingerprint images affected by this disease were found and an informal general description of each disease was created. Based on these descriptions and sets of common signs and their frequencies, we were then able to classify the diseases into 5 categories. These categories are later used in the actual detection of the damaged areas in a fingerprint image and help to divide the large detection task into smaller bearable parts.

3.1. Database Content

The database contains 2,165 fingerprints in total. Table 1 describes exact numbers and percentages.

Table 1. Database Content

Disease	No. of fingerprints in the DB	Percentages [%]	No. of patients
Fingertip eczema	1,107	51.132	17
Psoriasis vulgaris	326	15.058	9
Dyshidrotic eczema	247	11.409	4
Hyperkeratotic eczema	118	5.450	2
Verruca vulgaris	96	4.434	4
Scleroderma	50	2.310	1
Acrodermatitis continua	40	1.848	1
Colagenosis	36	1.663	1
Raynaud's phenomenon	9	0.416	1
Effusion of fingers	35	1.617	1
Cut wound	18	0.831	2
"Unknown" disease	83	3.834	1
Total	**2,165**		**44**

The fingerprints were acquired using various fingerprint scanners (Sagem MSO 300, UPEK EikonTouch 500, UPEK Eikon II, TBS 3D Enroll, Dinolite Pro), most of them, however, come from dactyloscopic cards. [1]

3.2. Influence of Particular Diseases on Fingerprint Images

First, by observing and comparing the actual fingerprint images, 12 common features were established. 7 of them are local features: straight lines (SL), a grid (G), small papillary lines disruptions (PLD), small "cheetah" spots (CS), larger round/oblong spots (ROS), large irregular spots (IS) and dark places (DP). The other 5 were global image patterns: blurriness of (parts of) the image (B), a significantly high contrast of the image (HC), the entire fingerprint area affected (EA), total deformation of the fingerprint image (TD) and a significantly high quality and healthy fingerprint (HQ).

For every disease its image features were counted (see Tables 2 and 3). Fingerprint images obtained from optical scanners were excluded as their character is significantly dissimilar to the others. The actual number of images taken into account is stated in the column "Σ".

Table 2. Local Features of Damaged Fingerprint Images

Disease	SL [%]	G [%]	PLD [%]	CS [%]	ROS [%]	IS [%]	DP [%]	Σ
Fingertip eczema	**72,03**	24,65	15,91	12,24	32,34	16,61	15,73	572
Psoriasis vulgaris	**40,37**	6,42	2,75	12,84	**48,17**	32,57	**62,84**	218
Dyshidrotic eczema	**63,11**	7,38	14,75	18,03	**78,69**	29,51	32,79	122
Hyperkeratotic eczema	3,92	0	**66,67**	15,69	**74,51**	3,92	5,88	51
Verruca vulgaris	3,17	0	14,29	12,70	**74,60**	0	25,40	63
Scleroderma	0	0	0	0	0	0	30,43	23
Acrodermatitis continua	14,29	0,00	0,00	**85,71**	**60,00**	14,29	**65,71**	35
Colagenosis	**100,00**	**78,13**	0	0	15,63	0	25,00	32
Raynaud's phenomenon	0	0,	**100,00**	0	0	0	0	8
Effusion of fingers	10,00	0	**73,33**	**43,33**	**63,33**	6,67	13,33	30
Cut wound	**93,75**	0	0	0	18,75	0	12,50	16
"Unknown" disease	**100,00**	**86,67**	0	0	**76,67**	30,00	**73,33**	30

Table 3. Global Features of Damaged Fingerprint Images

Disease	B [%]	HC [%]	EA [%]	TD [%]	HQ [%]	Σ
Fingertip eczema	18,01	21,50	**40,38**	36,36	29,02	572
Psoriasis vulgaris	34,86	27,06	**61,93**	**58,72**	18,35	218
Dyshidrotic eczema	30,33	30,33	31,97	29,51	9,84	122
Hyperkeratotic eczema	31,37	29,41	9,80	0,00	37,25	51
Verruca vulgaris	19,05	**80,95**	7,94	7,94	**76,19**	63
Scleroderma	0	0	0	0	**100,00**	23
Acrodermatitis continua	**48,57**	25,71	**100,00**	**100,00**	0	35
Colagenosis	9,38	40,63	0	0	25,00	32
Raynaud's phenomenon	0	0	0	0	**100,00**	8
Effusion of fingers	23,33	16,67	**40,00**	16,67	3,33	30
Cut wound	37,50	**68,75**	0	0	**50,00**	16
"Unknown" disease	30,00	20,00	**90,00**	**83,33**	0	30

Along with the analysis, following informal descriptions of each disease were created.

Fingertip eczema

Fingertip eczema is a very dry inflammatory non-infectious disease which occurs on the palmar surface or the fingertips. The skin becomes cracked and scaly and usually starts peeling off which results in exposition of red and tender skin surface. [2] [3] [4]

As the number of fingerprints with fingertip eczema in the database is large, a wide range of typical features was observed. There are two groups of these fingerprints: (i) less and (ii) more severely damaged. In the first group of fingerprints, occurrence of thin lines of different directions was typical. These lines often connect or cross each other. In some cases, small round white spots were present and in other, occasional dark areas make the papillary lines partially unreadable. However, overall, papillary lines of fingerprints of the first group are generally very well readable and it is possible to remove the influence of the disease from the fingerprint.

In the second group, the damage is more severe. Fingerprints are usually almost completely damaged, straight lines cover the entire fingerprint area and create grids by crossing each other. The background is darker and large irregular spots can be seen. As the papillary lines cannot be seen at all, this type of damage is by no means recoverable.

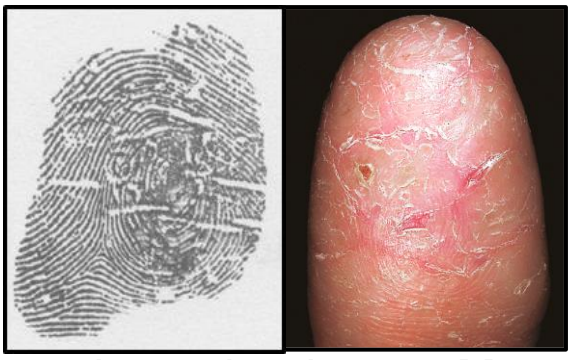

Figure 1. Fingertip Eczema [3]

Psoriasis vulgaris

Psoriasis is a common, chronic and inflammatory disease of the skin which is often indistinguishable from a serious form of *hand eczema*. It is characterized by dry and scaling plaques covered with dry scales that peel in layers [2] [3].

Fingerprints affected by psoriasis are completely damaged in the vast majority. Papillary lines are mostly unreadable. The most frequent feature is a large irregular dark spot bounded by a white border. Apart from this feature, the presence of larger dark areas or thick lines is also common, as well as round and oblong spots.

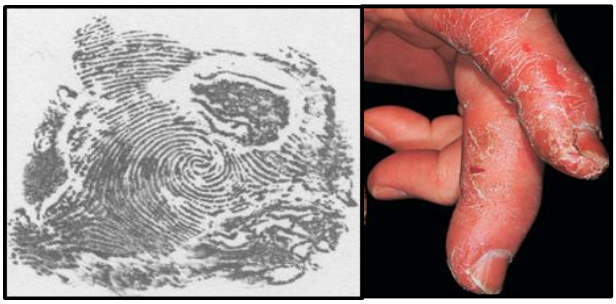

Figure 2. Psoriasis Vulgaris [3]

Dyshidrotic eczema

Also known as *pompholyx*, this disease is a variant of *hand and foot dermatitis* that make skin extremely dry. Its typical features are itching vesicles and scales located on the palms and sides of fingers. [3]

Fingerprint images damaged by dyshidrotic eczema are generally covered with irregular blurred shapes with no specific form. Another typical feature is a thick line. These fingerprints were divided into two groups, according to how severe the damage is. In the first group of less severely affected fingerprints, the entire area of a fingerprint is often covered, but papillary lines remain visible. Papillary lines are usually disrupted at multiple places and irregular blurred white spots may appear.

Fingerprints in the second group are seriously damaged and cannot be repaired. The image area is typically covered by thicker lines in combination with large blurred white spots. Papillary lines are not sufficiently visible.

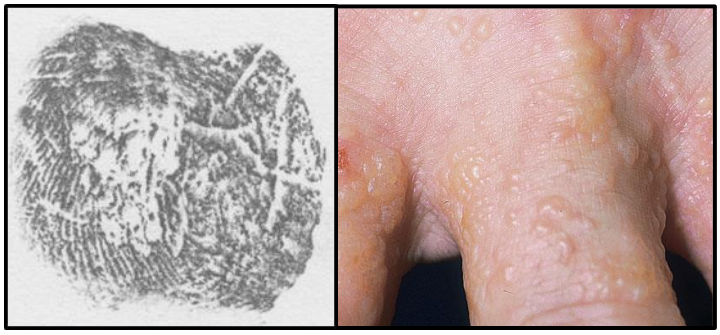

Figure 3. Dyshidrotic Eczema [4]

Hyperkeratotic eczema

A chronic form of *hand eczema* characterized by the occurrence of orange and brown scales with cracks between them. [2] [3]

Only one third to one half of the fingerprint area is usually affected. Sometimes, only the papillary lines are multiply disrupted. In other cases however, papillary lines are distorted and the direction of papillary lines is difficult to determine. Small to medium round spots are likely to be present.

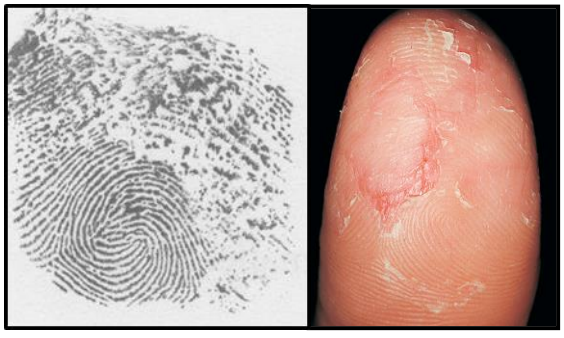

Figure 4. Hyperkeratotic Eczema [3]

Verruca vulgaris (warts)

This is a very common skin disease, characterized by the presence of stiff elevated bumps on the skin surface. They grow in size which is in average about 5 mm but can reach up to more than 1 cm. On their surface, tiny black dots may appear. [2] [3]

The influence of this disease on the fingerprint images is minor and easily removable. Typically, 1 to 4 round white spots occur, sometimes with black dots in their center.

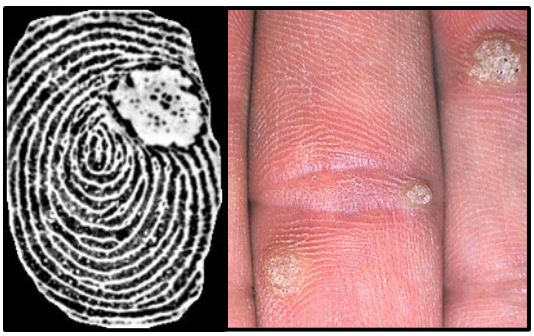

Figure 5. Verruca Vulgaris [3]

Systemic scleroderma

Scleroderma is characterized by the appearance of hard, smooth and ivory-colored areas. In the early stage, affected areas are red and swollen, later they become completely immobile and lose their natural peaked contour. [2] [3]

The fingerprints in the database did not show any signs of damage. It can be therefore concluded that the number of acquired fingerprints was not sufficient to describe the disease's influence on fingerprint images.

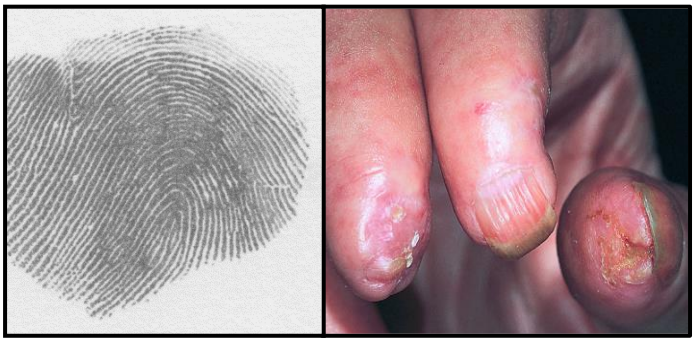

Figure 6. Systemic Scleroderma [3]

Acrodermatitis continua

Also known as *acrodermatitis continua of Hallopeau* or *dermatitis repens*, this disease is a chronic inflammatory disease of the hands and feet and one of the less frequent types of *psoriasis vulgaris*. The outbreak of the disease is accompanied by assymetric formation of pustules of the fingertips and continues with eruption of fresh pustules with hyperkeratotis and crusting. As the disease progresses, nails can even float away. [2]

Fingerprint images are typical for the occurence of small round spots that look alike a cheetah skin and cover usually the whole fingerprint area. Larger oblong or round spots occur as well and straight lines or cracks are also not an exception. Papillary lines cannot be recognized at all, the original strucutre of the fingerprint is completely covered. Larger dark areas are often present and the spots can be blurred together. Almost in all cases, the fingerprint image is completely damaged and cannot be repaired.

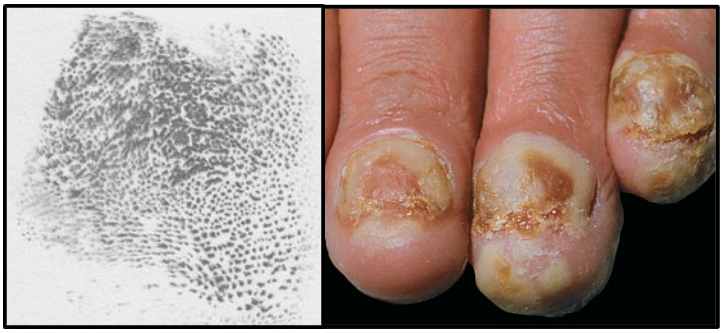

Figure 7. Acrodermatitis Continua [4]

Colagenosis

Colagenosis is a connective tissue disease, an inflammatory autoimmune disease. [5]

The only typical feature of fingerprints with this disease is thin lines crossing each other. Under these lines, papillary lines are well visible.

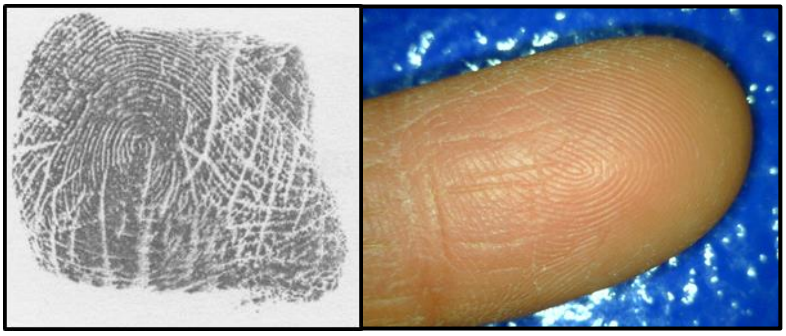

Figure 8. Colagenosis. Source: Database

Raynaud's phenomenon

A vascular skin disease that often accompanies an associated disease (most often scleroderma). The fingers have sequential discolorations: they first become pale and cold, then white, blue and finally red. This is caused by constrictions of the small arteries and arterioles in fingers. [2][3]

As Raynaud's phenomenon causes discoloration only, fingerprints in the database are always healthy and undamaged.

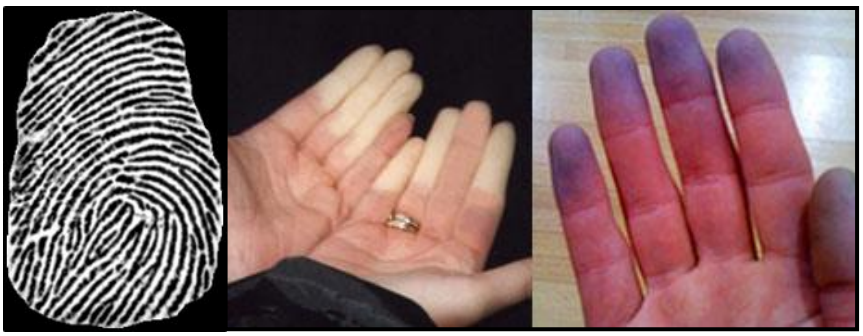

Figure 9. Raynaud's Phenomenon [14]

Effusion of fingers

Although being stated as a disease in the database, effusion of fingers is only a syndrome which manifests itself by a strong swelling. It is one of the symptoms of *systemic scleroderma*, for instance.

Papillary lines are typically disrupted at many places and small to medium spots are present. In general, papillary lines are clearly visible, sometimes, however, white spots make them unreadable.

Cut wound

Cut wound typically causes either a straight line in a fingerprint image or a more blurred white area. The damage is minor and should not be difficult to remove.

"Unknown" disease

Fingerprints of this unnamed disease are totally covered with lines of different thickness and length and are therefore unreadable. They are very much alike those with fingertip eczema.

Figure 10. Effusion of Fingers (Left), Cut Wound (Middle) and Unknown Disease (Right)

3.3. Classification of Damaged Areas

Based on the above-mentioned features and characteristics, 5 feature classes were established and every disease was classified into one or more of them. Such classification is supposed to help to assess each type of damage individually and make the detection process easier by assigning different detection methods to each type.

Straight lines and grids

Fingertip eczema, cut wound, colagenosis, dyshidrotic eczema, "unknown" disease. (See Figure 11.)

Small papillary lines disruptions

In this case, papillary lines are disrupted at multiple places but no significant damage is present. Representatives are: *dyshidrotic eczema*, *hyperkeratotic eczema*, *effusion of fingers* and *fingertip eczema*. (See Figure 12a.)

Small "cheetah" spots

The only representative of this group is *acrodermatitis*. (See Figure 12b.)

Round/Oblong spots

Although round or oblong spots occur in most diseases, typical representatives with a significant amount of them are: *verruca vulgaris*, *effusion of fingers*, and *psoriasis*. (See

Figure 14.)

Large irregular spots

Psoriasis and severe form of fingertip eczema often cause extreme damage to the fingerprint and one of their features are also large spots of irregular shape. (See Figure 15.)

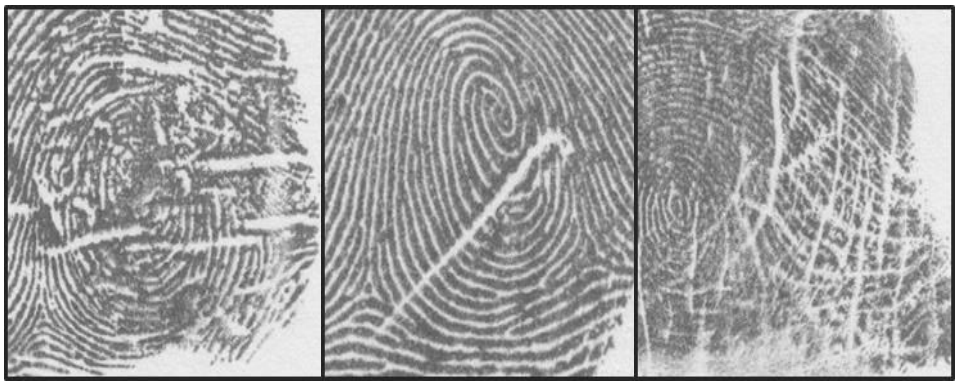

Figure 11. Examples of Fingerprints with Straight Lines or Grids

Figure 12. Examples of Fingerprints with a) Small Papillary Lines Disruptions and b) "cheetah" Spots

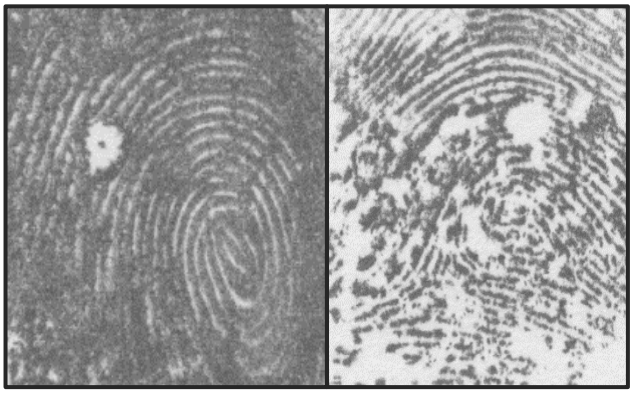

Figure 13. Examples of Fingerprints with White Spots

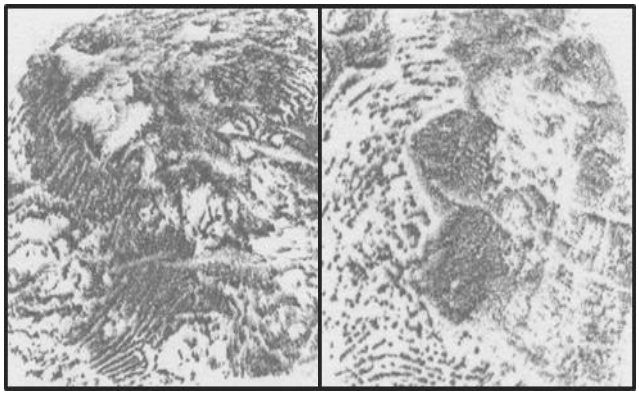

Figure 14. Examples of Fingerprints with Large Irregular Spots

Also, diseases were classified into 3 categories according to the seriousness of the damage.

1. *Minor damage:* verruca vulgaris, Raynaud's phenomenon, cut wound, scleroderma.
2. *Medium damage:* mild form of fingertip eczema, mild form of dyshidrotic eczema, hyperkeratotic eczema, effusion of fingers, colagenosis.
3. *Major damage (unrecoverable):* acrodermatitis, severe form of fingertip eczema, severe form of dyshidrotic eczema, psoriasis, "unknown" disease.

4. Damaged Area Detection

The actual detection of anomalies and damaged areas in fingerprint images is a combination of a top-down global approach and a bottom-up pixel-by-pixel approach. The global approach is based on an analysis of certain characteristics of an $n \times n$ region of interest (ROI) and consists of two distinct methods: Block Orientation Field Analysis and Histogram Analysis. The bottom-up approach uses the Flood Fill algorithm to locate some of the local features in the fingerprint image and determine their type.

The output of each of the three aforesaid methods is a list of detected anomalies, their size and coordinates of the first pixel belonging to the damaged area. Not all of the features found during the database analysis can be detected yet and all methods can be undoubtedly further enhanced. However, the actual detection produces satisfactory results.

4.1 Block Orientation Field

In the standard fingerprint recognition pipeline, an orientation field is computed in order to estimate the directions of ridges in the image before we can proceed to next steps of papillary lines extraction [6]. The orientation field is a field of gradients in the image, computed for every pixel (i,j). In order for the information about the estimated orientation to be more precise and useful, a *block orientation field*, obtained via transformation of the per-pixel orientation field for every $w \times w$ image block, is used.

For the computation of the block orientation field, we used the gradient-based method [7][8]. The steps or the algorithm are as follows: [8]

1. Compute the gradients $\partial_x(i,j)$ and $\partial_y(i,j)$ at each pixel (i,j) using a gradient operator. We used the simple Sobel operator.
2. Divide the original image into $w \times w$ blocks.
3. Compute the estimation $\theta(i,j)$ of the ridge orientation for every image block centered at (i,j) according to the following equations.

$$v_x = \sum_{u=i-\frac{w}{2}}^{u=i+\frac{w}{2}} \sum_{v=j-\frac{w}{2}}^{v=j+\frac{w}{2}} 2\delta_x(u,v)\delta_y(u,v) \tag{1}$$

$$v_y = \sum_{u=i-\frac{w}{2}}^{u=i+\frac{w}{2}} \sum_{v=j-\frac{w}{2}}^{v=j+\frac{w}{2}} (\delta_x^2(u,v) - \delta_y^2(u,v)) \tag{2}$$

$$\theta(i,j) = \frac{1}{2} tan^{-1}(\frac{v_y(i,j)}{v_x(i,j)}) \tag{3}$$

A block orientation field for a healthy fingerprint image estimated using the foregoing algoritm is usually fairly smooth and continual. The only discontinuities are its singular points (core and delta). However, if a block orientation field is computed for a fingerprint affected by a skin disease or for other low-quality fingerprint, the result is characterized by frequent discontinuities in damaged areas.

Therefore, in our method, the resulting block orientation field was analyzed for any discontinuities that would suggest possible damage in the fingerprint. The estimations $\theta(i,j)$ for each image block were saved into a 2-dimensional array of floats and this array was afterwards scanned both row-wise and column-wise in order to find discontinuities in

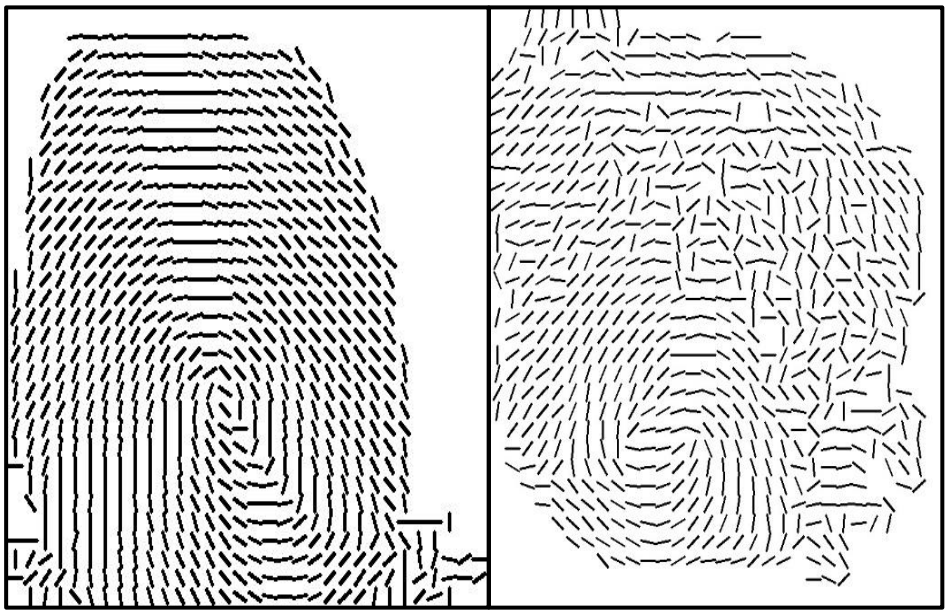

Figure 15. An Orientation Field Form a Healthy Fingerprint (Left) and from a Fingerprint with Hyperkeratotic Eczema (Right)

both *x*- and *y*-directions. A block was marked as a discontinuity if

$|\theta(i,j) - \theta(i,j+1)| > 45°$,

where both estimations $\theta(i,j)$ and $\theta(i,j+1)$ have a value between 0° and 180°.

As the main goal of this method is to find global anomalies of the fingerprint image, not discontinuities in the block orientation field only, two enhancement steps were made:

- Deletion of singular discontinuities. Blocks were unmarked provided that they

did not have any other discontinuities in their 8-neighborhood.

- Completion of unmarked blocks that have more than 5 neighbors marked as a discontinuity in order to fill holes.

In addition, detection of whole chains of damaged blocks was implemented because sometimes gradient differences may not be larger than 45°, yet they can still be a part of a damaged area due to an alternate change from negative to positive difference and vice versa between gradients in a row/column.

With this approach, we were able to extract seriously damaged or low-quality areas of the fingerprint and determine their size and location. As an example, see Figure 17. Particular blocks are highlighted according to how they were detected: red stands for row-detection, blue for column-detection, purple blocks were detected both row- and column-wise and cyan blocks were completed in the end to “fill the holes”.

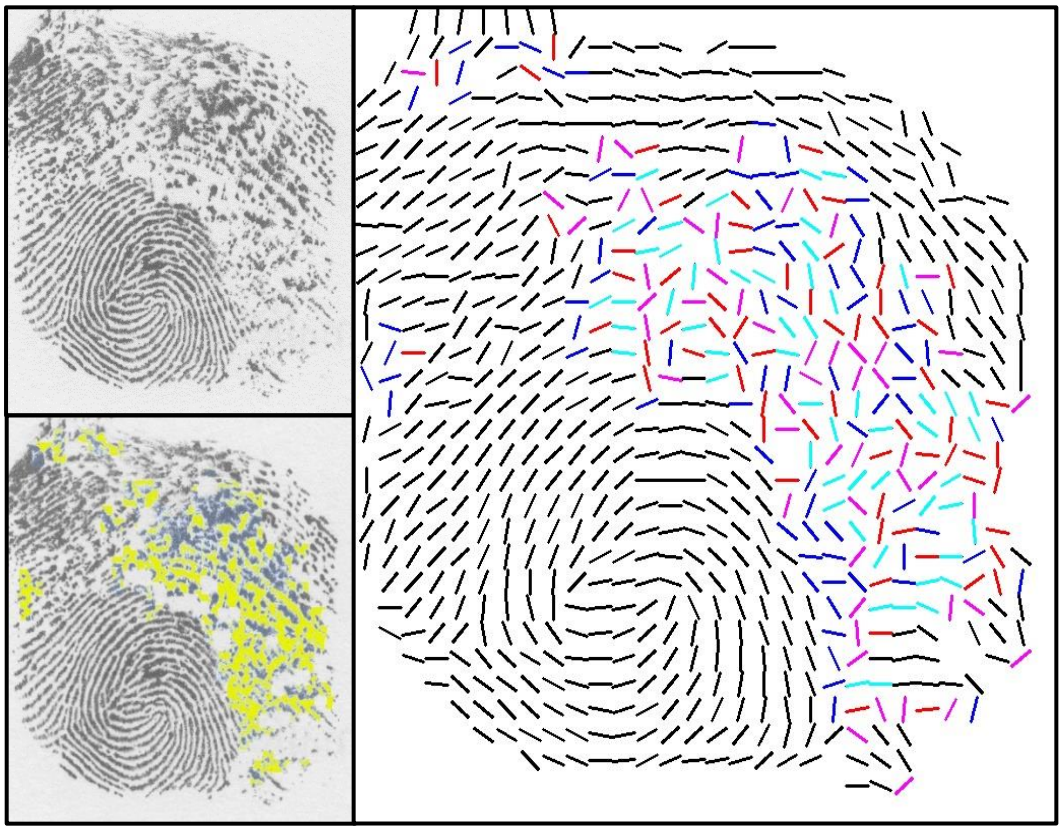

Figure 16. A Fingerprint Affected by Hyperkeratotic Eczema (Top Left), Orientation Field with Highlighted Blocks (Right) and a Final Highlighted Image (Bottom Left)

4.2. Histogram Analysis

Histogram of an image illustrates the distribution of values of brightness in the image and is often used for equalization and other image enhancemet techniques.

We have found that a histogram computed for any fingerprint image is similar; it contains a high number of light pixels and a high number of dark pixels, greyscale values are present less frequently. The histogram image has therefore a bimodal shape: two similarly high peaks and one valley in between them. Both from the characterictics of a fingerprint image and by practical experimenting we observed that a histogram computed for any region of interest from the fingerprint area (the region must not be partially in the fingerprint area and partially in the background) has to have similar characteristics,

provided that it belongs to a healthy fingerprint. The reason for it is that an ideally healthy fingerprint is characterized by smooth dark ridges and clear light valleys, both having a similar width. They represent the two high histogram values and the border, as a gradual transition between these colors, represents the grayscale values between the two peaks in the histogram. See Figure 18.

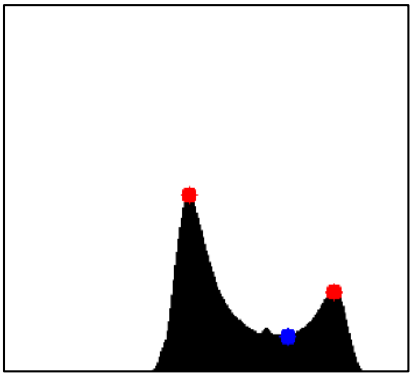

Figure 17. An Ideal Bimodal Histogram

However, the lower the quality, the less the histogram resembles the ideal bimodal histogram. Although a damaged ROI does not necessarily imply a non-bimodal histogram, as a histogram generally only provides an information about intensity distribution of an image, a non-bimodal histogram always implies a damaged or a low-quality area. We therefore implemented an algorithm that divides an image into several square $w \times w$ ROIs and for each of them it computes a histogram. The histogram is than analysed: the algorithm searches for two peaks and a valley and tests their positions and values in the histogram.

Several histograms computed for healthy ROIs have been analyzed in order to determine the estimation of the minimum and maximum peak and valley heights, positions and relations between them. The following tests and limits were established. „p“ stands for the ROI size in pixels „dark peak“ means the highest value in the half of histogram that has lower values (darker colors) and „light peak“ stands for the other peak.

1. Peak Height Test: The value of the dark peak must be between 0.003*p and 0.025*p, the value of the light peak between 0.004*p and 0.042*p. The difference in the limits is here because wider fingerprint valleys usually do not decrease quality whereas wider ridges may cause the fingerprint pattern to be less readable.
2. Valley Height Test: The valley has to have a maximum of 0.0065*p, otherwise too many grayscale colors are present.
3. Peaks Height Difference Test: There cannot be a situation where the lower peak is less than 0.025*p and the higher peak is more than 0.004*p. This test helps to eliminate extreme situations of either a very dark ROI or a very light ROI.
4. Valley Distance From the Lower Peak Test: The horizontal distance (difference between colors) between a valley and the lower peak must be more than 0.002*p (not too close);
5. Height Difference of the Valley from the Lower Peak Test: The difference between values of the valey and the lower peak must be more than 0.0017*p.

A histogram must meet all the five conditions to be considered valid. Therefore if any of these tests is evaluated as negative, the histogram is marked as invalid and the area from which it was computed is considered damaged or low-quality. The implemented

algorithm is also able to distinguish background from other areas. Its output is a labeled array of the same size as the input image. 0 stands for „background“, 1 for „ok“ and 2 for „damaged“. In Figure 20, blue illustrates „background“, green „ok“ and red „damaged“. Note again that a valid histogram does not imply an undagamed area. The conditions and constants above are a subject of testing and enhancing and may vary with different databases of fingerprints.

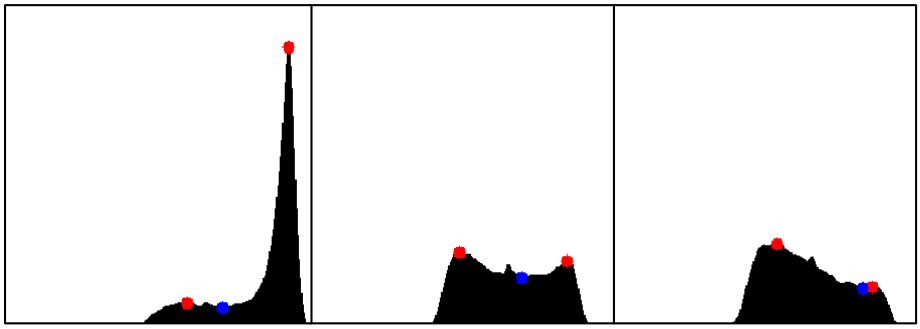

Figure 18. Examples of Invalid Histograms

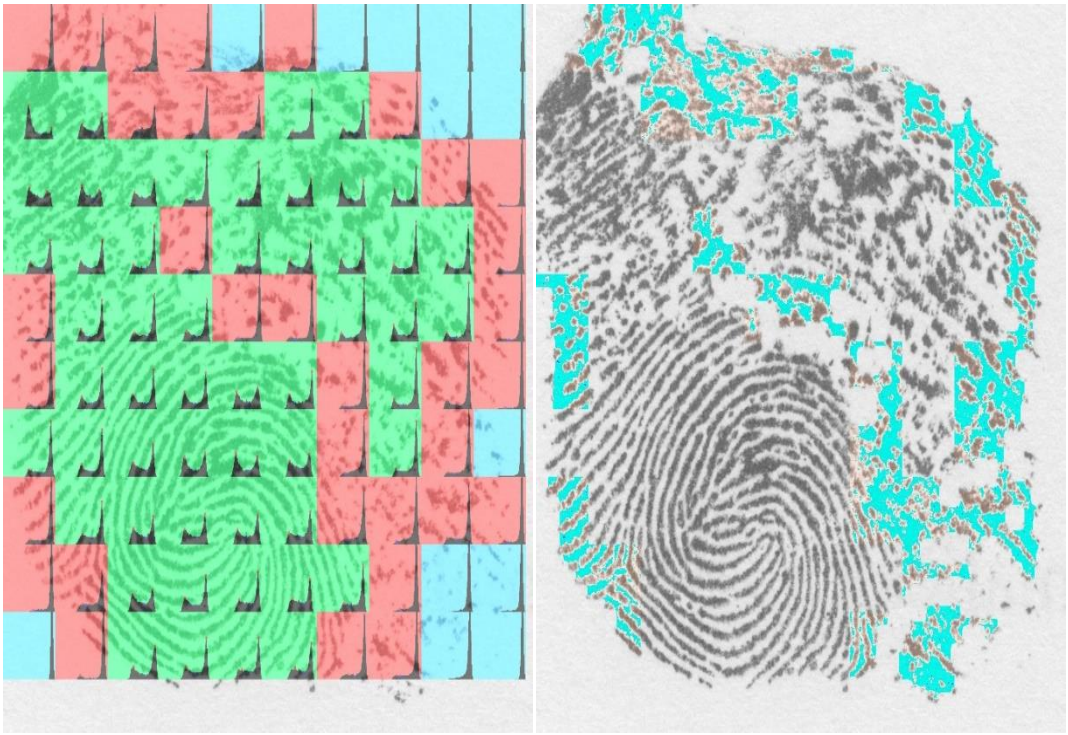

Figure 19. Resulting Histograms (Left) and a Highlighted Fingerprint (Right)

4.3. Flood Fill Detection

Flood Fill [15] is an algorithm used for filling connected areas of an image that have the same coloring with a replacement color. It has 3 parameters: a *target color*, a *replacement color* and a *start pixel*. It is based on examining the color of all pixels in the 4- or 8-neighborhood of the start pixel and changing the color of pixels with the target color to the replacement color. With the use of either recursion, or stack/queue, the colored pixels become next start pixels so in the end, the entire area with the same color is determined.

The most basic recursive algorithm **FloodFill**(*target_color*, *replacement_color*, *start_pixel*) has the following steps:

1. If the *target_color* is the same as the *replacement_color*, return.
2. If the *start_pixel* has a different color than the *target_color*, return.
3. Call FloodFill on the pixel above the *start_pixel*.
4. Call FloodFill on the pixel below the *start_pixel*.
5. Call FloodFill on the pixel on the right of the *start_pixel*.
6. Call FloodFill on the pixel on the left of the *start_pixel*.
7. Return.

In our method, we chose the Scanline Flood Fill [15] with a stack. This algorithm differs from its basic form by its reduced space and time complexity which is achieved by filling whole lines instead of single pixels.

The reason why we chose the Flood Fill algorithm for our detector is its ability to locate single-colored areas in the fingerprint image and determine their sizes, which is an extremely useful method when used on a thresholded binary image. Therefore, a fingerprint image was first preprocessed. The preprocessing steps always contain contrast and brightness adjustment, then thresholding, series of erosions, dilations, opening and closing operators and Gaussian blurring, according to whether we detect white or black structures, and a closing thresholding. In addition, the preprocessing step is combined with fingerprint area detection according to [13], which is used to find borders of the fingerprint area. We have found this useful especially when detecting white areas; without the added border lines a number of white areas are not detected, mainly those close to the fingerprint area border.

After preprocessing, detector parameters such as target color and minimum and maximum target size of areas are set, Flood Fill algorithm is called and from all the detected areas, either round or oblong areas are selected. The selection process is based on the ratio between the longer and the shorter side of the area‘s bounding rectangle: if it is below 1.8, it is considered round, and if it is over 2.3, it is considered oblong.

Four types of detection have been implemented so far: (For explanation of the groups see chapter 3.3.)

(i) detection of small „cheetah“ spots;

(ii) detection of small papillary lines disruptions;

(iii) detection of larger round white spots; and

(iv) detection of thick lines.

Table 4 shows exact characteristics of each type of detection, including the minimum and maximum number of pixels of a filled area. The results are somehow limited but satisfactory. See Figures 20-23.

Table 4. Characteristics of each Flood Fill Detection

Detection	Target color	Min. size	Max. size	Shape
(i)	black	100	400	round
(ii)	black	200	600	oblong
(iii)	white	500	20,000	round
(iv)	white	500	12,000	oblong

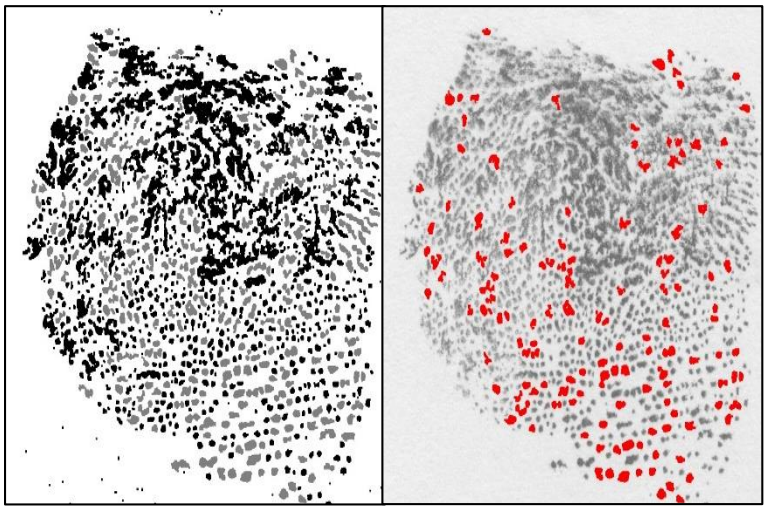

Figure 20. Detection of *Papillary Lines Disruptions (hyperkerat. eczema)*

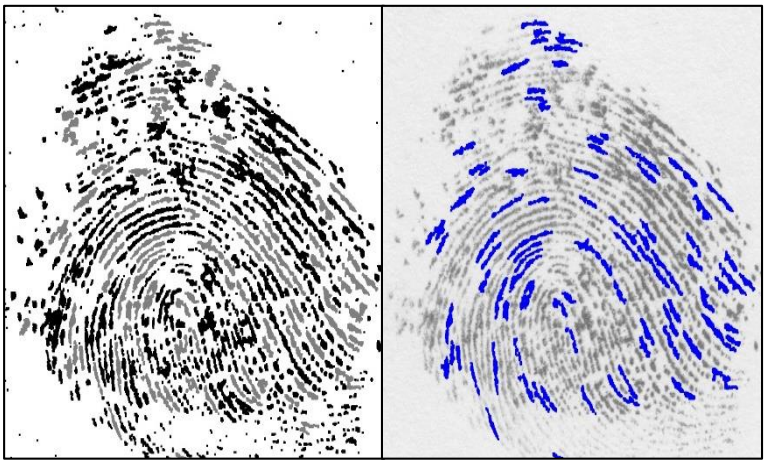

Figure 21. Detection of "cheetah" Spots (Acrodermatitis)

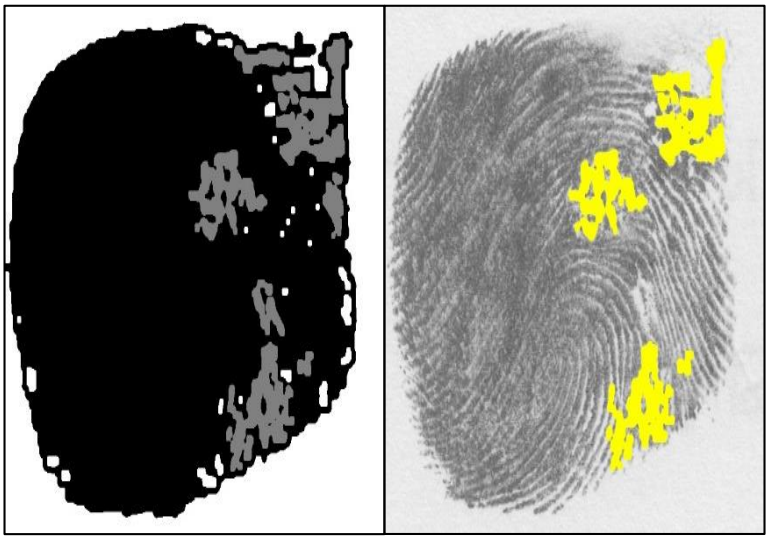

Figure 22. Detection of Lines (Fingertip Eczema)

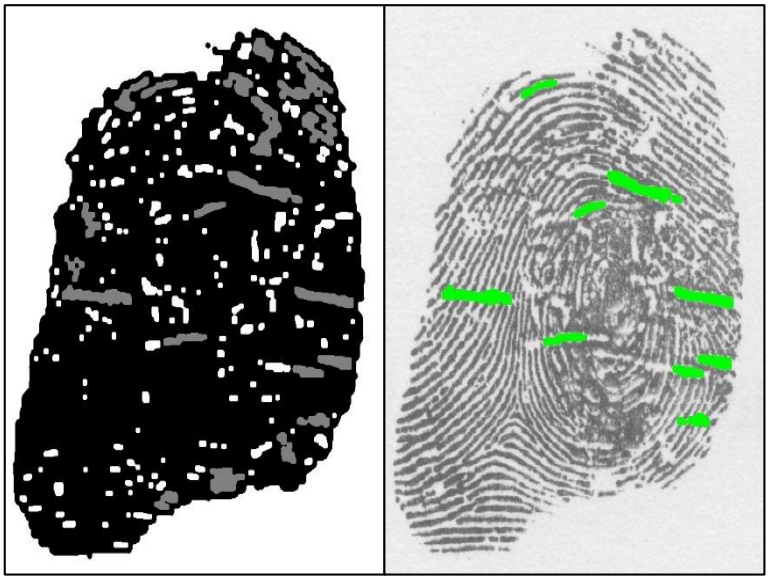

Figure 23. Detection of *White Spots* (*Verruca Vulgaris)*

5. Fingerprint Image Quality Measurement

Using the combination of the two top-down methods, Block Orientation Analysis and Histogram Analysis, it was possible to determine the extent of damage and decide whether the fingerprint image can be further used or not.

This is how the methods are combined. First, the methods are called separately and the result of each of them is saved into an $n \times n$ array of integers (the same size as the input image). Each pixel is labeled „0“ (background), „1“ (all right) or „2“ (damaged). After that the same is done for background segmentation [13] and in this case, pixels are labeled only „0“ or „1“. Finally, all three arrays are combined: if a pixel is labeled „0“ in the backround array, it is considered a background; if a pixel is labeled „2“ in either of the first two arrays, it is considered damaged; the rest of the pixels are considered that they belong to a healthy area.

Then, percentage of damaged areas can be easily computed. If damaged pixels cover more than 60% of the overall fingerprint area (excluding background), the fingerprint is labeled as too damaged.

6. Experiments

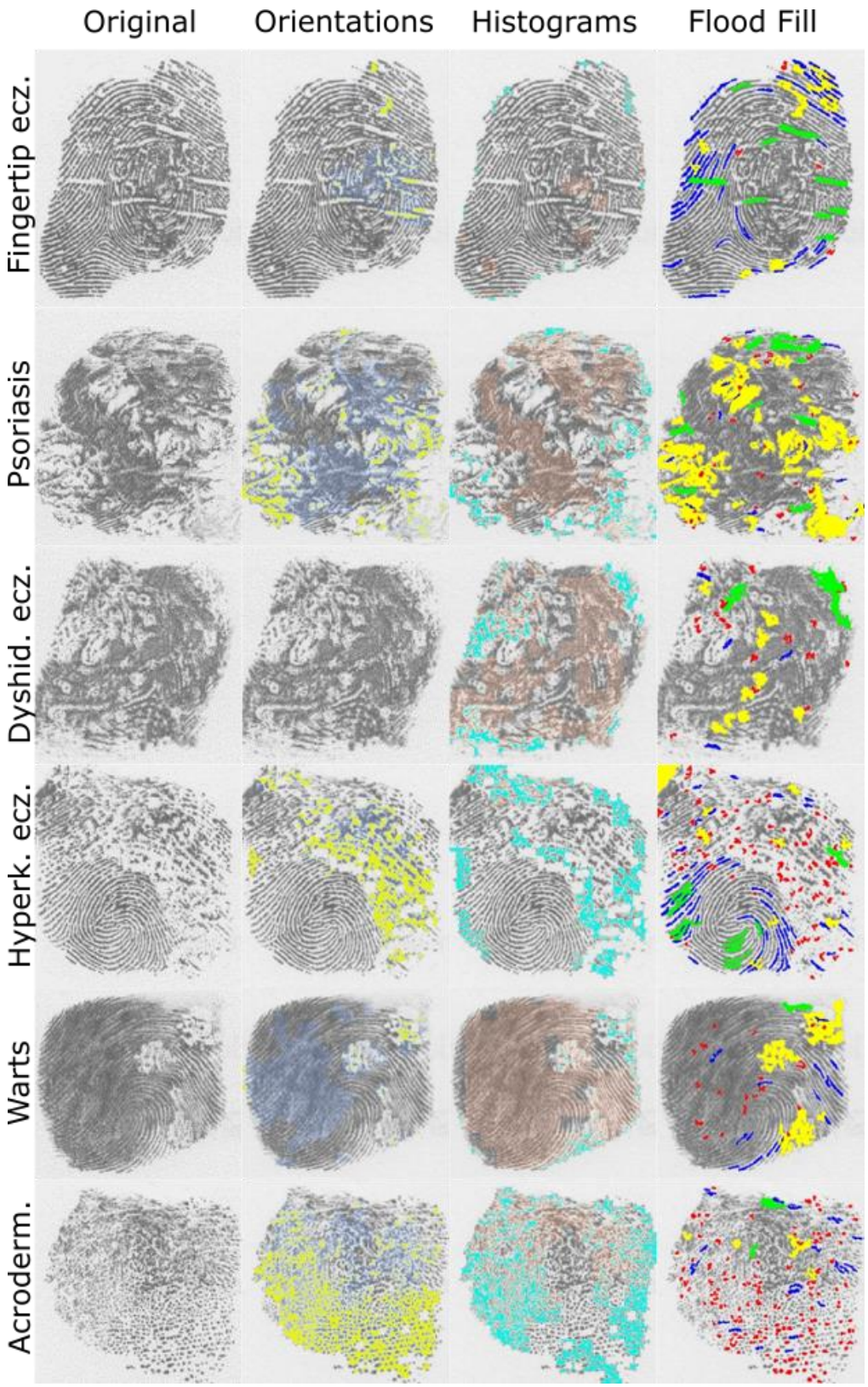

Figure 24. Examples of Outputs (1)

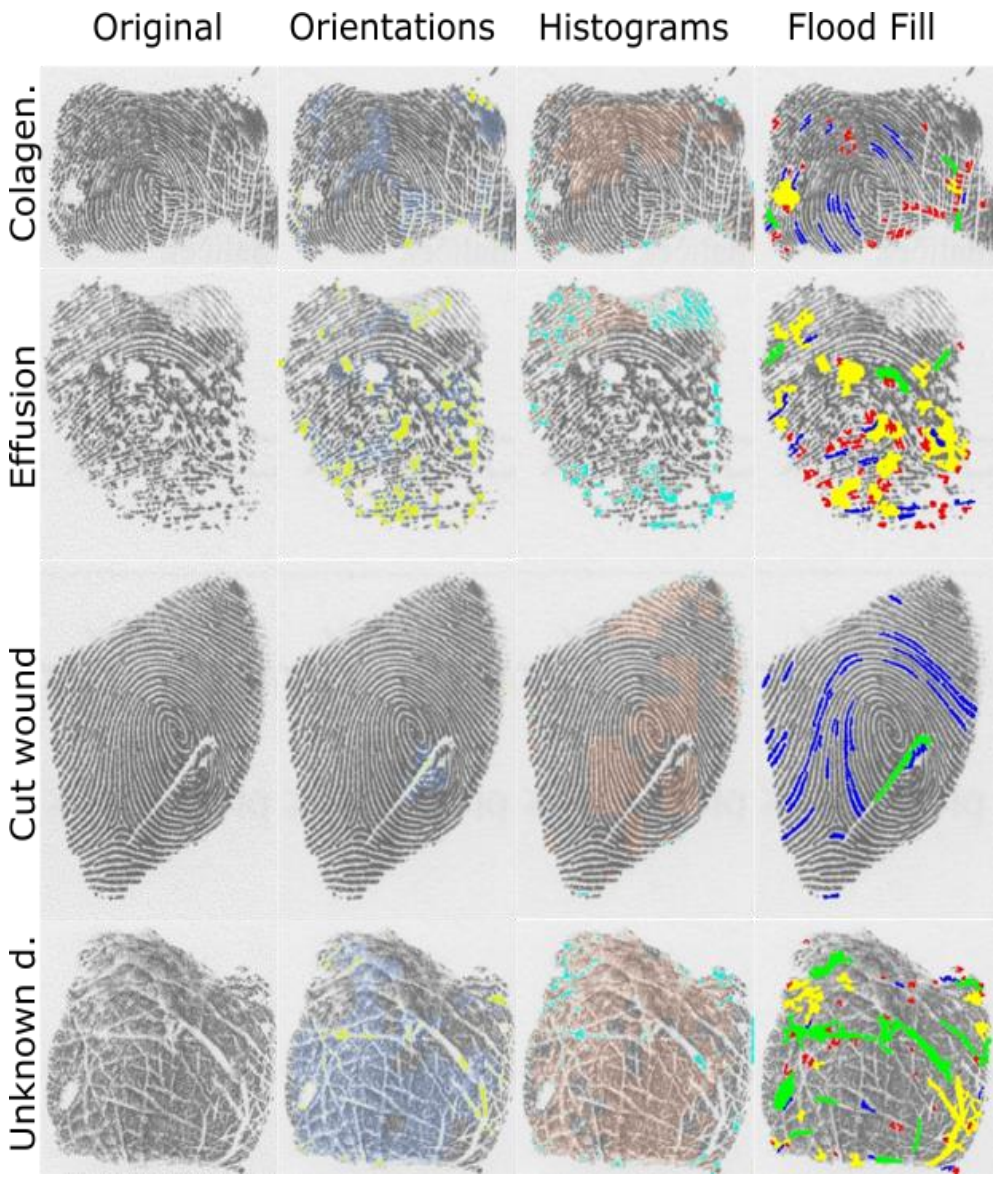

Figure 25. Examples of Outputs (2)

7. Conclusion

After our diseased fingerprint database was analyzed, three methods of detection of areas influenced by skin diseases in the fingerprint were implemented. Detection from block orientation field and detection based on histogram analysis measure global characteristics of a fingerprint image and the last one uses the Flood Fill algorithm for the detection of abnormalities in fingerprint images, such as spots or lines. By combining the first two methods, we also created a fingerprint quality measurement which determines the extent of damage. All methods are ready to be enhanced and further developed.

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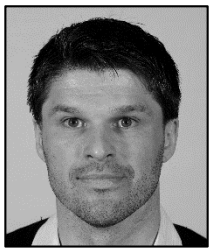

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