

# Adaptive technique for matching the spectral response in skin lesions' images

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**Abstract.** The suggested technique is a subsequent stage for data obtaining from diffuse reflectance spectra and images of diseased tissue with a final aim of skin cancer diagnostics. Our previous work allows us to extract patterns for some types of skin cancer, as a ratio between spectra, obtained from healthy and diseased tissue in the range of 380 – 780 nm region. The authenticity of the patterns depends on the tested point into the area of lesion, and the resulting diagnose could also be fixed with some probability. In this work, two adaptations are implemented to localize pixels of the image lesion, where the reflectance spectrum corresponds to pattern. First adapts the standard to the personal patient and second – translates the spectrum white point basis to the relative white point of the image. Since the reflectance spectra and the image pixels are regarding to different white points, a correction of the compared colours is needed. The latest is done using a standard method for chromatic adaptation. The technique follows the steps below:

- Calculation the colorimetric XYZ parameters for the initial white point, fixed by reflectance spectrum from healthy tissue;
  - Calculation the XYZ parameters for the distant white point on the base of image of non-diseased tissue;
  - Transformation the XYZ parameters for the test-spectrum by obtained matrix;
  - Finding the RGB values of the XYZ parameters for the test-spectrum according sRGB;
- Finally, the pixels of the lesion's image, corresponding to colour from the test-spectrum and particular diagnostic pattern are marked with a specific colour.

## 1. Introduction

The main goal of our investigations is a development of non-invasive technique for skin cancer diagnostics using optical spectra in the range of wavelength from 380 to 780 nm, where are the most significant changes between healthy and diseased skin.

In a previous investigation we achieved the pattern distributions based on reflected spectra, corresponding to some types of skin damage [1]. The patterns are normalized ratio between spectra of healthy and diseased tissue. The main problem in this investigation – the lack of patients in the set of every kind of cutaneous pathology that is patterned, is attended with other one - variations of the spectra in dependence on position of the tested area used for spectrum, obtaining inside of one lesion and stage of cancer progress [2]. Developing the presented technique we want to support the solving these problems combining images and spectra, and ensure the fidelity of the patterns.



The current investigations in the area give much information about human skin properties [3] and relation between illness and different features of optical signals [4, 5]. However the process of illness recognition is still unstable and depends on variable factors. The analysis of the all actual optical methods applied in practice for non-invasive skin cancer diagnostics [6] shows that “further studies are needed in finding the appropriate method or combination of methods that can have wide clinical applications”.

Searching for answer of the question: “which areas of the healthy skin and tissue inside of the lesion produce particular spectra?”, we defined three tasks for realization as a part of the technique:

1. The spectra obtained from the pigmented skin match the pixels of the same areas in the image
2. The spectra of the healthy skin corresponds to the pixels of healthy skin in the image
3. Division the healthy spectrum into pattern distribution, the result will be a spectrum for pigmented area/ lesion, adapted to particular subject, if there is available “patterned” disease.

For this work we use well developed mathematical techniques for operating with the signals that are part of colorimetry. The present standards in that area establish two methods for finding the parameters of one colour: by spectral distribution in the range of visible light and by integrated signals from three detectors of visible light [7]. The both type of obtaining leads to 6 parameters description: 3 basic - XYZ and 3 relative -xyz that are primary in CIE system [7]. Two of them – x,y, form chromaticity, and are presented as a graphical diagram named Locus. The all other used parameters are result from transformation of the XYZ [8,9].

The use of three detectors for R(red),G(green) and B(blue) reproducing signals is the base of image registration by cameras. Development of computer technologies brought to establishment of special standard (ICC) for exchanging the information about colour parameters between different digital devices [10]. This standard also describes translations, needed for adaptation the colours measured in different conditions.

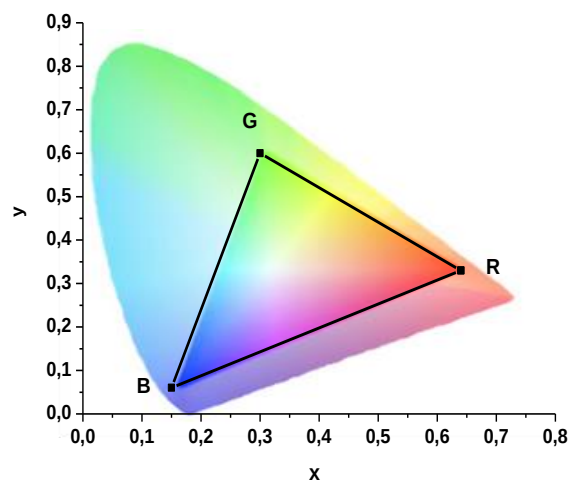
There are described results from our first attempt to apply the ICC standard in achievement of the aim to combine spectral data with the registered digital images.

## 2. Methods and materials

According to the ICC standard cameras are calibrated in sRGB space. It means generation of RGB reproducing signals that gives chromaticity coordinates inside of triangle area in Locus diagram with relative white point to illuminant –D65 – averaged daylight. Chromaticity coordinates –x,y,z of basic stimulus – Rp,Gp,Bp and white point for the sRGB are given in table 1. Figure 1 shows the position of basic triangle inside of Locus.

**Table 1.** sRGB and white source coordinates

|   | Rp     | Gp     | Bp     | white point<br>D <sub>65</sub> |
|---|--------|--------|--------|--------------------------------|
| x | 0,6400 | 0,3000 | 0,1500 | 0,3127                         |
| y | 0,3300 | 0,6000 | 0,0600 | 0,3290                         |
| z | 0,0300 | 0,1000 | 0,7900 | 0,3583                         |



**Figure1.**The sRGB triangle area inside of Locus

The cameras are not colorimeters, because they transform the colours outside of the area of triangle to points inside of it, and the standard [8] fixes the common used transformations about it. However, colorimetry gives calculation /measurement of colour lightness and chromaticity by:

- Integrated signal from three detectors corresponding to three stimuli
- Spectral distribution

That is why we can find a colour, once from registered spectral distribution and again – as a relation between reproducing signals for pixels of the image of the same area. These two colours could be directly compared at the level of chromaticity, if the both coordinates are inside of the sRGB triangle. Specially developed software, appropriate to rules of registration, has been used for calculation the chromaticity coordinated for spectra and pixels of the images. Conditions of registration and calibration of devices in both cases are described below.

### 2.1 Spectral registration

System USB4000, product of "Ocean Optics", Inc. equipped with a fibre and a high-sensitivity linear CCD detects the reflected light dispersed by a grating with 600 lines/mm, and a total spectral resolution of the micro-spectrometer approximately 1.5 nm. The portion of light reflected from a sample is expressed as percentage  $R$  (%), related to a signal reflected from a standard white surface (Spectralon®). The software calculates  $R$  by the following equation:

$$R_{\lambda} = \frac{S_{\lambda} - D_{\lambda}}{SR_{\lambda} - D_{\lambda}} \times 100\% \quad (1)$$

Where  $R_{\lambda}$  – reflectance (%),  $S_{\lambda}$  – intensity of the light reflected from the sample,  $D_{\lambda}$  – the dark current correction,  $SR_{\lambda}$  – intensity of the light reflected from the standard white surface, index  $\lambda$  – wavelength. Calibration procedure:

- Measurement of the light reflected from the white surface and the dark current measurement (without any external signal). The calibration procedure of the spectrometer fix the white point to E- illuminant [7], that means chromaticity coordinates  $x=0.3333$   $y=0.3333$ .

### 2.2 Image registration

For the test of our software, we used images, registered by •7.1 Megapixels camera – Olympus, initial calibration - sRGB and daylight to illuminate the tested skin

The CIE parameters of XYZ systems were calculated for the both cases – spectrum and pixels of the image. The coordinates are transformed according to standard colour adaptive procedure –CAT, for adaptation in case of different white points. The coordinates of chromaticity are compared by the difference between them. Finally – the pixels in the image have been marked by white colour in case of coincidence of coordinates.

In this work, two adaptations are implemented to localize pixels of the image lesion where the reflectance spectrum corresponds to the pattern. First adaptation of the pattern to the personal patient by multiplying to healthy spectra:

$$fd_p(\lambda) = fh_p(\lambda) \cdot fr(\lambda) \quad (2)$$

where  $fd_p(\lambda)$  is tested spectra for particular patient,  $fh_p(\lambda)$  -healthy spectra for particular patient,  $fr(\lambda)$  -pattern distribution for particular skin damage;

And second – translation of the spectrum white point basis to the relative white point of the image.

### 2.3 Main stages of the software processing

- CIEXYZ parameters calculation using spectra from skin areas and from adapted patterns;
- CIEXYZ parameters calculation for each image pixel;

- CAT (colour adaptation transformation)- using matrix M with coefficients defined by Bradford [11]

$$\begin{bmatrix} X_d \\ Y_d \\ Z_d \end{bmatrix} = [M] \begin{bmatrix} X_s \\ Y_s \\ Z_s \end{bmatrix} \quad [M] = \begin{bmatrix} 1.0209581 & 0.0132500 & 0.0107183 \\ 0.0216398 & 0.9773060 & 0.0002158 \\ 0.0040457 & -0.0079939 & 1.0896730 \end{bmatrix} \quad (3)$$

Where XYZ – colour parameters in CIEXYZ; Index d- illuminant E; Index s – illuminant D<sub>65</sub>.

- Obtaining the similarity by comparing the distance between coordinates of the points from spectrum and pixels and fixing the pixels with  $\Delta x$  and  $\Delta y$  under a limiting value.

$$\Delta x = [(x_{spectrum} - x_{pixel})^2]^{1/2} \quad (4)$$

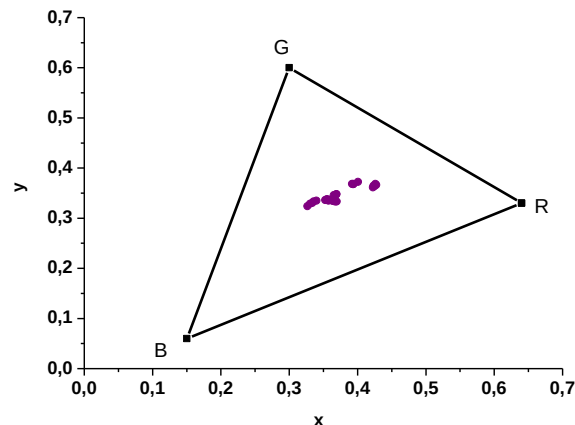
$$\Delta y = [(y_{spectrum} - y_{pixel})^2]^{1/2}$$

The test data include spectra obtained from

- pigmented skin areas
- 4 different areas of healthy skin: elbow areas- medial and lateral, hand-palm, and surrounded pigmented area and also images of the same areas
- six patterns for skin damages: Basal-Cell Carcinoma (BCC); Compound Nevus; Derma Nevus; Dysplastic Nevus; Malignant Melanoma (two patterns).

### 3. Experimental results

Figure 2 gives the graphical view of the point corresponding to particular test –spectra and their position as chromaticity.



**Figure 2.** Chromaticity coordinates of some test-spectra and sRGB triangle

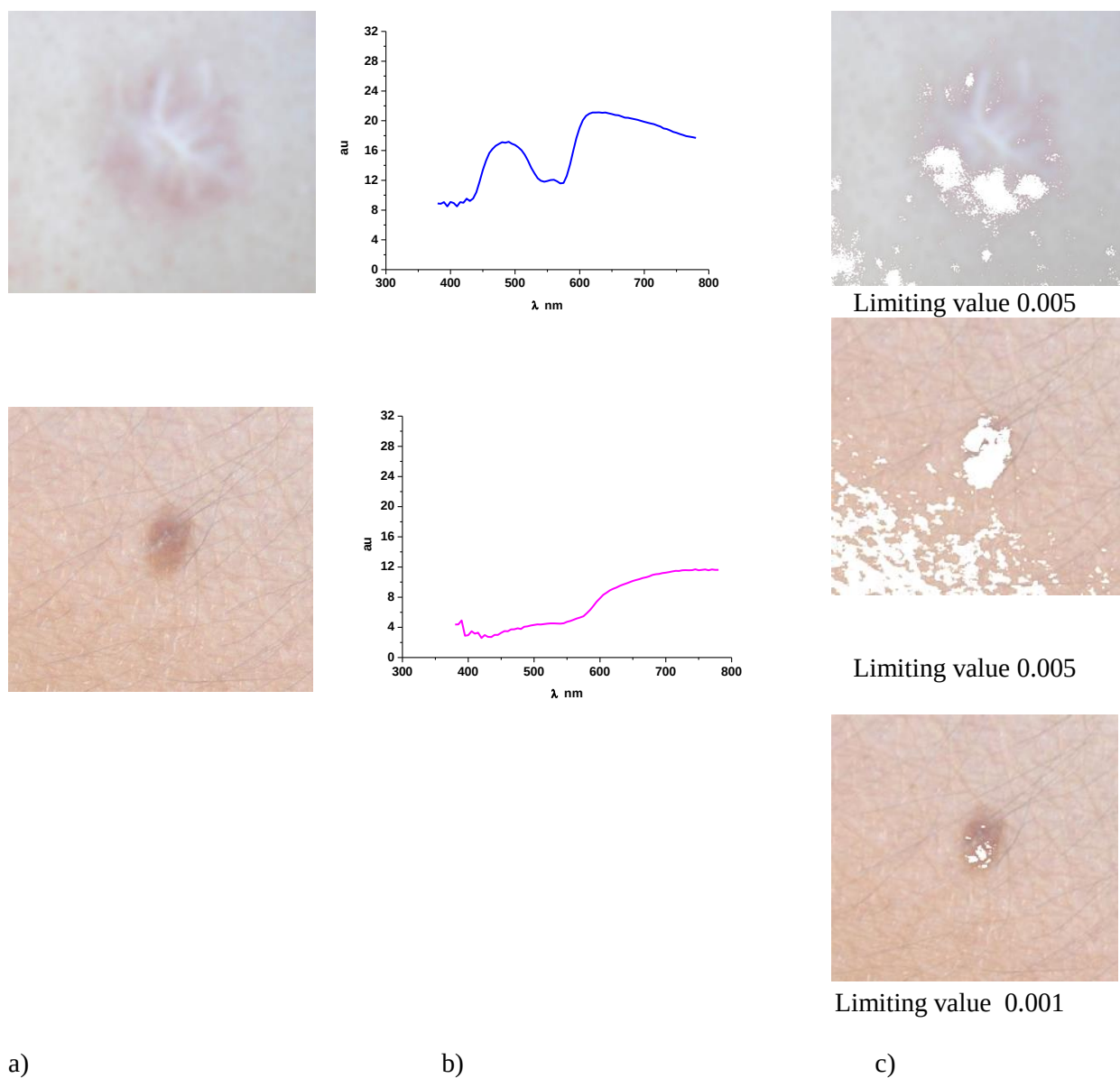
The figures 3 and 4 show matched pixels in the images in limiting distance between chromaticity coordinates of pigmented and healthy areas and spectra, obtained from the same areas.

Figure 5 shows results of matching pixels using different “healthy” spectra applied to pigmented areas of one patient.

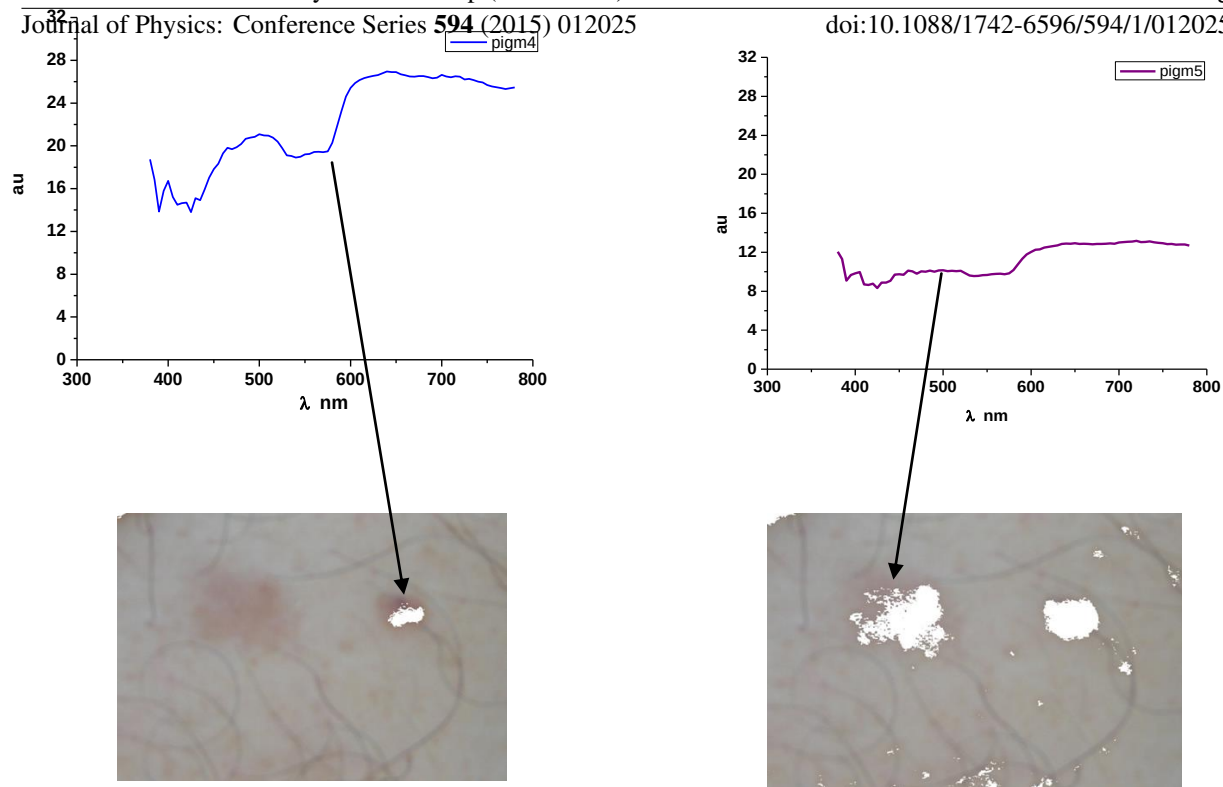
Figure 6 shows matching with use of three types of “healthy” spectra.

At figure 7 are given spectrum of surrounded “healthy” spectrum and results of matching pixels with different limiting values.

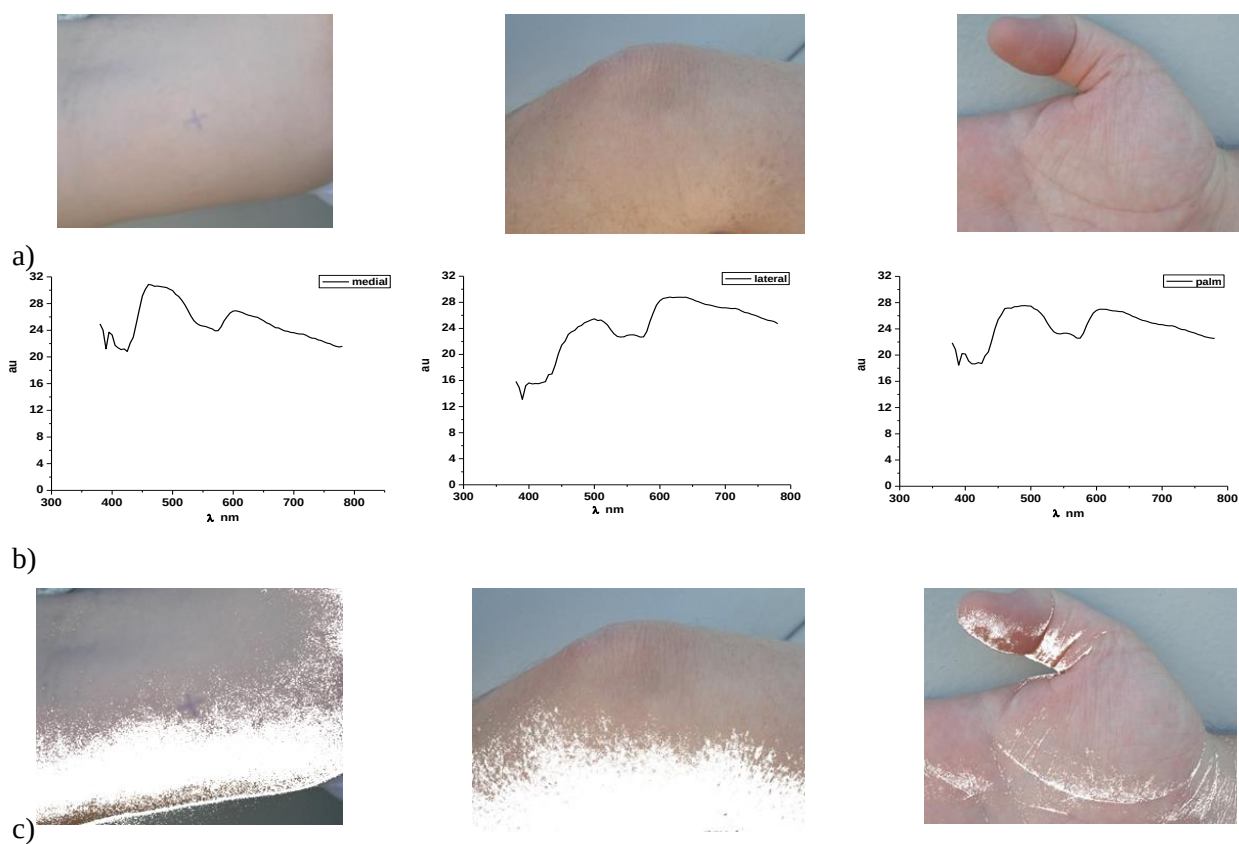
Figures 8 and 9 are presented the test – spectra, results of calculation using patterns and matched pixels in the image for limiting value 0.003.



**Figure 3.** Original images - a), registered spectra -b), images with matched pixels for pigmented areas – c)



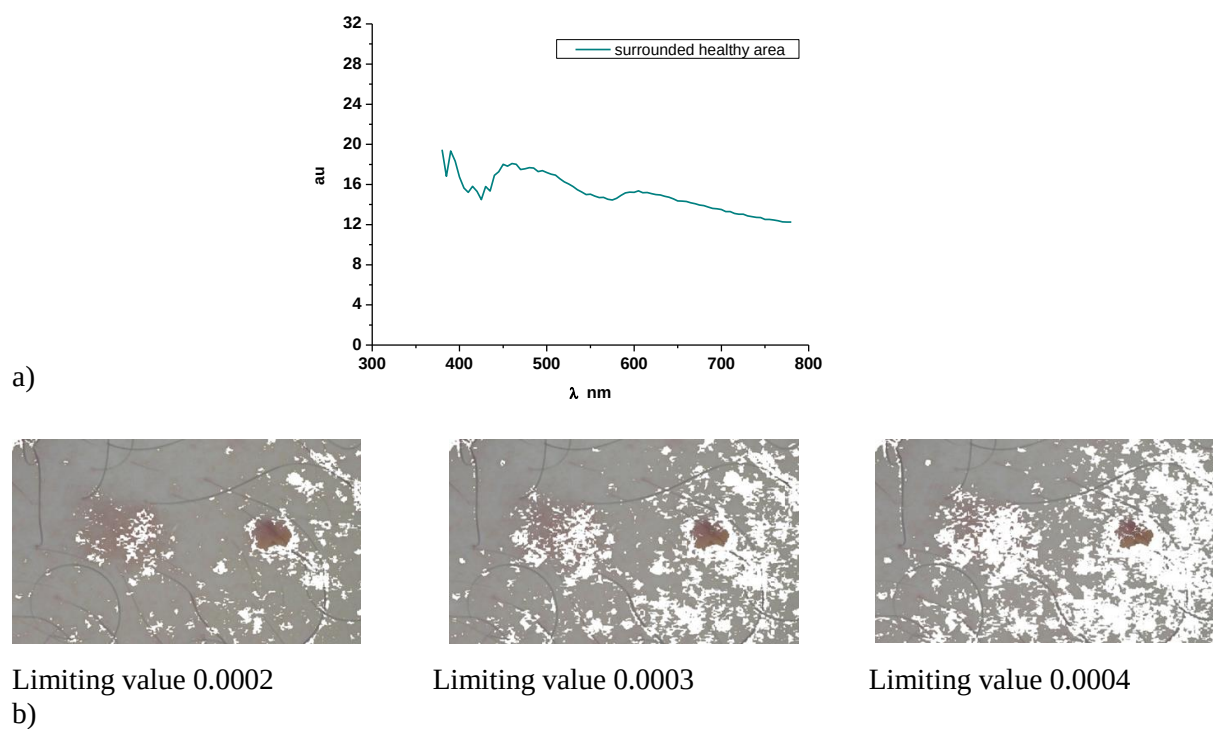
**Figure 4.** Spectra and matched pixels for two different areas of one patient



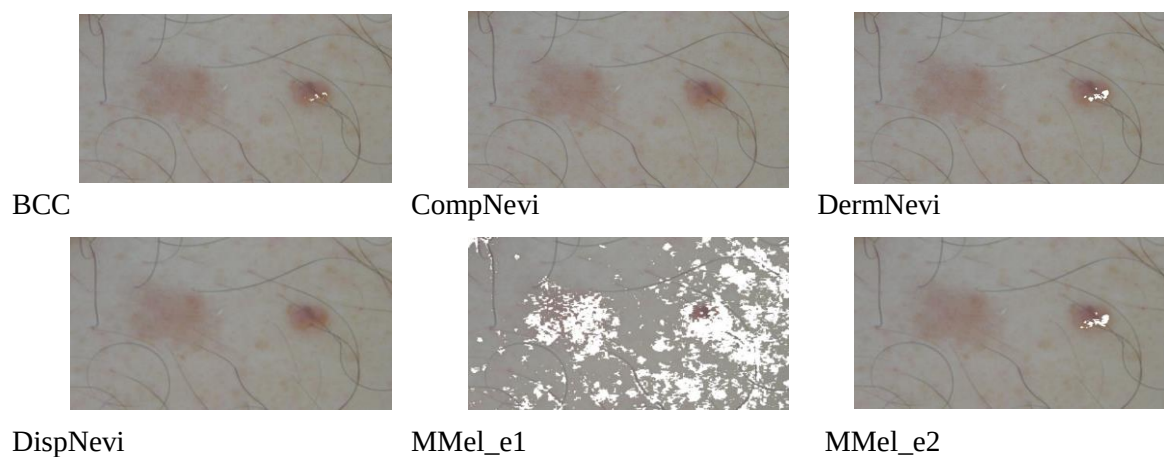
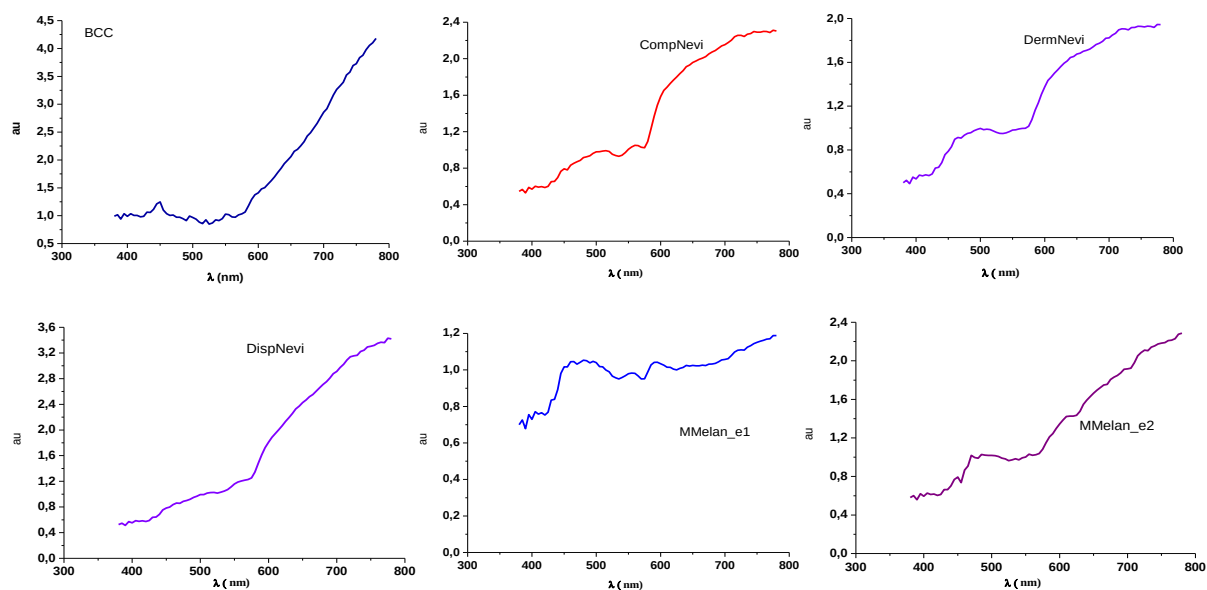
**Figure 5.** Original images – (a), spectra – (b) and matched pixels – (c) for healthy areas



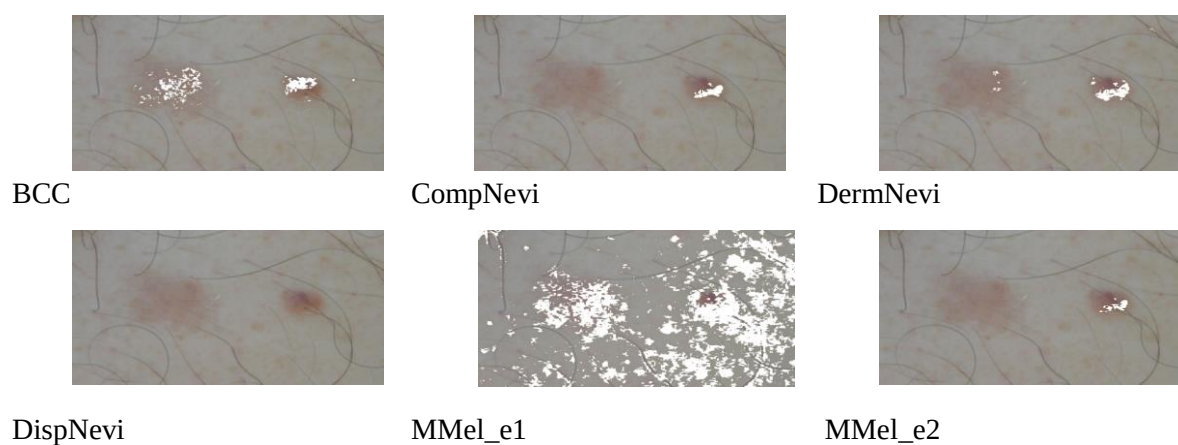
**Figure 6.** Matched pixels from: a)- medial area healthy spectrum, b)- lateral area healthy spectrum, c)- palm area healthy spectrum



**Figure7.** Spectrum from surrounded healthy area- a), matched pixels with different limiting values – b)



**Figure 8.** Spectra for different patterns based on lateral healthy spectrum and corresponding matched pixels in the images



**Figure 9.** Corresponding matched pixels in the images results from different patterns based on surrounded area healthy spectrum

#### 4. Discussion

The points of chromaticity coordinates of the spectra are inside the sRGB triangle (fig. 2) it means that the spectral chromaticity could be directly compared with the points from the image.

Analysing the results from pixel matching we extracted needed conditions for registration:

For the spectra:

- The position of obtaining healthy spectra is very important for the extraction of the adapted spectra. The spectrum from surrounded lesion area seems to be most suitable for this aim.
- The numeric aperture of the fibre – if it is too high the signal is averaged from healthy and diseased area

For the images:

- Equal lightening of the whole area – healthy and diseased.
- If the level of illumination is too low or too high, the sensors work with non-linear transfer of signals. As a result the possible number of chromatical coordinates decreases. It changes the distance for comparison.
- Available blics always give bad results of processing.

Regarding to the fidelity of presented pattern distributions and in respect to results for different limiting values and subjects it could be said that only the different types of nevi are suitable for testing diagnoses using these reflectance spectra transformations. Similar effect of applicability is observed as well, when compare feasibility of diffuse-reflectance spectroscopy for cutaneous lesions diagnosis with other spectral techniques [12]. The melanin-pigmented pathologies, such as nevi, are highly differentiated by sub-type, when their reflectance spectra are compared, but non-melanoma pathologies do not reveal high diagnostic specificity of differentiation, if only their reflectance properties are used as diagnostic indicators.

#### 5. Conclusion

The problem of matching pixels in the image coloured from obtained spectrum give us two main conclusions:

First conclusion must be that at this initial stage of the work we fix more problems than good results. In spite of fact that theoretically the problem could be solved, practical experiments show very strong dependence on used illumination and detection devices.

Second one – application of ICC standard principals has to be adapted to this particular task.

#### 6. References

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