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DETECTION AND LOCALIZATION OF SKIN DISEASES IN FINGERPRINTS

DETEKCE A LOKALIZACE KOŽNÍCH ONEMOCNĚNÍ U OTISKU PRSTU

BACHELOR'S THESIS
BAKALÁŘSKÁ PRÁCE

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Assignment:

1. Study biometric literature in particular fingerprints and learn about influence of skin diseases in fingerprint recognition.
2. Design of an algorithm for detection and localization of skin diseases in fingerprints.
3. Implement the proposed algorithms from the previous steps.
4. Test the experiments and algorithms on a database (the database is available on STRaDe server) of fingerprints influenced by skin diseases.
5. Discuss about the results, and check whether results lived up to expectations.

Recommended literature:

- Maltoni, D., Maio, D., Jain, A.K. and Prabhakar, S.: *Handbook of Fingerprint Recognition*. Springer, 2009, pages 512. ISBN 978-1-8488-2254-2.

Detailed formal requirements can be found at http://www.fit.vutbr.cz/info/szz/

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Abstract

This bachelor thesis discusses detection and localization of skin diseases in damaged fingerprint images and describes the solution implemented using image processing techniques.

Abstrakt

Tato bakalářská práce se zabyva problemetikou detekci a lokalizaci kožních onemocnění v poškozených snímcích otisků prstů a popisuje řešení realizované pomocí technik zpracování obrazu.

Keywords

Image processing, biometrics, skin diseases, fingerprint recognition, OpenCV, blob detection algorithm

Klíčová slova

Zpracovaní obrazu, biometrie, kožní onemocnění, rozpoznávání otisků prstů, OpenCV, blob detekční algoritmus

Reference

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Rozšířený abstrakt

Hlavním cílem této bakalářské práce bylo naprogramovat aplikaci, která detekuje až 3 různá onemocnění otisku prstu. Výsledný program se skládá ze 3 částí. První část se zabývá analýzou obrazu otisku, 2. část se věnuje detekci konkretního onemocnění a poslední část implementuje grafické uživatelské rozhraní. Aplikace také vizuálně zvýrazní poškozené části otisku na obrázku a určí procento poškození.

Aplikace nejdříve provede analýzu vstupního obrázku otisku prstu. Z původního obrazu se vytvoří 3 mezivýsledky, které jsou potom použity v detekci onemocnění a také se vytvoří mapa poškozených bloků. Analýza se provede ve 3 krocích: předzpracování, nalezení poškozených částí otisku a analýza papilárních linií. V průběhu předzpracování, původní obraz se transformuje do podoby, která umožňuje nejednoduší detekci onemocnění. Analýza papilárních linií převede obraz na mapu bloků a následně nalezené všechny poškozené bloky.

Po analýze se provede detekce onemocnění, která je implementovaná pomocí 3 algoritmů: detekce bílých bodů, detekce linií a detekce tzv. gepardových skvrn. Každý algoritmus je založen na blob algoritmu. Výsledkem této části je informace o přítomnost konkretního onemocnění na otisku.

Aplikace se ovládá grafickým uživatelským rozhraním. Rozhraní nabízí 2 módy operace. První je detailní mód, který provede analýzu a detekci nad 1 obrázkem otisku. Aplikace ukáže všechny korky vedoucí k výsledku analýzy. Uživatel může uložit výsledky. 2. mód provádí analýzu nad celým adresářem obsahující obrázky otisků prstů. Výsledkem 2. módu je statistika o každém detekovaném onemocnění.

Aplikace je implementovaná v jazyce C++. GUI je implementován pomocí knihovny Qt a funkce pracující z obrázky pomocí knihovny OpenCV.

Testování bylo provedeno na sadě otisků které byly poskytnuty ze strany výzkumné skupiny STRaDe. Výsledky považuji za velmi úspěšné. Onemocnění akrodermatitida bylo detekováno s přesnosti 95,3 %, atopický ekzém s přesnosti 61.3 % a bradavice s přesnosti 77.2 %.

Detection and Localization of Skin Diseases in Fingerprints

Declaration

Hereby I declare that this bachelor's thesis was prepared as an original author's work under the supervision of Mrs. Mona Heidari. All the relevant information sources, which were used during preparation of this thesis, are properly cited and included in the list of references.

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Nemanja Vasiljević
May 16, 2019

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Contents

1 Introduction **3**

2 Biometrics **4**
2.1 Introduction to Biometrics 4
2.2 Verification systems 4
2.3 Identification systems 4

3 Live-Scan Fingerprint Sensing **6**
3.1 Capacitive fingerprint scanners 6
3.2 Thermal fingerprint scanners 6
3.3 Electric field fingerprint scanners 6
3.4 Piezoelectric fingerprint scanners 7
3.5 Piezoelectric fingerprint scanners 7
3.6 Ultrasound fingerprint scanners 7

4 Skin structure **8**
4.1 The Epidermis 9
4.2 The Dermis 9
4.3 The Subcutaneous 9

5 Skin diseases **10**
5.1 Atopic eczema 10
5.2 Dyshidrotic eczema (Pompholyx) 10
5.3 Hyperkeratotic eczema 10
5.4 Verruca vulgaris (warts) 10

6 Application design **13**
6.1 Application goals 13
6.2 Application design overview 13
6.2.1 Image Analyzer Design 14
6.2.2 Disease Detection Process 14
6.2.3 Data flow 14
6.2.4 Graphic User Interface and Application Usage 15

7 Implementation **17**
7.1 Image analyzer 17
7.2 Damaged Area Finder 19
7.2.1 Fingertip Eczema 20

7.2.2 Verruca vulgaris . . . 21
7.2.3 Acrodermatitis . . . 22
7.3 Papillary Lines Analyzer . . . 23
7.4 Disease Detector . . . 24
7.4.1 Blob detection algorithm . . . 24
7.4.2 Filtering Blobs by Color, Size and Shape . . . 25
7.4.3 Sub-detector for Acrodermatitis . . . 26
7.4.4 Sub-detector for Atopic eczema . . . 27
7.4.5 Sub-detector for Wart . . . 27

8 Experiments and Results **28**
8.0.1 Disease Detector Results . . . 28
8.0.2 Possible Extensions and Enhancements . . . 28

9 Conclusion **30**

Bibliography **31**

A Experimental results **32**

Chapter 1

Introduction

With advance of technology our society became more electronically connected and more mobile, therefore security became one of the most important things today. It was needed for improving methods for determining person's identity. Establishing person's identity using methods such as PIN, passwords and cards are not enough reliable. PIN and password can be forgotten, shared or in some cases can be guessed, cards can be lost, etc. Therefore biometric identifiers became more popular. The main reason why biometric identifiers became so much popular it's because they are consider more reliable for person identification. It's very hard to forge or misplace biometric identifiers, and some of them are unique for every person. Fingerprints are the most popular biometric identifier today, they are unique and remains unchanged.

There isn't two people that have exactly the same fingerprints. Even identical twins, with identical DNA, will have different fingerprints. Fingerprints remain almost unchanged through whole lifespan and therefore are one of the most reliable methods for person recognition. These unique properties allow fingerprints to be used in all sorts of ways, including for biometric security, background checks, mass disaster identification, and in criminal situations.Although that using fingerprints as primary way for person identification is very efficient, it has their own disadvantages.

People who suffered from some kind of skin disease, that affected fingertip skin, may have also their fingerprint pattern affected and damaged. Skins diseases only affecting the color of skin almost don't have impact on quality of resulting fingerprint image. But if skin disease affects and changes structure of papillary line, its often impossible to determine original structure of papillary lines and it's impossible to decide if claimed identity is the user's identity. In this case user is restricted by not being able to use fingerprint recognition system, even if his fingers don't have any symptoms of skin disease anymore [6]. Persons that were affected by these types of diseases are in disadvantages and can't use fingerprint recognition system. The goal of this thesis is to contribute improving algorithms for detecting skin diseases that attack structure of papillary line and their localization. Chapter

2 gives introduction to basic biometrics while chapter 3 describes concept of live-scan and different sensing technology. Chapter 4 describes skin structure and chapter 5 introduces different skin diseases that are subject of this thesis.

Chapter 2

Biometrics

2.1 Introduction to Biometrics

In the early days of civilization, people lived in small communities where they could easily recognize each other. However, an explosion in population and increasing mobility in modern society required the development of identity management systems that are capable of efficient record, maintain and obliterate person identities. Biometric recognition, or simply biometrics, offers more reliable way for person precognition. Since biometric identifiers are more connected to an individual, therefore it is harder to manipulate, share or forget them. Biometric traits represent a strong relationship between a person and his identity. The most commonly used biometric identifiers are: face, fingerprint, had geometry, had/finger vein, iris, signature and voice. Biometric systems measure one or more biometric identifiers of an individual to determinate or verify his identity. Process of collecting biometrics identifiers, their extraction, template creation and storing in database, is called enrollment process. Depending on the application context, biometric systems can be called either a verification system or identification system[5].

2.2 Verification systems

Verification systems are used for authenticating person's identity by comparing the captured biometric identifiers with her previously enrolled biometric template in the system. Verification systems are based on 1:1 comparison and their goal is to confirm whether claim identity is true. Verification systems are more accurate than identification systems, even when sized of database increases [12][5].

2.3 Identification systems

Identification systems seek to identify an unknown person, or unknown biometric. Captured biometric identifiers are compared with every enrolled template in database until they match. Identification systems are described as a one-to-many matching system, where n represents the total number of biometrics in database [12][5].

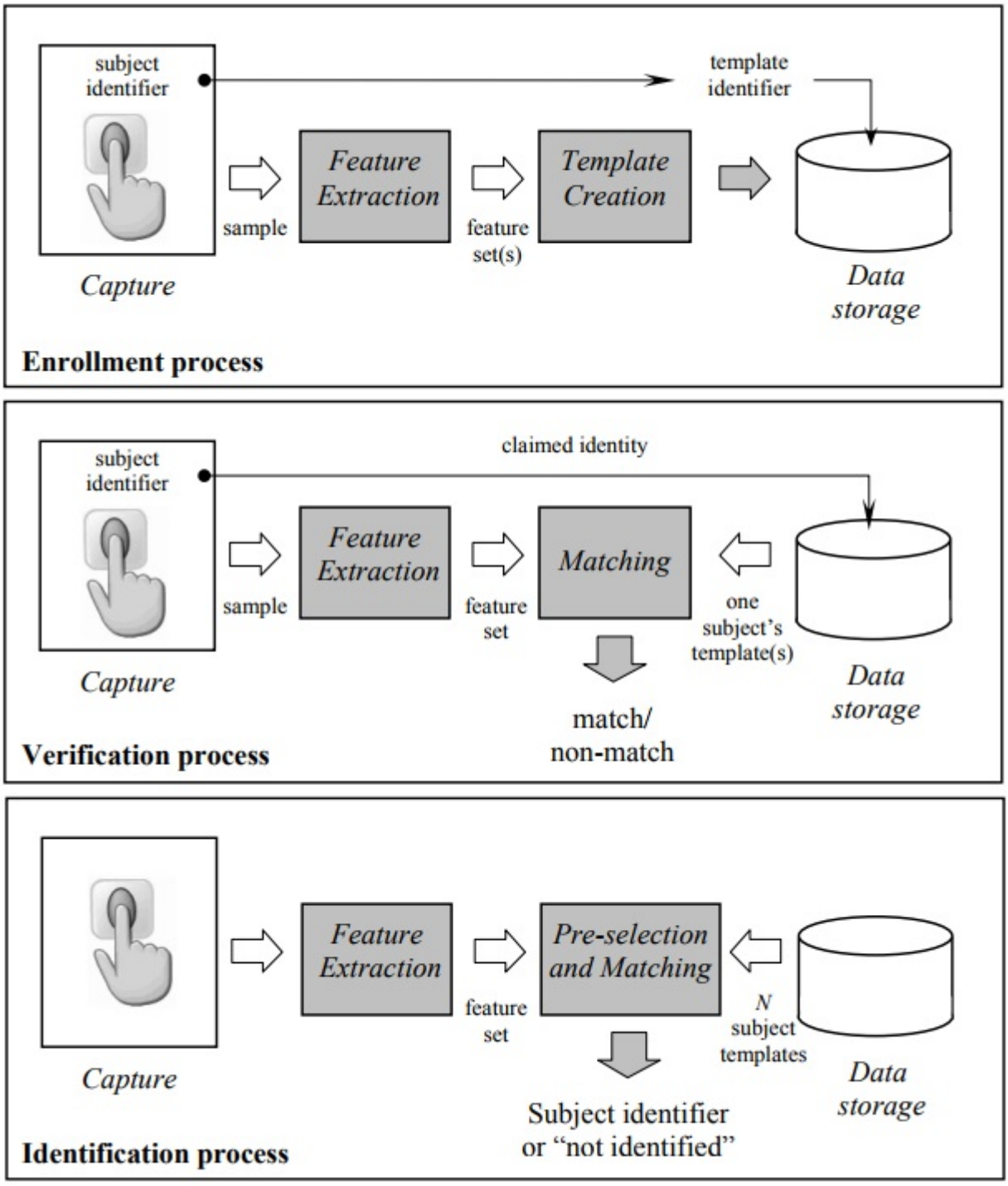

Figure 2.1: Biometric systems. Source: [5]

Chapter 3

Live-Scan Fingerprint Sensing

Live-scan fingerprinting is technique and technology used by law enforcement or private facilities to capture fingerprints electronically, without using some traditional methods like ink and paper. The most important part of a live-scan fingerprint scanner is the sensor (or sensing element), which is the component where the fingerprint image is formed. These scanners can be divided into several groups upon their sensing technology.

3.1 Capacitive fingerprint scanners

Fingerprint scanners based on a capacitive sensing technology are also very common type of fingerprint scanners. The sensor itself is a two-dimensional array of conductive plates. Small electrical charges are created between the surface of the finger and each of the silicon plates when a finger is placed on the chip. By measuring that electrical charges, it is possible to reconstruct the profile of papillary lines ridges and valleys and thus to reconstruct the fingerprint image. This type of sensors cannot be easily deceived by presentation of photography or printed image of fingerprint because they measure distance and therefore three-dimensional surface is needed [5].

3.2 Thermal fingerprint scanners

Thermal sensors are built from pyro-electric material that produces current based on temperature difference. After putting finger on sensor, fingerprint ridges produce a different temperature then the valleys. Therefore it is possible to acquire fingerprint's image [5].

3.3 Electric field fingerprint scanners

Main advantage of electric field sensors is that they are able to acquire a high quality fingerprint image under the surface of skin. This advantage can be used in cases where skin has suffered from some disease. Scanners are based on emitting a radio frequency sinusoidal signal and on matrix of antennas that receives a small signal that is modulated by surface of skin. That signals represent the electric field in subsurface of finger skin and by measuring it is able to acquire fingerprint image [5].

3.4 Piezoelectric fingerprint scanners

This type of scanners is based on pressure-sensitive sensors. After mechanical stress is applied to sensor, they produce an electrical signal. Since ridges and valleys are present at different distances from the sensor surface, sensor will produce different current for ridges and valleys. Unfortunately, these sensors are not able to detect all difference between ridges and valleys and resulting image can be blurred [5].

3.5 Piezoelectric fingerprint scanners

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3.6 Ultrasound fingerprint scanners

The ultrasound sensors are based on sending acoustic signal toward finger surface and capturing their echo. Sensor has two main components: first is transmitter, used for sending acoustic signals, and receiver, used for receiving echo signals. Ultrasound sensors acquire fingerprint image from subsurface of finger skin and therefore resulting image are not effected by dirt or oil accumulations on finger. This type of scanners, are very expensive and acquiring image takes couple minutes, therefore they are not globaly represented [5] [11].

Chapter 4

Skin structure

The skin is largest organ in human body, comprising about 15% of the body weight. In terms of chemical composition the skin is 2% lipids, 25% protein and 70% water. Each square centimeter of skin has 6 million cells, 5,000 sensory points, 100 sweat glands and 15 sebaceous glands. The skin is divided in three layers: epidermis (the outer layer), dermis and subcutaneous (fat) layer [11][8].

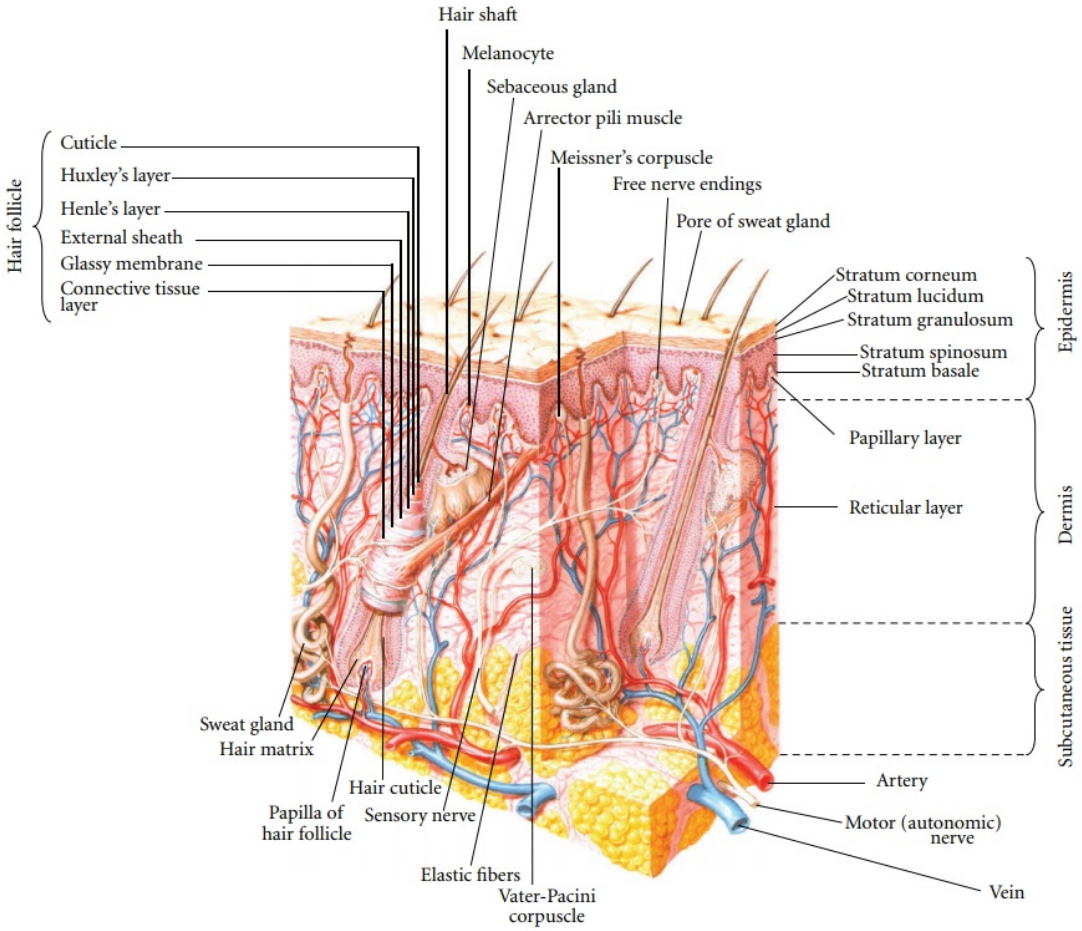

Figure 4.1: Skin structure. Source: [13]

4.1 The Epidermis

The epidermis is the top most layer of the skin. This layer has no blood supply, but it is nourished by the blood vessel in the dermis. Two important groups of cells are located in this layer. First group is Keatinocytes. Their lifespan begins in lowermost portion of epidermis, as they mature, they move upwards and eventually at the end of their life cycle, they reach uppermost layer of the epidermis. This cells makes the skin waterproof and tough. Another significant group of cells in the epidermis are melanocytes. Melanocytes produce melanin, the pigment responsible for skin tone and color. Melanin protects skin from strong sunlight and is able to dissipate over 99% of absorbed UV radiation. Melanin also determinate skin color, more melanin means that person will have darker skin [9].

4.2 The Dermis

The dermis is the middle layer of skin and it is the thickest skin layer. The dermis contains tiny blood vessels (capillaries) that carry oxygen and nutrients. This layer is involved in regulation of the body temperature [9].

4.3 The Subcutaneous

Subcutaneous tissue is the innermost layer of the skin located under the dermis consisting of connective tissue and fat molecules. This layer protects the bones, muscles and organs under the skin from psysical damage. Additionally, the subcutaneous acts as heat insulator protecting underlying tissues from cold and overheating [9].

Chapter 5

Skin diseases

5.1 Atopic eczema

Atopic eczema causes the skin to become red, swollen, itchy and cracked. The skin became thickened and cracked, which results in exposition of red to brownish-gray patches. In base case atopic eczema results only with small patches of dry skin but in others atopic eczema may results in widespread red, inflamed skin all over the body. Atopic eczema can affect any part of the body, but in most cases affects the hands [4].

5.2 Dyshidrotic eczema (Pompholyx)

Pompholyx is characterized by sudden eruptions of usually highly pruritic, symmetric vesicles on the palms, lateral fingers or plantar feet. Hads-alone involvement occurs in 80%. The acute process involves initial vesiculation, with is usually marked on the palms and lateral aspects of the fingers. The process ends with peeling sometimes leaving a cracked red base. It is one of the most common skin disorders. It is not related to blockage of sweat ducts, although palmoplantar hyperhidrosis is common in these patients. Itching precedes the appearance of tiny water-filled vesicles on the palms and sides of the fingers which are relatively deep seated. The skin may be red and wet. The vesicles slowly resolve and are replaced by erythematous scaly patches. Chronic eczematous changes with erythema, scaling, and lichenification may follow [7].

5.3 Hyperkeratotic eczema

Hyperkeratotic eczema is a condition which happens on the hands and/or feet palm. It is a well-known yet a complicated entity that is usually chronic and difficult to be cured by therapy. The visible signs are represented by dry, thick, gray plaques implicating the palmar and/or plantar surfaces [3].

5.4 Verruca vulgaris (warts)

Warts (verruca vulgaris) [10] are extremely common benign epidermal neoplasms that are caused by human papilloma viruses (HPVs). Warts commonly appear at sites of trauma, on the hand, in periungual regions. HPVs induce hyperplasia and hyperkeratosis. Large widespread warts occur in immunodeficient patients as well in patients with atopic eczema.

The aggressive surgical therapy may result in scarring. The lesions can affect all fingers of both hands [7] .

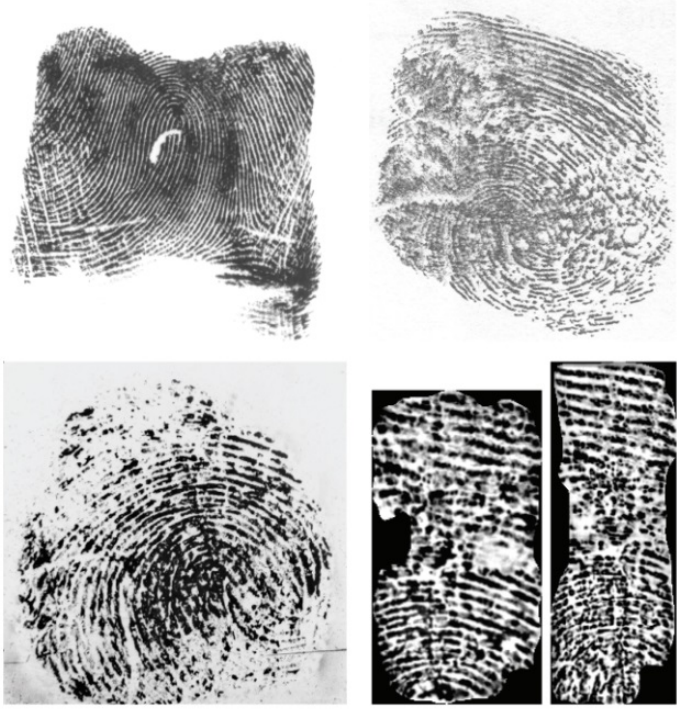

Figure 5.1: Atopic eczema(same person). Source:[7]

Figure 5.2: Verruca vulgaris (same person). Source: [7]

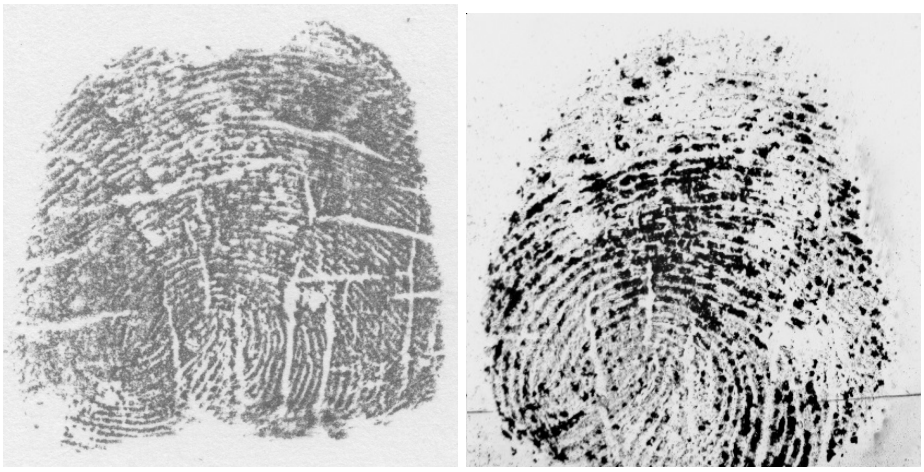

Figure 5.3: Dyshidrotic eczema (same person). Source: database

Figure 5.4: Hyperkeratotic eczema (same person). Source: database

Chapter 6

Application design

The main task of this thesis was to develop an application which is capable of detecting 3 different skin diseases causing the damage of fingerprints. Final application consists of 3 major parts, one is responsible for analyzing fingerprint images, the second one is responsible of detecting the disease and the final part provides graphical user interface.
This chapter describes the design and functionality of the application.

6.1 Application goals

The main object of the resulting application is the implementation of diseases detection algorithm, which will provide results on the sample of fingerprint scans with very high accuracy. The primary function of resulting application is ability to classify images based on extracted features after analyzing them. Output of the application is a report of the disease which most likely caused the damage on the fingerprint for every analyzed image.

Apart from main goal, application contains several sub-goals that logically connected with main goal which are: -Ability to determinate healthy and damaged parts of the fingerprint -Ability to determinate if a fingerprint is damaged at all, that is to determinate percentage of damaged area and probability of fingerprint reconstruction.

These goals are achieved by creating a GUI application that whose three main building blocks are going to be discussed in the following section

6.2 Application design overview

Image analysis and disease detection both play significant role in the final product of this thesis.
The task of this image analysis is to process the input image of a fingerprint and create intermediary picture for every of the 3 diseases that could be detected by this application. These intermediary pictures are later used to detect possible diseases. Besides this task, image analysis process also creates a map of possible damaged blocks, which is used for filtering detected defects and for computing percent of damaged area in fingerprint.
The disease detection process of the highly depends on the number and types of extracted image features provided by image analysis. The main task of this component is to detect

defected areas in fingerprint that have similar characteristics as some of the 3 diseases. After detection process the damaged areas are highlighted on the original fingerprint image.

6.2.1 Image Analyzer Design

Since this component has several tasks, the design is divided in three important parts: preprocessing, damaged area finder and papillary lines analyzer.
The preprocessing is responsible for changing input image to the point which allows the best possible detection. This means that fingerprint image undergoes several different changes that have a goal to remove noise and to transfer colors from shades of gray to only black and white color.
The papillary lines analyzer transforms input image into a map of blocks and for every block determines if it is damaged. This map has two main usages. It is used at the end of disease detection process for filtering results. This means that every detected area needs to have at least one damaged block to be considered as disease. The Papillary lines analyzer is also used to determinate percent of damaged area in fingerprint image and to determinate if fingerprint can be reconstructed.
Damage area finder is process which takes preprocessed fingerprint picture and extracts white areas in fingerprint that represent defects with very high probability. Output of this component is used by disease detection process.

6.2.2 Disease Detection Process

Since there is wide range of possible types of damages that could occur in fingerprint image, this process is done by several sub-detectors, for different types of damage: - White spots detector - Lines detector - Cheetah-spots detector
Each of them is based on blob detection algorithm with different parameters for every type of damage. The Detector output is information if some of the diseases is detected and the area of fingerprint where disease was detected.

6.2.3 Data flow

From design view, it is important to determinate the inputs and outputs of particular classes and describe the data flow of the application.

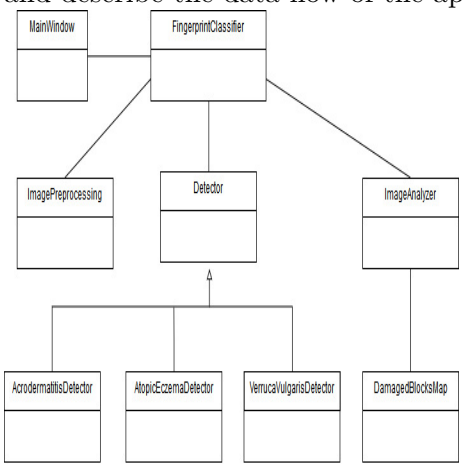

Figure 6.1: Simplified application class design.

A fingerprint image is the input given by the user through GUI. FingerprintClassifier object takes image and passes it to main pipeline and in the end retrieves output data such as names of detected disease, estimated percentage of the damaged area and images that will be used to visualize the damaged parts of fingerprint.
ImageAnalyzer object analyzes input image. The result of this process is the orientation field map and the map of possible damaged areas in fingerprint image. The detectors requires a normalized fingerprint image as an input and uses damaged area map to filter out possibly incorrectly detected areas. The output is the information about detected diseases, such as name of disease and area where disease was detected.

6.2.4 Graphic User Interface and Application Usage

The application was designed with graphical user interface that allows the user to load fingerprint image or to select a directory containing fingerprint images.
Application offers two different modes of operation:
Detailed mode – this mode is focused on visualization of the detection in application. The result of this mode is several new tabs containing important information that explains in high detail the process of image detection. First tab displays orientation field map and second tab shows image of damaged blocks that is computed by using orientation field. Main goal of damaged blocks image is to visualize amount and location of damaged area. Rest of tabs contain images that visualize the process of filling white spaces and areas that indicate detected disease. Application offers to the users to saves the resulting images by simply selecting output directory in main tab. This mode is started by pressing button "Run on file" and requires input file to be selected.

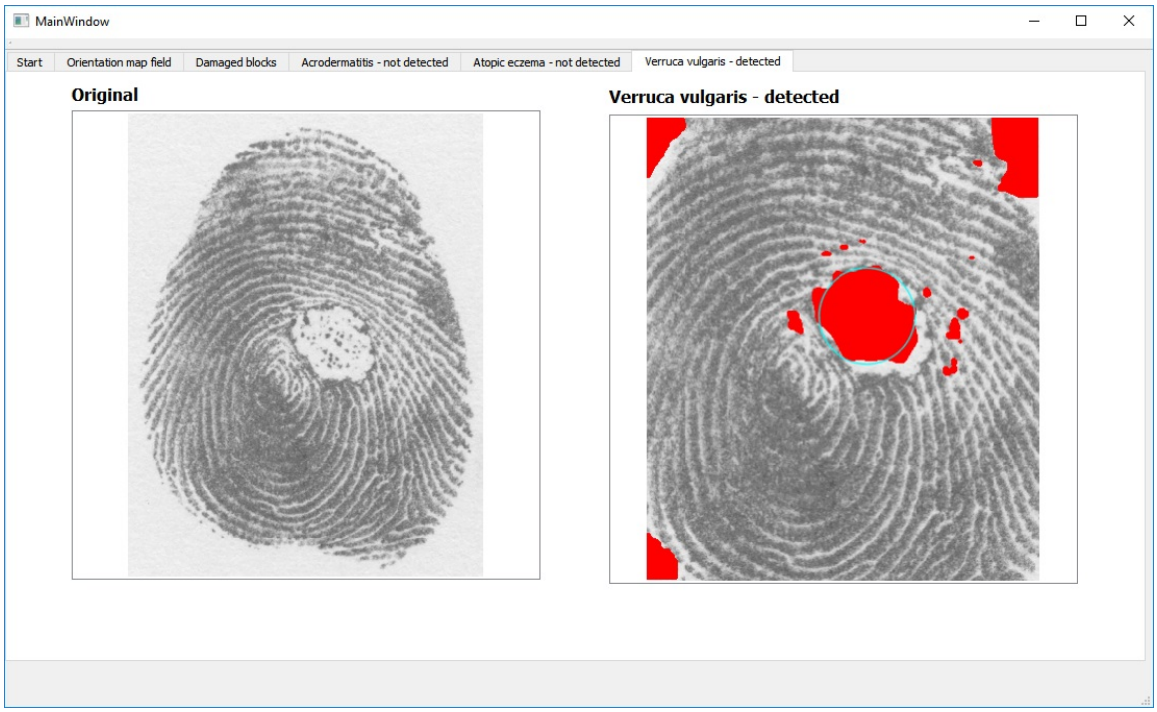

Figure 6.2: GUI results for detailed mode

Statistic mode – in this mode application takes an input location of a directory containing fingerprint images. Every image in input directory is processed and result of this mode is simple report holding the information of statistics that describe how many times each disease was detected. This mode is started by pressing button “Run on folder” and requires input directory to be selected.

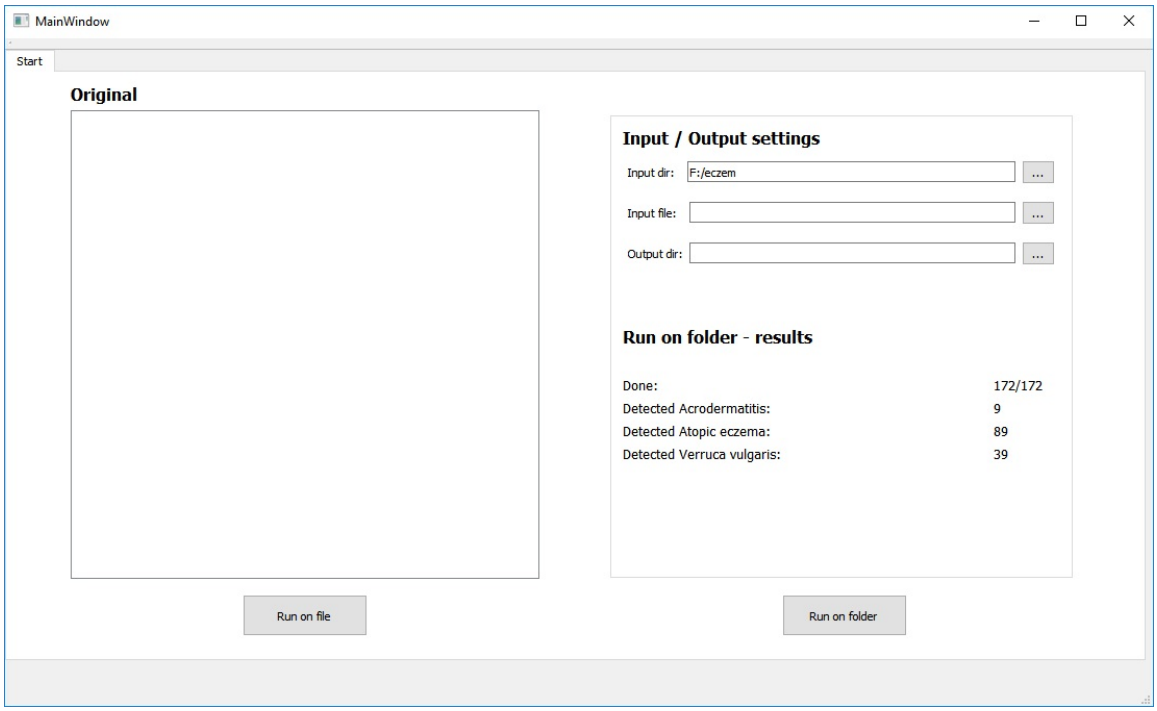

Figure 6.3: GUI results for Statistic mode

Chapter 7

Implementation

The application was developed using programming language C++, framework QT (version 5.9 under LGPL licence) for graphic user interface and using Open Source Computer Vision library (version 4.1.0 under BSD license).
In this chapter, the specific algorithms used to create this application will be described and their advantages and disadvantages will be discussed, alongside with it some of the core functions that are essential for program functionality and data structures that were used for storing through this process will be explained and described.

7.1 Image analyzer

The first step after loading input image is image preprocessing, which transoforms it in a way that allows the application to work with whole fingerprint. It would be unnecessary to load image in BGR format because whole program works and relies on only white and black color. Therefore image is loaded in grayscale format. Next step was to brush and highlight papillary lines. That was achieved by increasing contrast and brightness of image. In this step papillary lines which are represented with lower intensity (effect of unequal scanning of all parts of fingerprint) are highlighted.

Figure 7.1: left - input picture, right - image increasing contrast and brightness

Next step was histogram equalization. Histogram is statistic representation of the tonal distribution in a digital image. Example of histogram distribution is shown in figure 7.2. Horizontal axis represents individual intensity and vertical axis represents pixels count with corresponding intensity. In this histogram we can see, that individual intensity are not represented equally and some of them are not represented at all. Histogram equalization [1234] is a spatial domain method that produces output image with uniform distribution of pixel intensity means that the histogram of the output image is flattened and extended systematically. Resultant histogram is shown in figure 7.2.

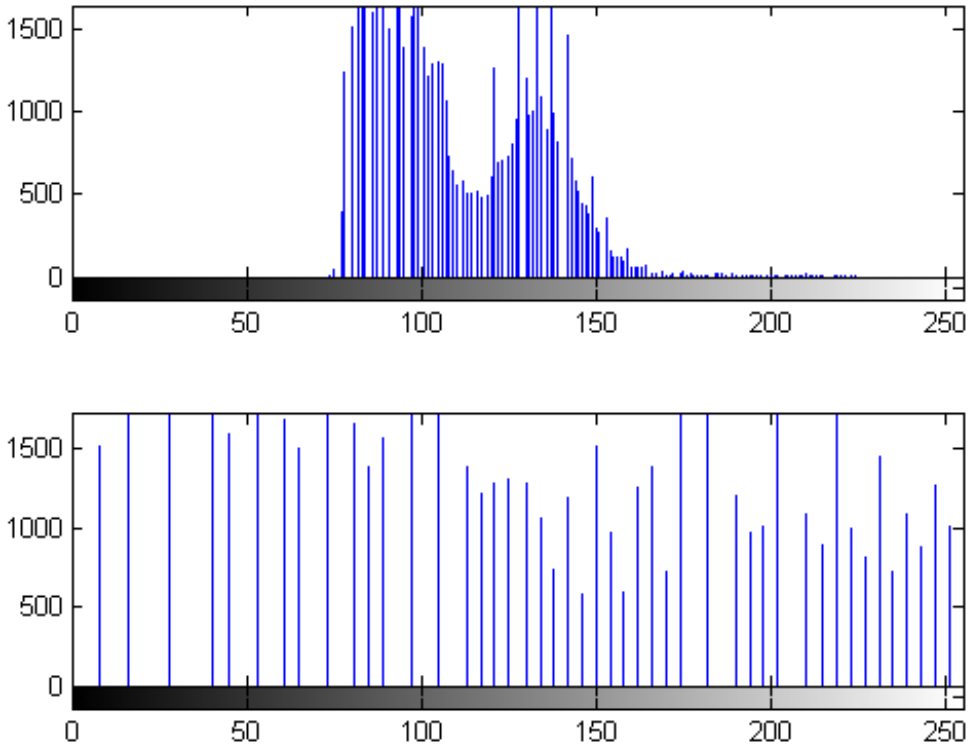

Figure 7.2: Histogram graph

Applying this method quality of image will be increased and lower illuminated areas will be highlighted. This step allows parts of fingerprint that are less imprinted to be also used. Histogram equalization was implemented using function cv::equalizeHist() from library OpenCV. The figure 7.3 shows an image before and after histogram equalization. It is obvious how parts with lower illumination were highlighted and distinguished from background.

Smoothing is often used to reduce noise within image and prepare the image for segmentation. Most of smoothing methods are based on low pass filters and for implementation of this application Gaussian low pass filter was used.

Figure 7.3: Left - fingerprint before and after using histogram equalization.

Figure 7.4: Left - fingerprint before and after using gaussian filter.

Last part of image preprocessing is converting result image to binary image. This was implemented using method called thresholding. Global thresholding is the simplest type of thresholding. For every pixel in image following equation it is true:
Major problem in global trhesholding is determination of ideal value for thresh. Based on experimenting with threshold value on fingerprints with different types of disease was determined that disease such as Acrodermatitis prefers lower threshold value because of need to detected smaller spots in fingerprint image, where diseases such as Fingertip eczema and Varucca vulgaris had better results with bigger threshold value that eliminated unneeded small spots in fingerprint.

7.2 Damaged Area Finder

Considering that every disease have some specific characteristic for every disease program creates image containing damaged areas in specific way that allows specific characteristic of disease to be detected.

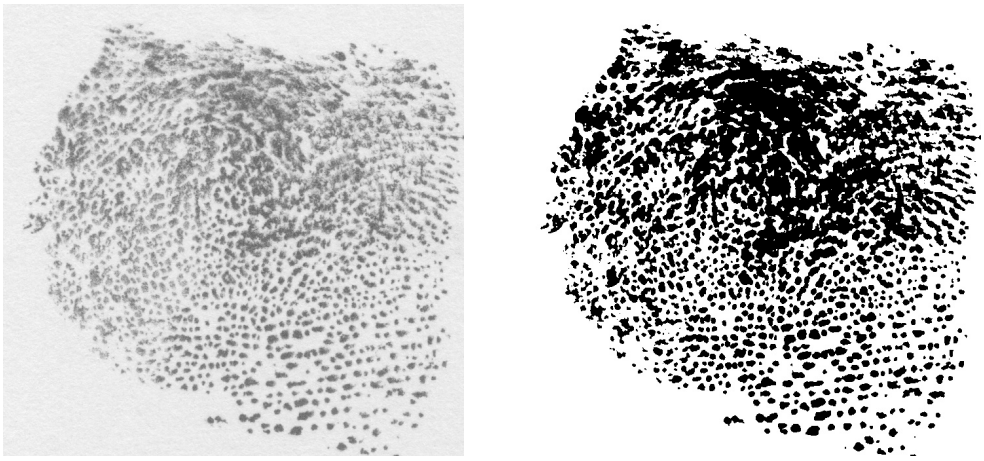

Figure 7.5: Left - input image, right image after preprocessing.

7.2.1 Fingertip Eczema

Main characteristic of this disease is that it creates long white lines in fingerprint. First step in extracting damaged areas for this disease is to crop the image. Resulting cropped image should contain only the fingerprint and its core, the background should be cut out. Function findBoundaries() is used to find the start and end points of the fingerprint. These points were later used to create rectangle which is used for cropping the image.

Figure 7.6: Left - full sized image, right croped image.

Next step was filling white spaces in fingerprint, because blob detection algorithm is capable only of detecting closed contours. Considering that area between papillary lines was also white, it was needed to create some algorithm which will work smarter and not just fill every pixel with white color.

First step was to compute the median of distance between two papillary lines. This

information will help the algorithm to ignore undamaged white areas between papillary lines. In the next step programs goes through the whole image pixel by pixel. Then creates a square with the size of median. Its center is positioned on current pixel. After this part, number of white and black pixels is calculated. If the ratio of white and black pixels is greater then 4:1 then block the will be filled. This method allows detection of all kinds of areas except the normal area between papillary lines. The main disadvantage of this approach is filling background, because after cropping image there will be still some background area, probably in corner of images, that will be filled and later possibly detected as disease.

Figure 7.7: Extracted white areas

7.2.2 Verruca vulgaris

This disease has one important characteristic in common with fingertip eczema. They both create white areas on fingerprint but in different shape. Because of this, same principle is applied in creating image for Wart, with several changes. Because wart creates white round areas the size of block in algorithm is doubled. This causes the detection of only areas with larger sizes and thin objects are ignored.

Next process is to make edges of filled areas round and potentially fill the gaps. This is done using functions cv::dilate() and cv::erode(). Effect of dilate operator [123] is to gradually enlarge the boundaries of regions of foreground pixel and effect of erode operator is to gradually shrink the boundaries. After analyzing fingerprint images in the database one more important property is detected. Although wart creates white spots in fingerprint, often these spots are not filled and contain small black spots inside them. Last step is to remove black parts inside filled areas. This is simply done by using function cv:findContours() with important flag RETR_EXTERNAL which allows to detect only contours that have no parents.

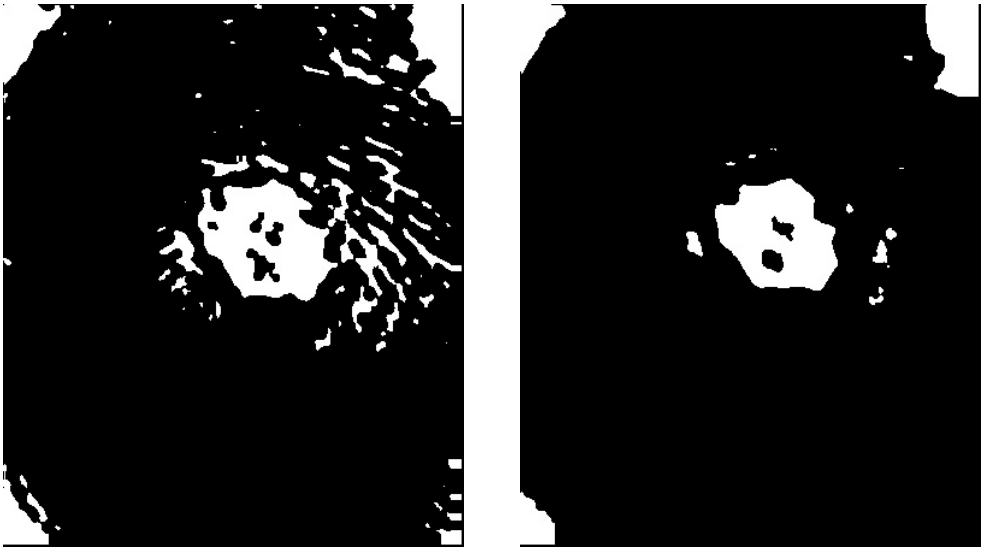

Figure 7.8: Difference between eczem photo and wart photo on fingerprint that is affected by wart.

Figure 7.9: Left: input image, right: damage area map.

7.2.3 Acrodermatitis

One of the main unique characteristic of acrodermatitis is that fingerprint have many small so called “cheetah” spots. These spots can be located anywhere on fingerprint, therefore the best solution is to not use cropped image. The only difference in preprocessing for this image is that the lower threshold value is used because it allows detecting even small spots in fingerprint image.

7.3 Papillary Lines Analyzer

The orientation field is one of the most commonly extracted features, since it used for many purposes: classification [10], detection of singular points, detection of fingerprint alterations, registration before matching, matching performance improvement and estimating the ridges direction. It describes direction of local ridge structure of fingerprint and provides rich information that is used for classifying the fingerprint image into one of the several fingerprint classes. The result is relatively smooth and continual image of ridges direction estimate.
If we try to compute orientation field map for fingerprint image that is damaged, we can clearly recognize with the naked eye which parts in the image are defected. This map is used to estimate possible damaged area caused by skin diseases. Orientation map was implementated using the gradient-based block orientation field algorithm. It sptes are as follows:

1. Compute the gradients g_x and g_y for each pixel at (i,j) using gradient operator. In this case a simple Sobel operator was used.
2. Divide the original image into w x w blocks.
3. Compute the estimation o(i,j) of the ridge orientation for every image block centered at (i,j) using next equations:

$$v_x = \sum_{u=i-\frac{w}{2}}^{u=i+\frac{w}{2}} \sum_{v=j-\frac{w}{2}}^{v=j+\frac{w}{2}} 2\partial_x(u,v)\partial_y(u,v)$$

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

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

Figure 7.10: Equations for estimation of the ridge orientation

The resulting block orientation field is afterwards analyzed for any discontinuities that may occur. Analyzing was done by doing row-wise and column-wise scanning approach that reveals areas of possible damage in fingerprint. For this analyzing was used Moore neighborhood. Current block at index (i, j) is compared with his successor and predecessor. If difference between these blocks were in both case bigger than 45 degrees, then current block will be marked as damaged.

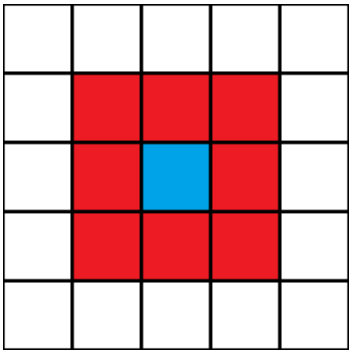

Figure 7.11: Moore neighborhood.

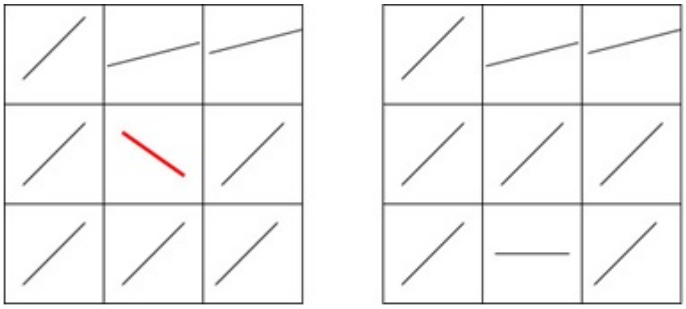

Figure 7.12: Left - block marked as damaged, right - block marked as healthy.

In several other papers that were using orientation field algorithm the size of blocks was usually 16 times 16, but for creating this application blocks of size 8 by 8 were used. The main reason behind using smaller block size is that usually straight white lines that were caused by disease were not detected as damaged areas. Negative side of picking lower block size then usual is that a plenty of small areas are falsely marked as damaged. This problem is solved by setting potentially damaged blocks to marked back as healthy if they don't have at least two damaged blocks in their surrounding.

Based on count of potentially damaged block application is able to determinate percent of damage in fingerprint and to conclude if it's able to reconstruct fingerprint.

7.4 Disease Detector

The disease detection is implemented using blob detection algorithm. Library OpenCv provides a convenient way to detect blobs and filter them based on different characteristics.

7.4.1 Blob detection algorithm

A blob is a certain object that represents a certain area of a frame. They are identified because they differ from other pixels in the frame. Blobs can be different things like: hands, faces, balls, etc. In this case blobs will represent damaged areas. The overall goal is to label each pixel within a blob with the same label number. The first stage in achieving this is to iterate through all the pixels, checking the label number of neighbouring pixels as you go. A buffer of equal dimensions as the original image (i.e. one buffer location per pixel)

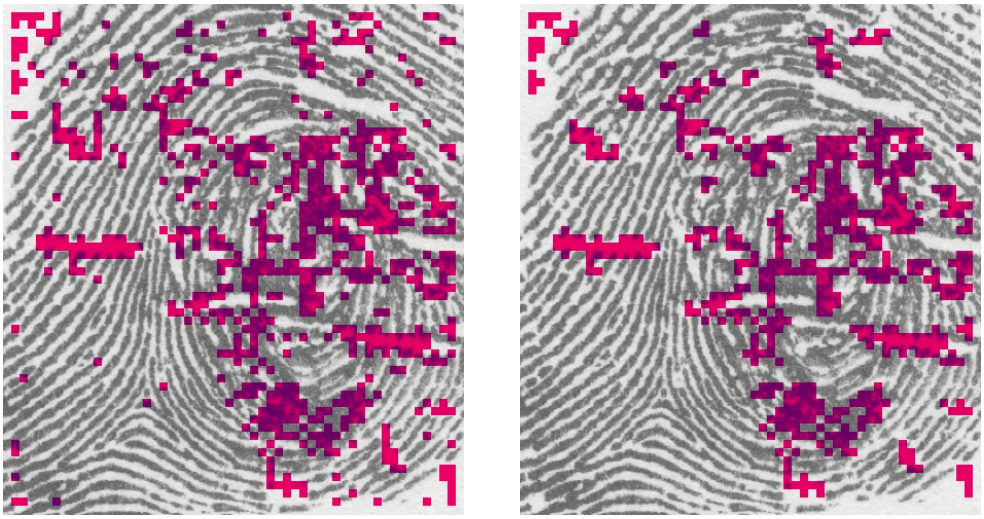

Figure 7.13: Left: damaged blocks before filtering, right: damaged blocks after filgering.

is needed to store the pixel labels. The buffer is initialised to all zeros, which equates to unlabelled. Scanning from top left to bottom right, the labelling kernel is applied per pixel (pixel position X). This is used to check the labels of neighbouring pixels (pixels A, B, C and D). The kernel shape means only neighbours that have already been labelled will be checked [1].

Figure 7.14: Pixel Labelling Process. Source: [1]

7.4.2 Filtering Blobs by Color, Size and Shape

The parameters on SimpleBlobDetector [2] can be set to filter only specific types of blobs.

- By color – This filter allows to set the intensity of blobs that will be detected. Values are in range <0, 255> where 0 represents darker blobs and 255 lighter blobs.
- By area – This filter allows to set minimum and maximum sizes of detected blobs. Measurement unit for this filter is pixel.
- By shape - This filter has 3 different parameters that closely describe shape of detected blobs.

  – Circularity - this parameter simply measures how close shape of blob is to circle. E.g. hexagon has lower circularity then circle, square has lower circularity then

hexagon etc. Formula for computing circularity is:

$$\frac{4\pi Area}{(perimeter)^2} \tag{7.1}$$

Based on this formula circle has circularity 1.00, square 0,785, etc.

– Convexity is defined as the (Area of the Blob / Area of it's convex hull). Now, Convex Hull of a shape is the tightest convex shape that completely encloses the shape.

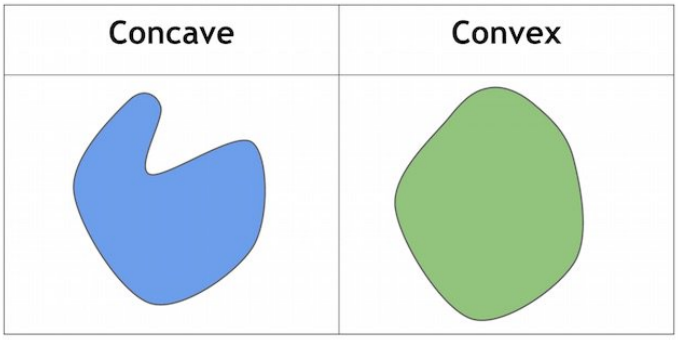

Figure 7.15: Blob convexity. [2]

– This measures how elongated a shape is. For example, circle has value 1, ellipse between 0 and 1 and line has value 0.

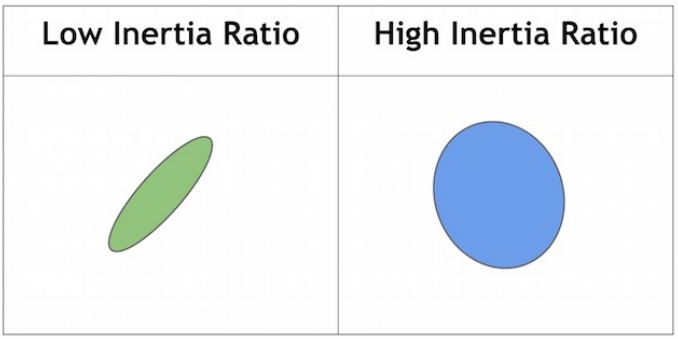

Figure 7.16: Blob intertia ratio. [2]

7.4.3 Sub-detector for Acrodermatitis

Based on fact that main characteristics of acrodermatitis is a large number of small black spots, detector is configured in following way:

Color	Area	Inertia ratio	Circularity	Convexity
black	<30, 300>	<0.55, max>	<0.50, max>	<0.1, max>

Figure 7.17: Blob parameters for detection acrodermatitis

In case that count of detected blobs is bigger than 60, presence of acdrodermatitis is postitive in fingerprint.

7.4.4 Sub-detector for Atopic eczema

For this disease goal is to detect white straight lines.

Color	Area	Inertia ratio	Circularity	Convexity
white	<300, 13000>	<0.10, 0.30>	<0, 0.1>	<0.55, max>

Figure 7.18: Blob parameters for detection atopic eczema

7.4.5 Sub-detector for Wart

For this disaese goal is to big round white areas.

Color	Area	Inertia ratio	Circularity	Convexity
white	<500, 100000>	<0.60, max>	<0.50, max>	<0.6, max>

Figure 7.19: Blob parameters for detection verruca vulgaris

Chapter 8

Experiments and Results

This chapter deals with description experiments resulting application and their results. Application was continuously tested during implementation of individual parts. This testing was very important as it allowed the algorithms to be corrected if it was needed.

	TP	FN	FP	TN
Acrodermatitis	7	5	13	357
Atopic eczema	89	83	63	147
Verruca vulgaris	7	10	87	288

Figure 8.1: Rejected and accepted samples.

	FAR	FRR	F1	ACC
Acrodermatitis	0.0351	0.4167	0.4376	0.9529
Atopic eczema	0.2739	0.4825	0.5494	0.6129
Verruca vulgaris	0.2320	0.5882	0.7727	0.1262

Figure 8.2: Detector accuracy measures.

8.0.1 Disease Detector Results

Second part of application is detection concrete disease in fingerprint image. Testing was undergone on group of fingerprint images taken from dactyloscopic cards. Total number of test fingerprint images is 382 . Table 8.1 shows the numbers of fingerprints images that were correctly / incorrectly detected. TP (True Positives) represents number of images that were correctly accepted, FN(False Negatives) represents number of images that were incorrectly rejected, FP(False Positive) stands for number of images that we incorrectly accepted and TN(True Negatives) represents number of images that were correctly rejected.

8.0.2 Possible Extensions and Enhancements

The major areas in which the program could be enhanced are:

- Image preprocessing

  One of the operation in this process is crop and although resulting image has fingerprint area as much as possible, problem occurs in edges of image where parts of background are also cropped. These parts later can cause problem during detection because they can have shaped similar as some disease. Solution would be to create map with information of background area in cropped image and use it as filter in detection process.

- Detection

  Concentration of disease in fingerprint can vary in different patient. Based on amount of detected blobs (for Acrodermatitis), size of detected blobs(for Verrica vulgaris), or length can be estimated probability of detected disease. Figure A.5 shows difference high concentrated and less concentrated acrodermatitis in fingerprint.

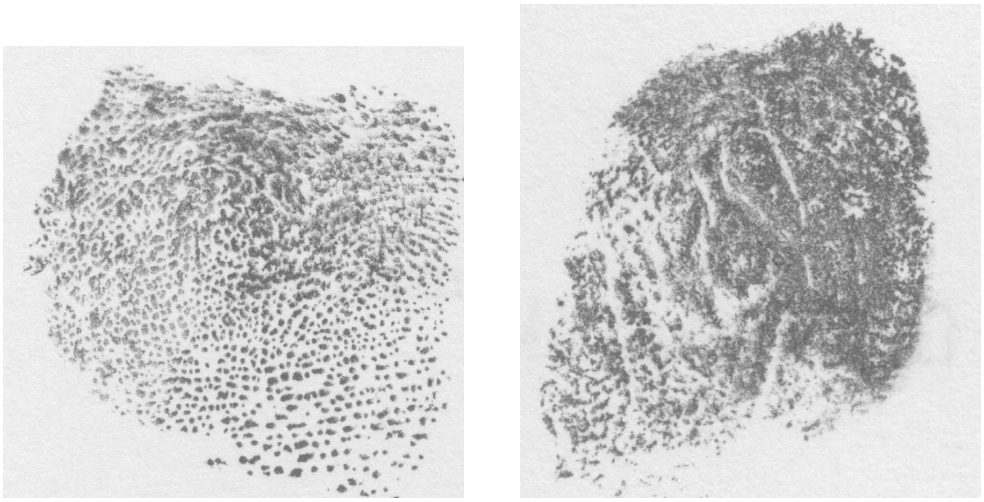

Figure 8.3: Concentration of acrodermatitis in different fingerprints. Source: database

- Speed

  Every sub-detector works with different input image therefore whole detection process could be implemented to work parallel.

- Other diseases

  So far, the application is capable detecting only three diseases: Acrodermatitis, Atopic eczema and Varruca vulgaris. There is still room for implementing detection for other diseases.

Chapter 9

Conclusion

This thesis deals with detection skin diseases in fingerprint images. The goal was to design and develop methods that will extract damaged area in fingerprint image and based on geometry properties and color of these areas to determinate which disease patient probably present in fingerprint image. The goal is met and blob detector for three types of skin diseases was developed: Acrodermatitis, Atopic eczema and Verrica vulgaris.

Based on analyzing provided database of fingerprint images affected by skin diseases following method were implemented: block orientation field, damaged areas finder and disease detector. The best results were achieved by using different properties in the damaged areas finder for each type of skin disease, allowing this method to focus on extracting only particular types of damages that are characteristic for given skin disease.

The disease detector uses Blob algorithm for detection of damaged areas. Using this method, program reached an accuracy of 95.3% for acrodermatitis, 61.3% for atopic eczema and 77.2% for verruca vulgaris.
The resulting program is a GUI application that allows the user to load fingerprint image, view and save the results. It can be used as an analytical tool for future researchers.

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Appendix A

Experimental results

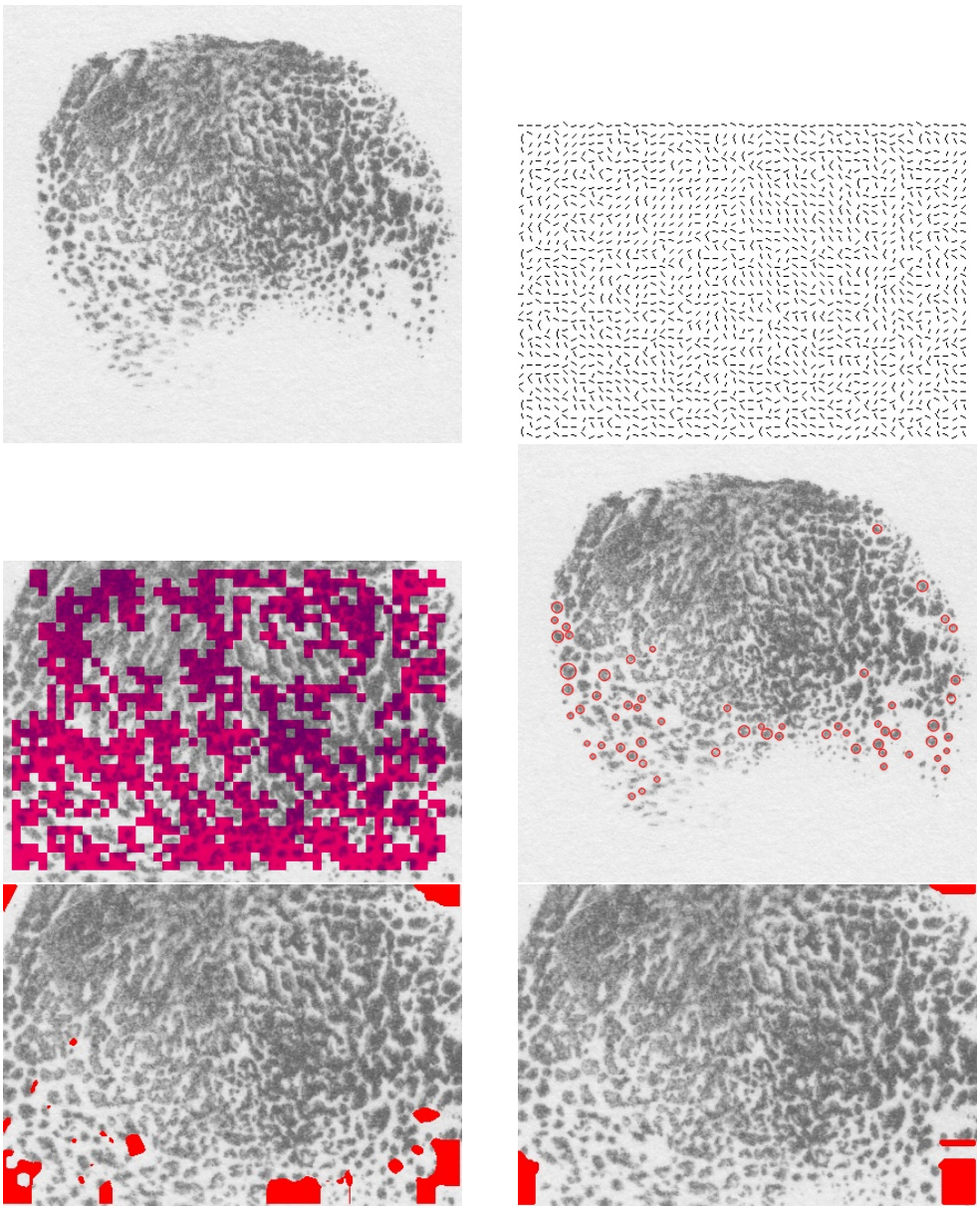

Figure A.1: Results for image affected by acrodermatitits.

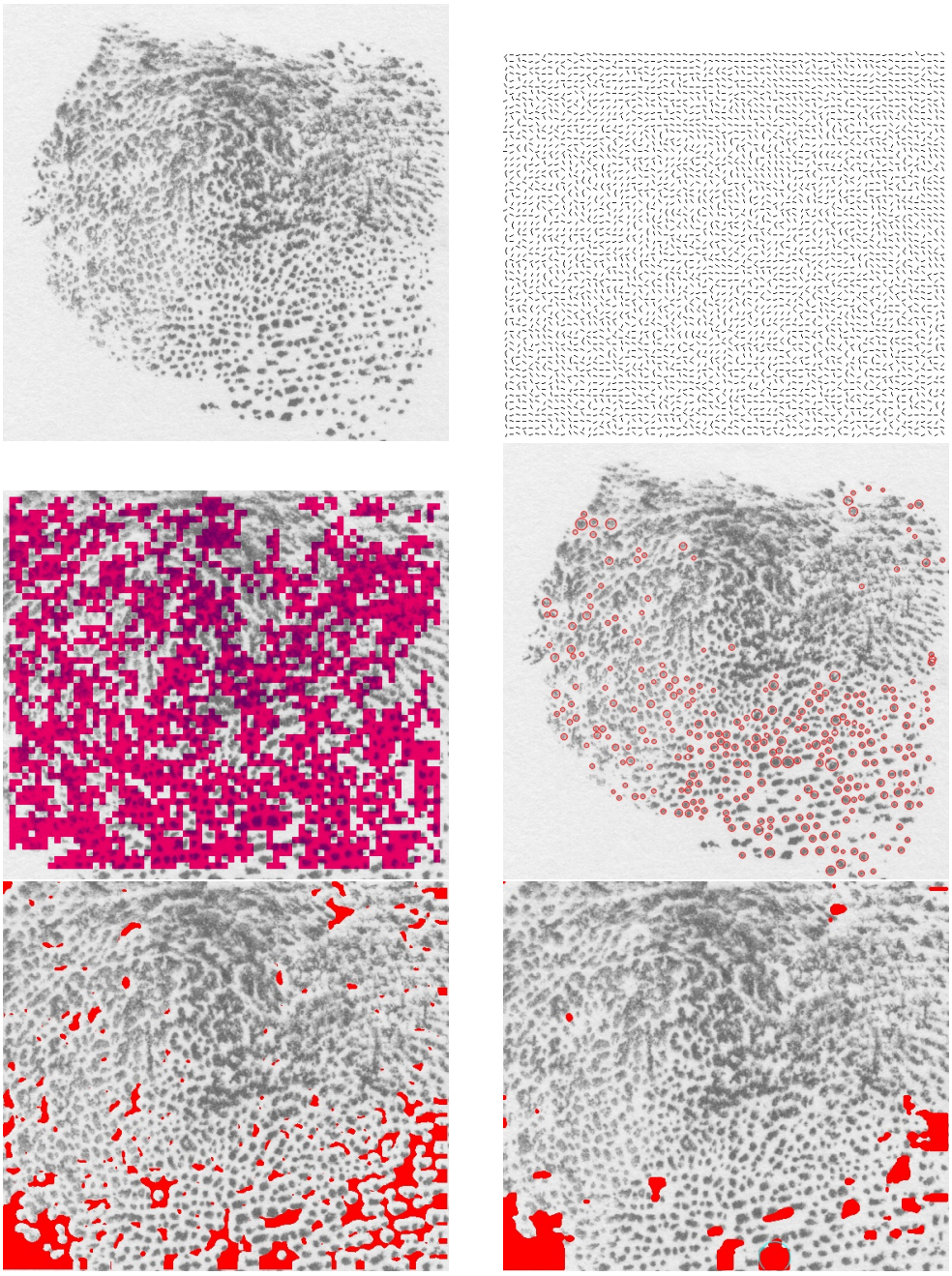

Figure A.2: Results for image affected by acrodermatitits.

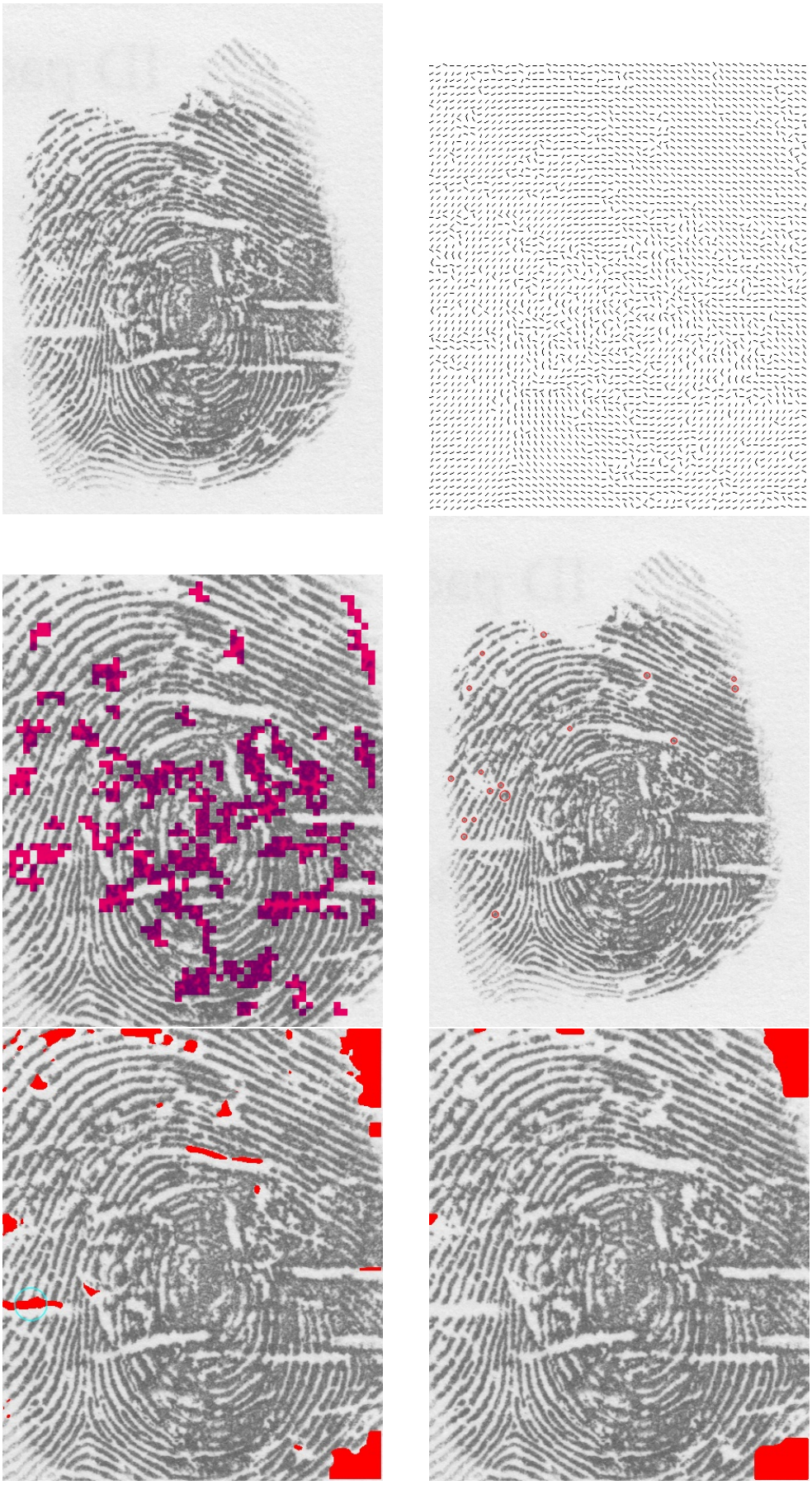

Figure A.3: Results for image affected by atopic eczem.

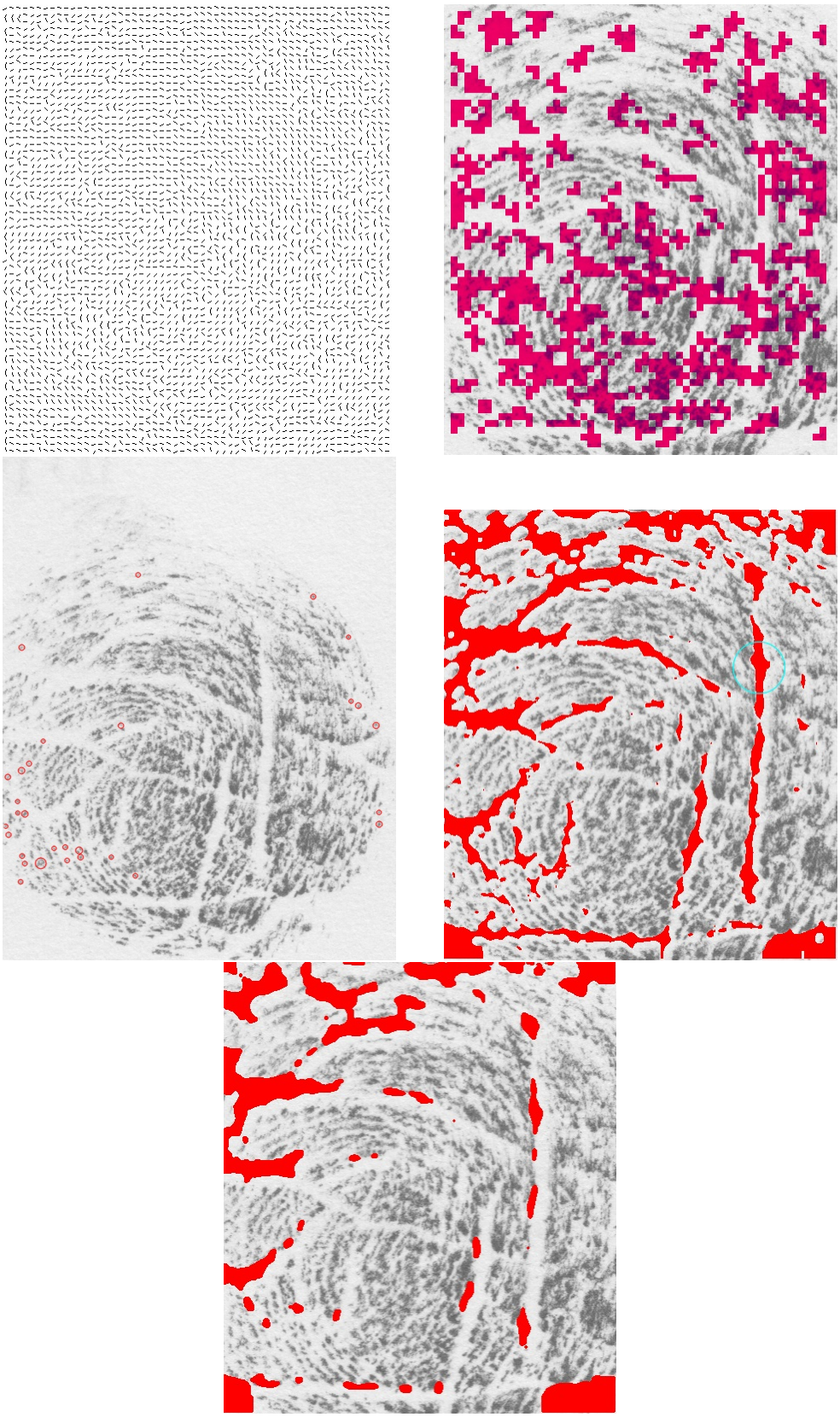

Figure A.4: Results for image affected by atopic eczem.

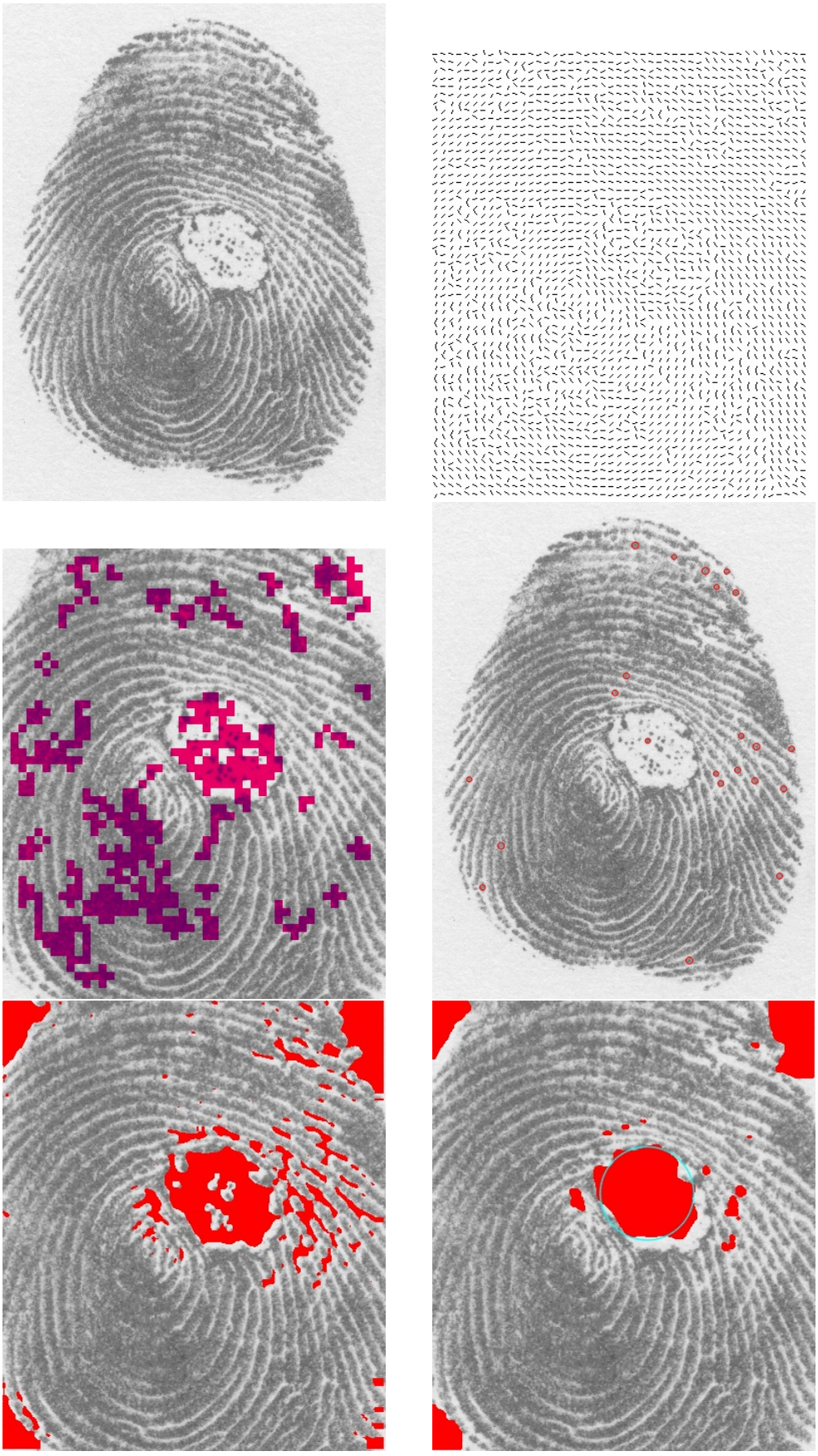

Figure A.5: Results for image affected by atopic eczem.