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Quality enhancement of multispectral images for skin cancer optical diagnostics

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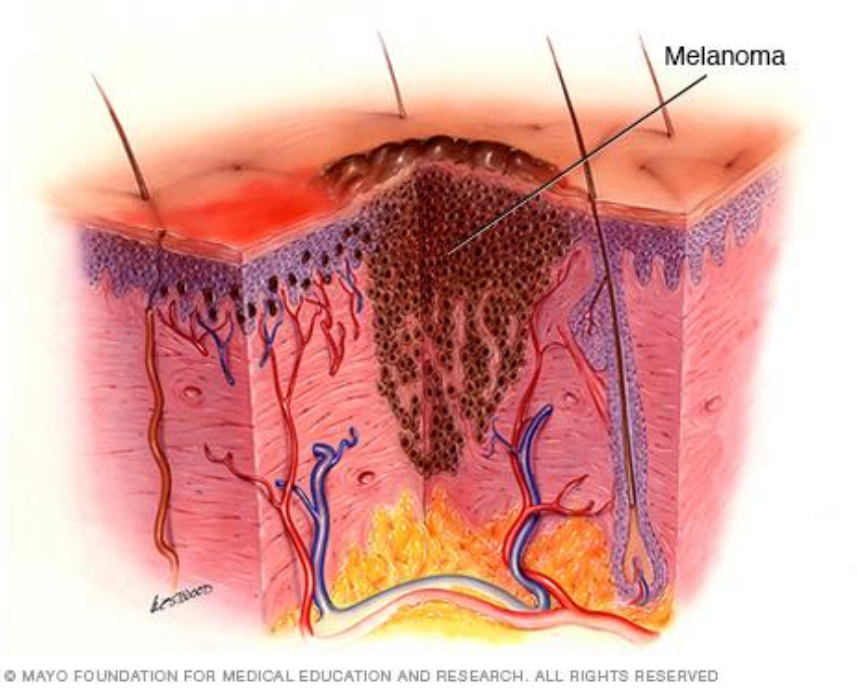
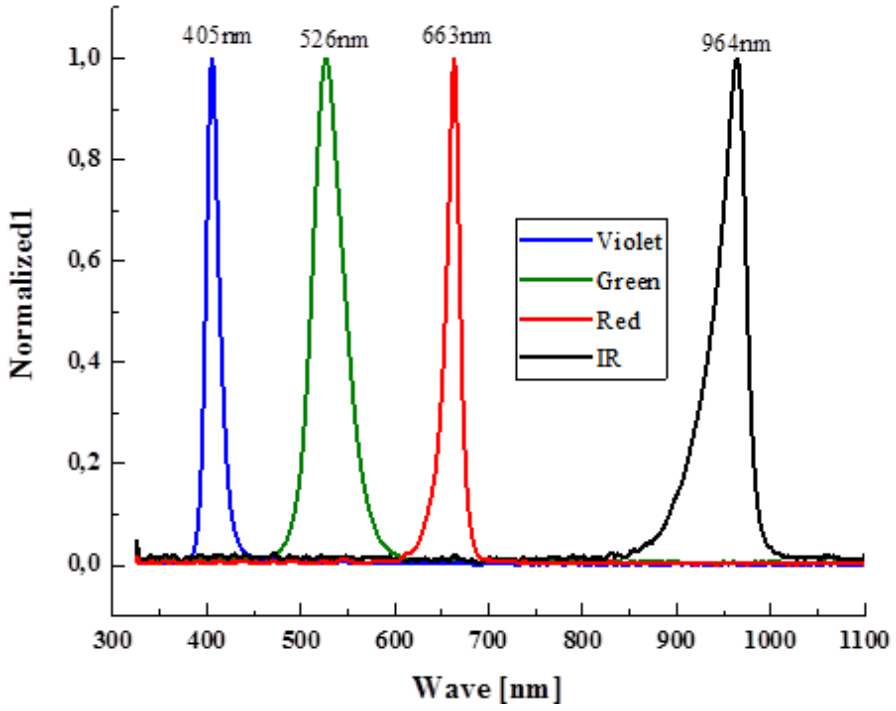
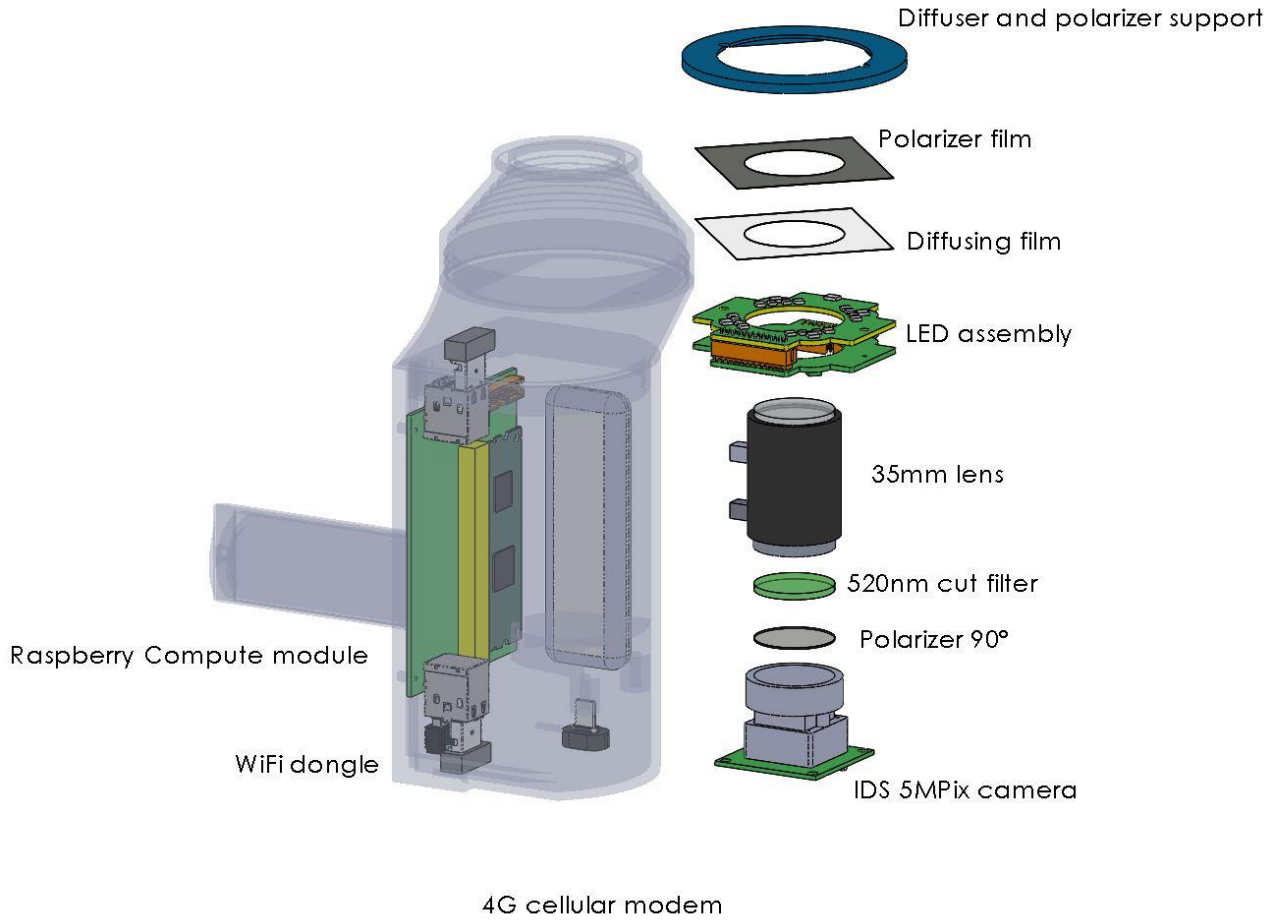
INTRODUCTION

Melanoma is the least common but deadliest skin cancer, accounting for only about 1% of all cases, but is the cause of the vast majority of skin cancer death.



EQUIPMENT AND METHODOLOGY USED FOR ANALYSIS





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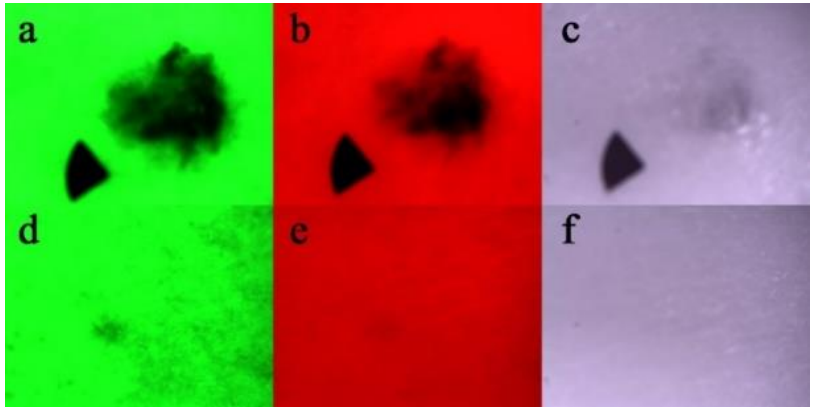
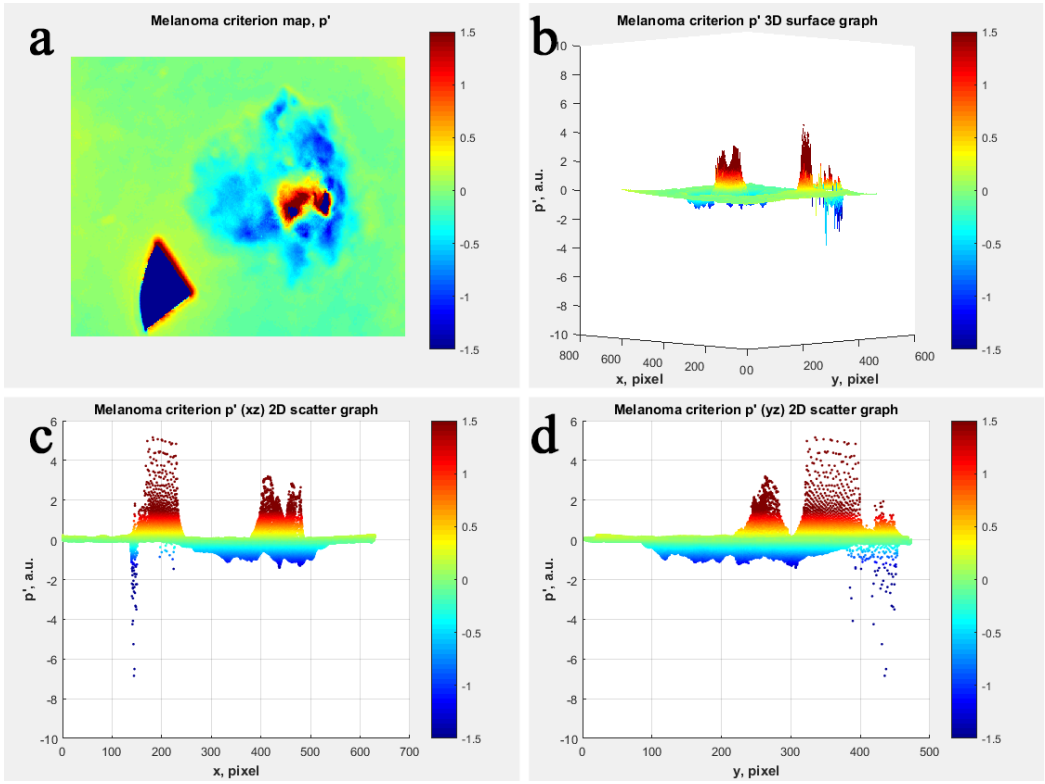


Melanoma criterion calculation method*:

$$p' = \lg\left(\frac{I(526)\cdot I_{skin}(663)\cdot I_{skin}(964)}{I(663)\cdot I(964)\cdot I_{skin}(526)}\right)$$

where

- $I(526)$, $I(663)$, $I(964)$ – reflectance images containing the malformation at 526 nm, 663 nm and 964 nm illumination, respectively.
- $I_{skin}(526)$, $I_{skin}(663)$, $I_{skin}(964)$ – reflectance images containing healthy skin fragment without malformations at 526 nm, 663 nm and 964 nm illumination, respectively.



when p'>0.5 – malformation is considered to be malign melanoma

*Diebele, I., Kuzmina, I., Lihachev, A., Kapostinsh, J., Derjabo, A., Valeine, L., and Spigulis, J., "Clinical evaluation of melanomas and common nevi by spectral imaging," Biomed. Opt. Express 3(3), 467-472 (2012).

PROPOSED METHODS OF MULTISPECTRAL IMAGE PROCESSING AND QUALITY ENHANCEMENT

Quality requirements

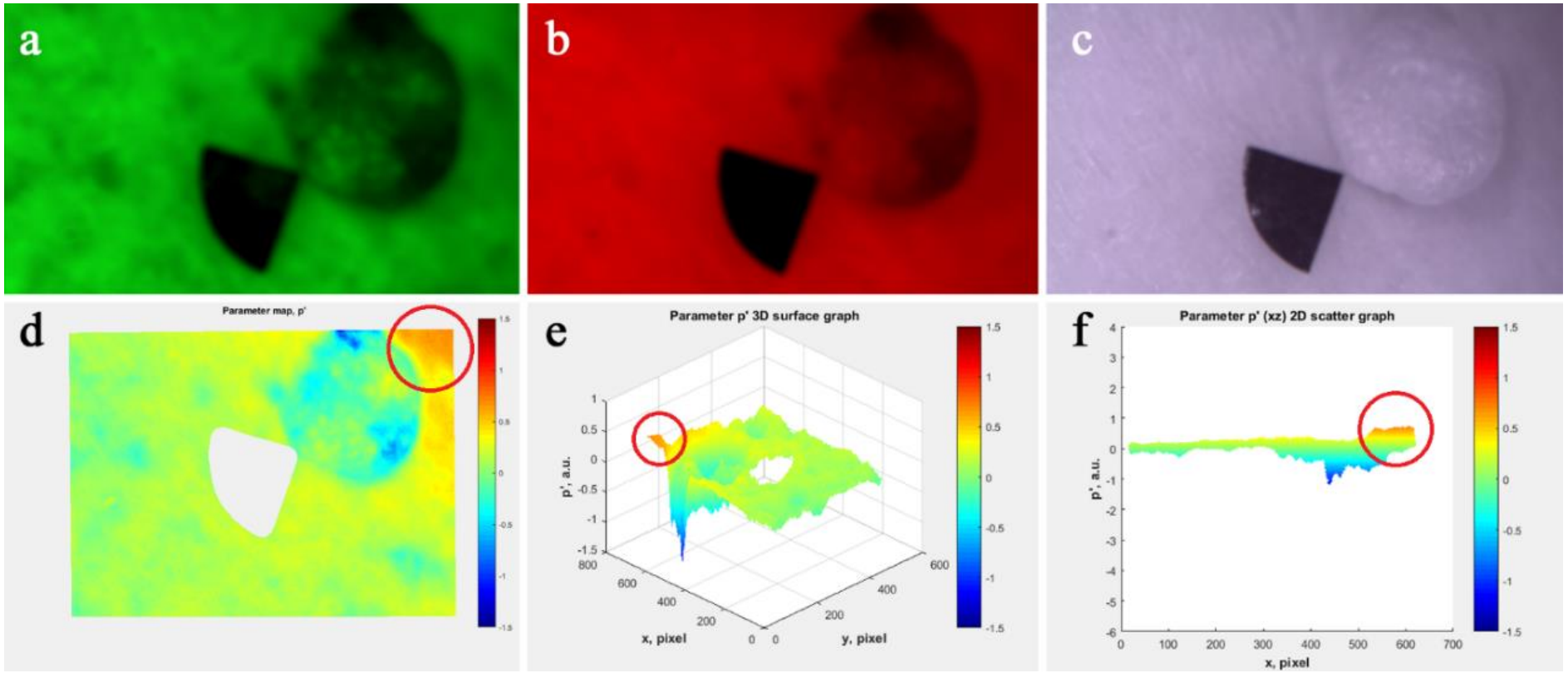
- Even lighting
- No excess non-skin objects
- Aligned images

Proposed methods

- Lightning balance
- Removal of hair
- Marker registration
- Image alignment

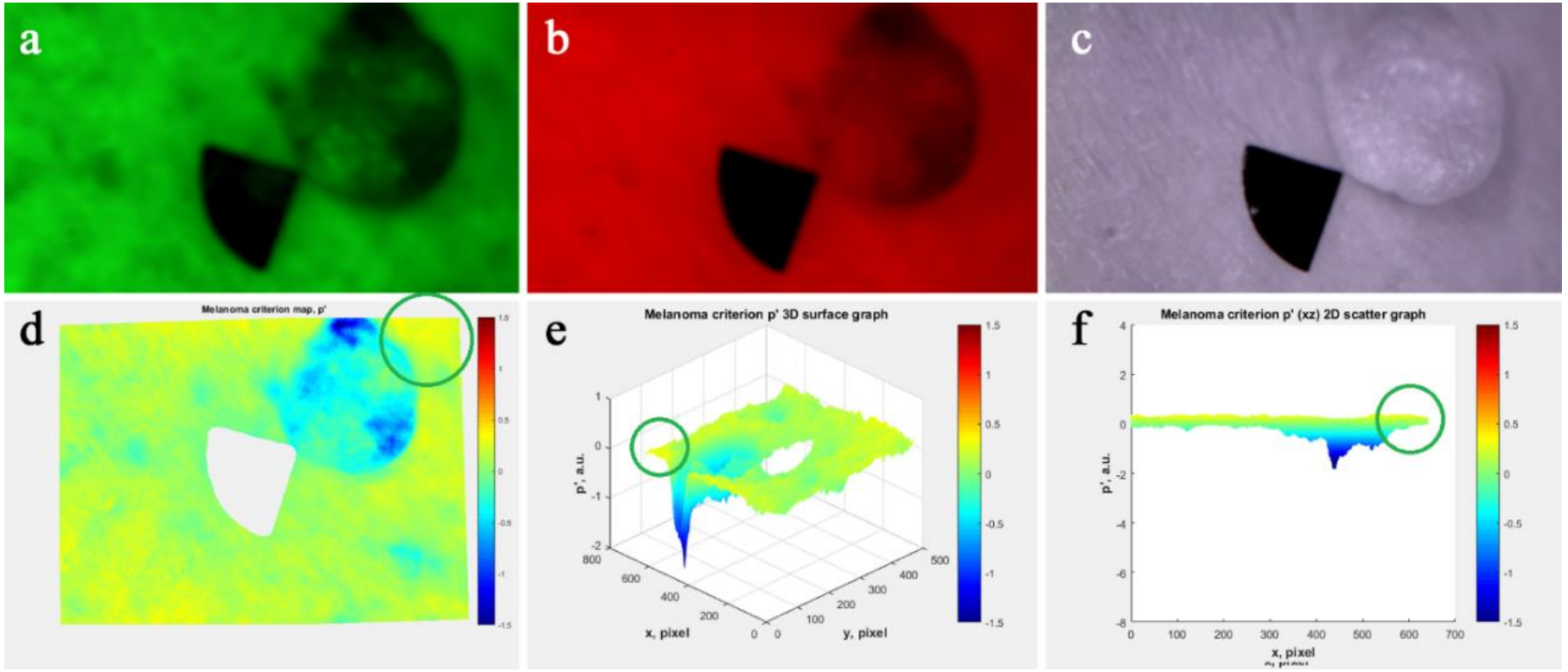
LIGHTING BALANCE

- Problem: uneven lighting affects the melanoma criterion map automatic analysis:



LIGHTING BALANCE

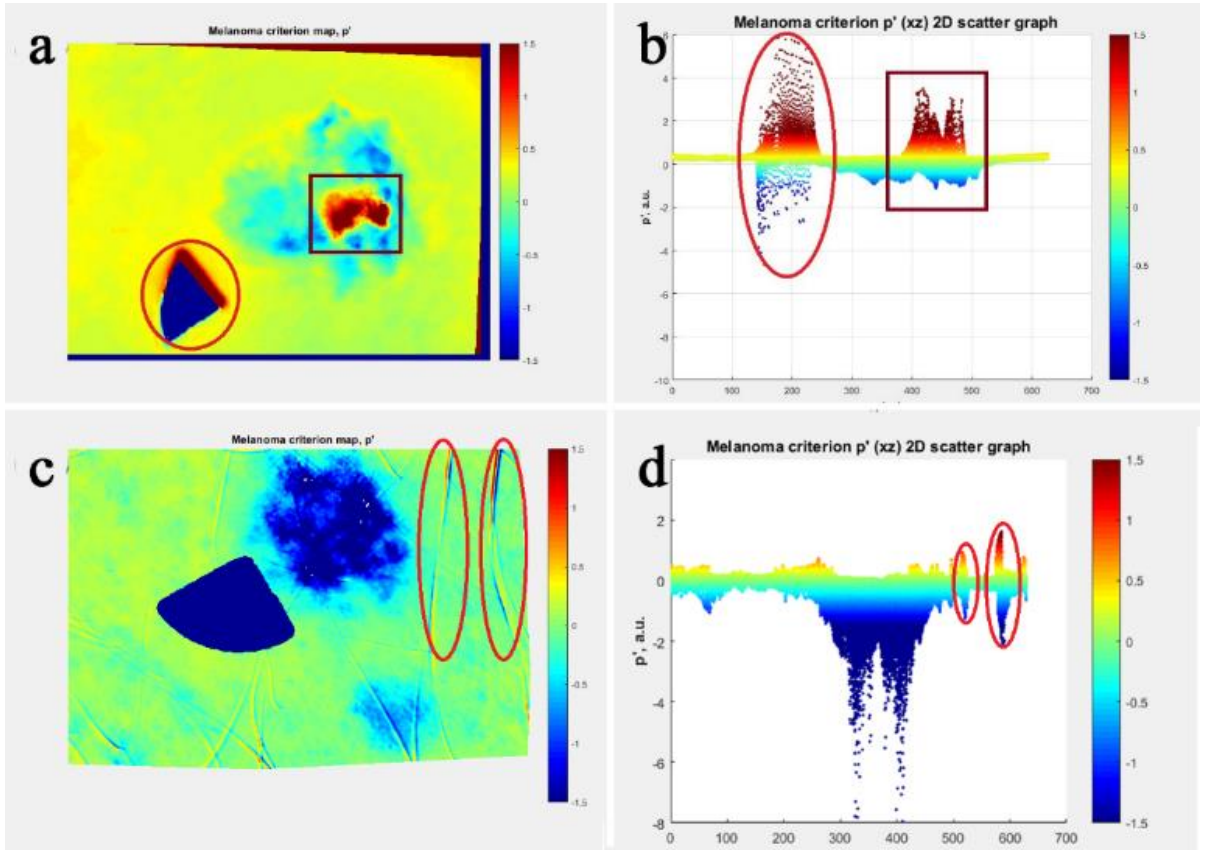
- Solution: to even the lighting in the acquired multispectral images an implementation of a high pass filter* is proposed.



*Makandar, A., Halalli, B., "Enhancement Techniques using Highpass and Lowpass Filters," International Journal of Computer Applications, Volume 109 - Number 14, DOI: 10.5120/19256-0999 (2015)

EXTRACTION OF NONSKIN FRAGMENTS

- Problem: The nonskin fragments affect the calculations of the melanoma criteria parameter:
  - Marker
  - Hair fragments



EXTRACTION OF NONSKIN FRAGMENTS (HAIR)

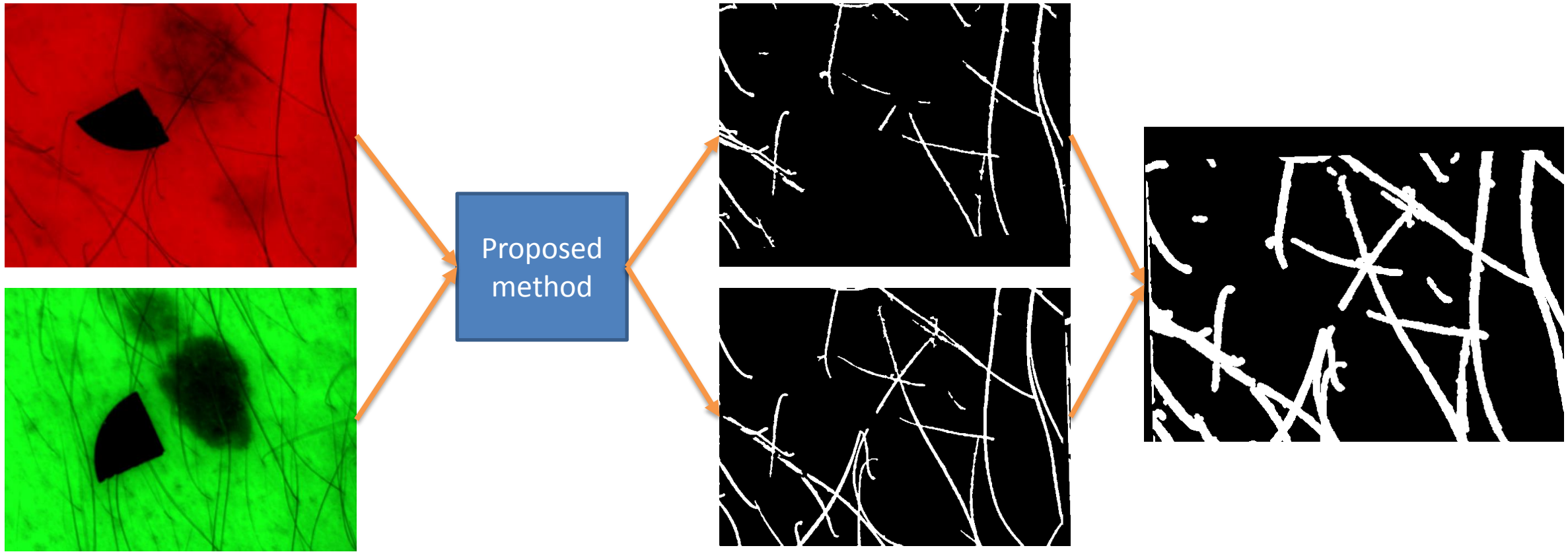
- Proposed method for hair fragments extraction:
  - Red and green spectral images are processed using the Dull Razor* method and two binarized hair region masks for both spectral images are obtained - H_{526} and H_{663}. Then, a resulting hair region mask H is created by merging both hair masks with a logical “OR” operator, adding the masks together:

$$H = H_{526} \,||\, H_{663}$$

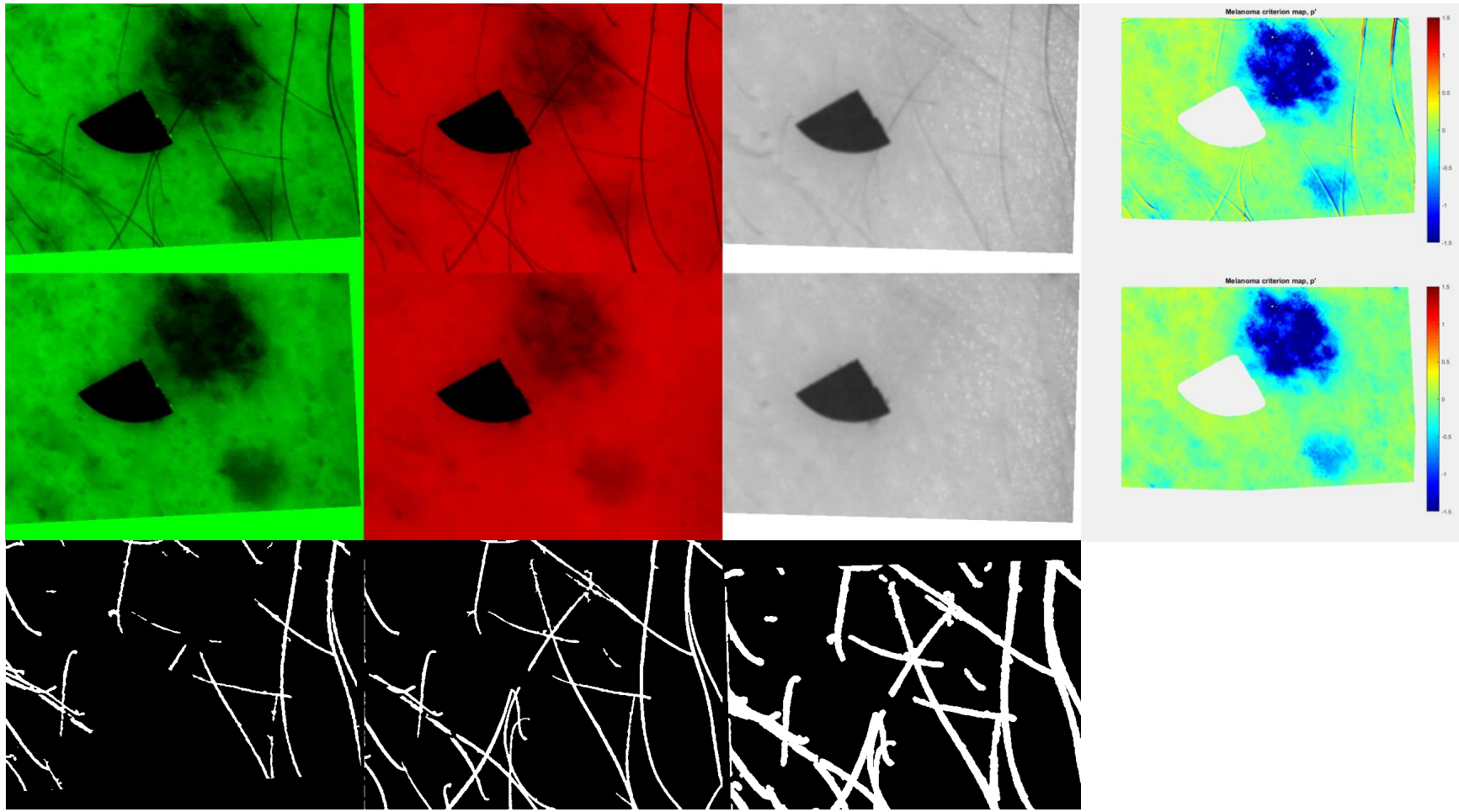
  - The resulting mask H is then dilated by standard means of MATLAB software, to better cover the hair.

*Lee, T., Ng, V., Gallagher, R., Coldman A., McLean D., “DullRazor: A software approach to hair removal from images,” Computers in Biology and Medicine 1997; 27: 533-543 (1997)

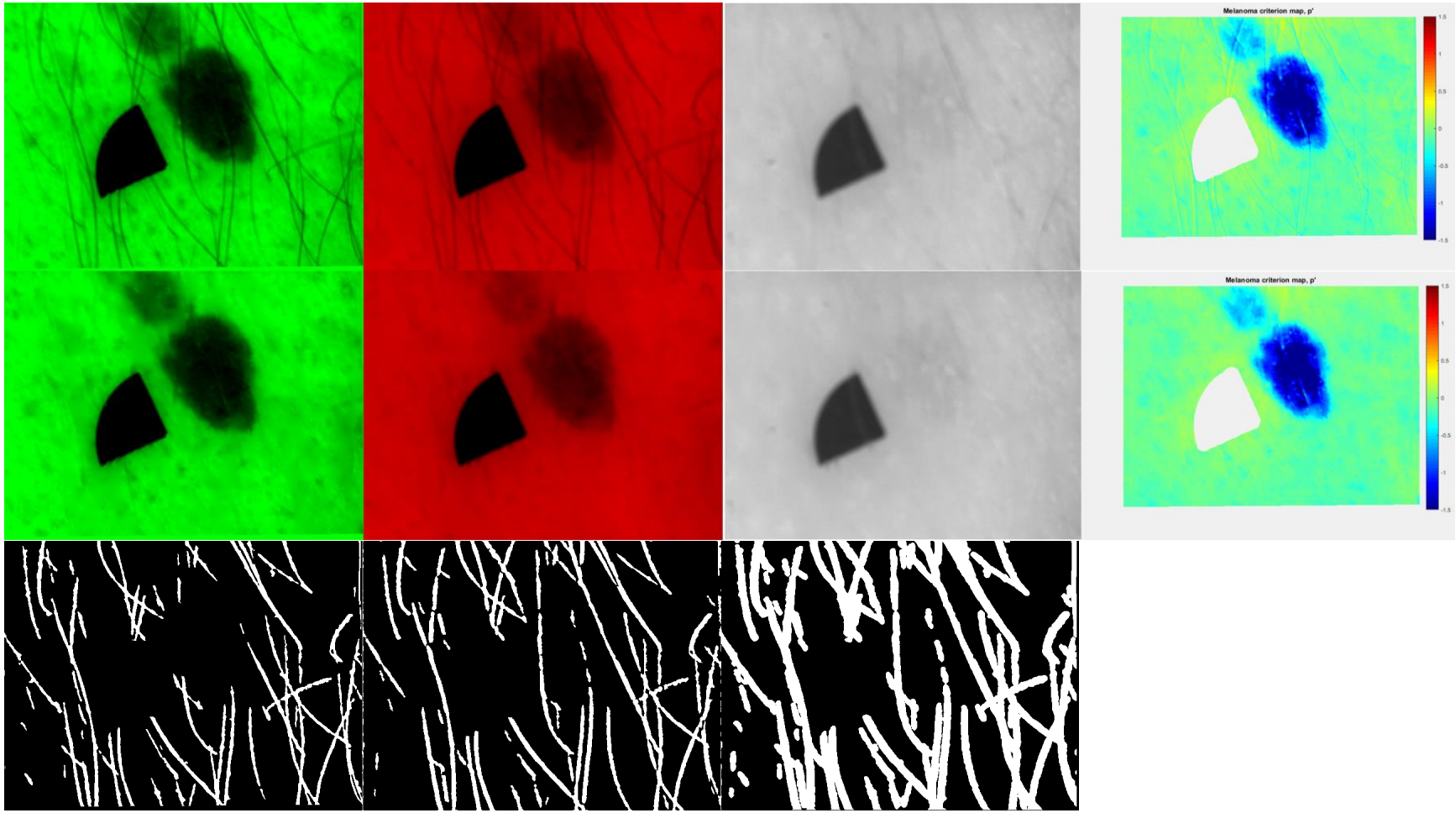
EXTRACTION OF NONSKIN FRAGMENTS (HAIR)



EXTRACTION OF NONSKIN FRAGMENTS (HAIR)



EXTRACTION OF NONSKIN FRAGMENTS (HAIR)



EXTRACTION OF NONSKIN FRAGMENTS (MARKER)

- Proposed method for marker extraction:
  - First, a thresholding method is implemented that allows distinguishing the dark areas (the marker) on the image and a binarized marker mask M_i is obtained:

$$M_i(x,y) = \begin{cases} 1, if\ img_{original}(x,y) < T \\ 0, if\ img_{original}(x,y) \geq T \end{cases}, i = \{526,663,964\}$$

  - The marker is registered on the infrared image, by marking the largest region of interest (ROI) of the binarized mask as the infrared image marker M_{964}.

$$M_{964} = \max(ROI_{964})$$

  - Red and green spectral images are processed by inspecting all the regions of interest and matching them with the infrared image marker M_{964}. The region closest to marker M_{964} in terms of distance and size is selected to be the marker:

$$M_i = ROI_i, \min(|c_{964} - c_i|, |A_{964} - A_i|)\ , \mathrm{i} = \{526,663\}$$

EXTRACTION OF NONSKIN FRAGMENTS (MARKER)

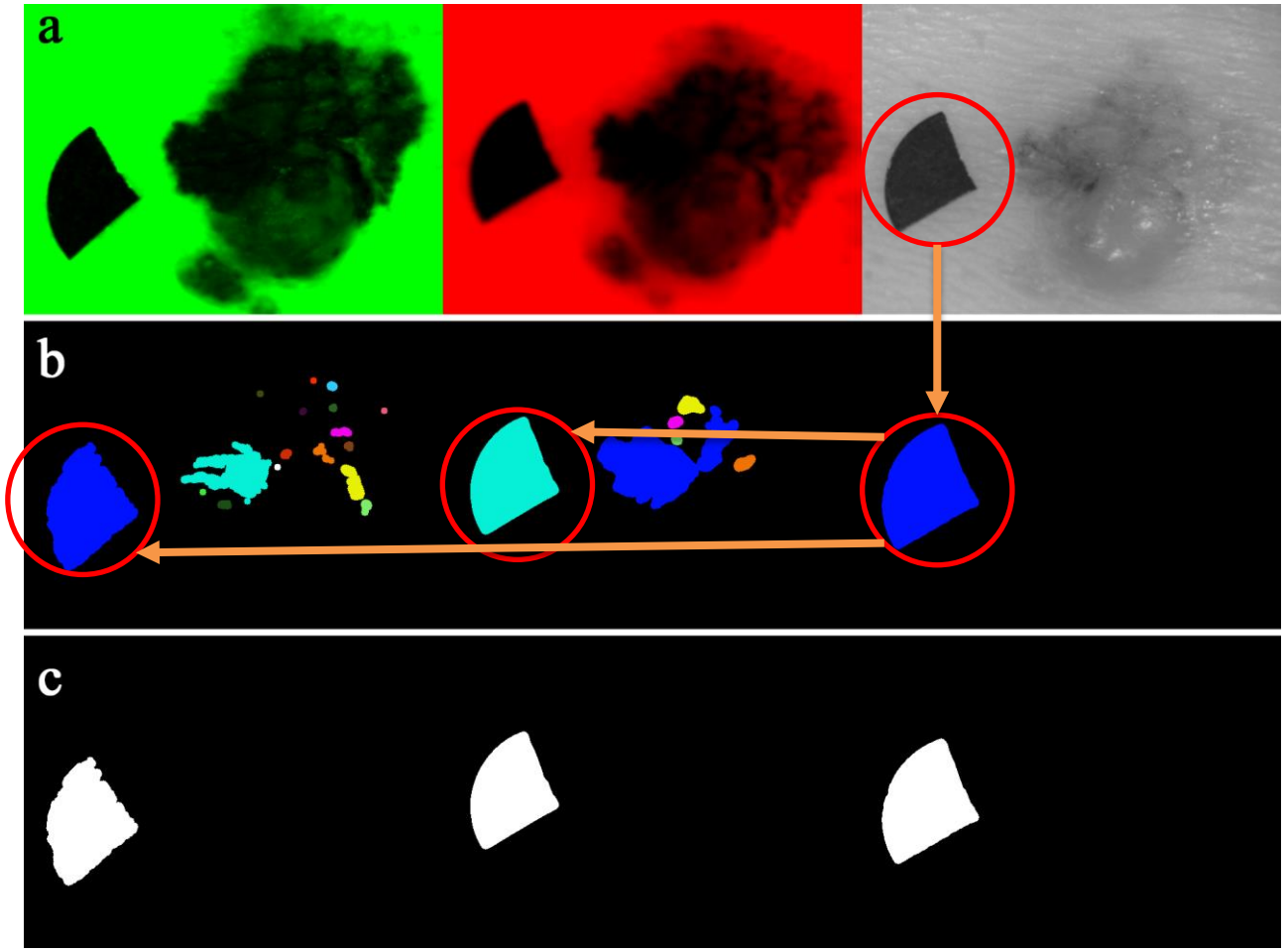


IMAGE ALIGNMENT

- Problem: all three different multispectral images are acquired using one device, but during the process of capturing the images the device may be moved slightly, resulting in distorted positions of the three multispectral images.

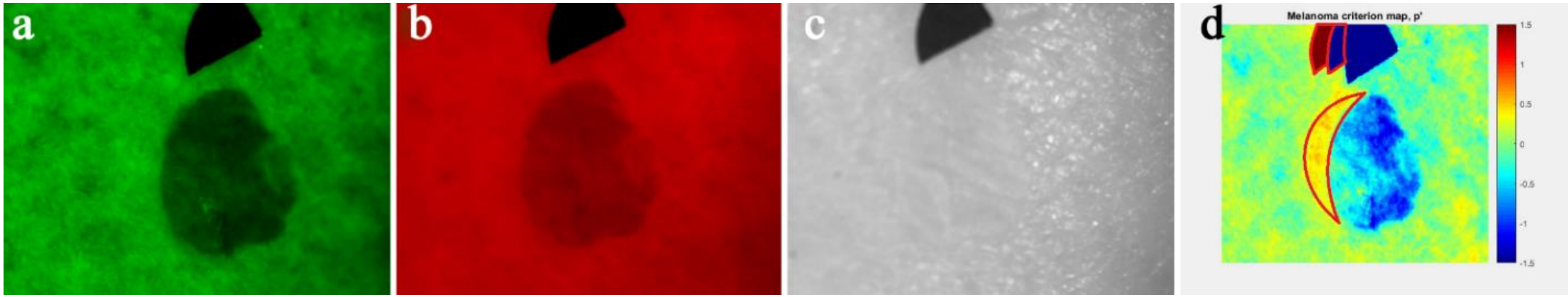


IMAGE ALIGNMENT

- The standard image registration algorithm performs image transformation based on all the information present on the image. But the spectral images may have dissimilar patterns.

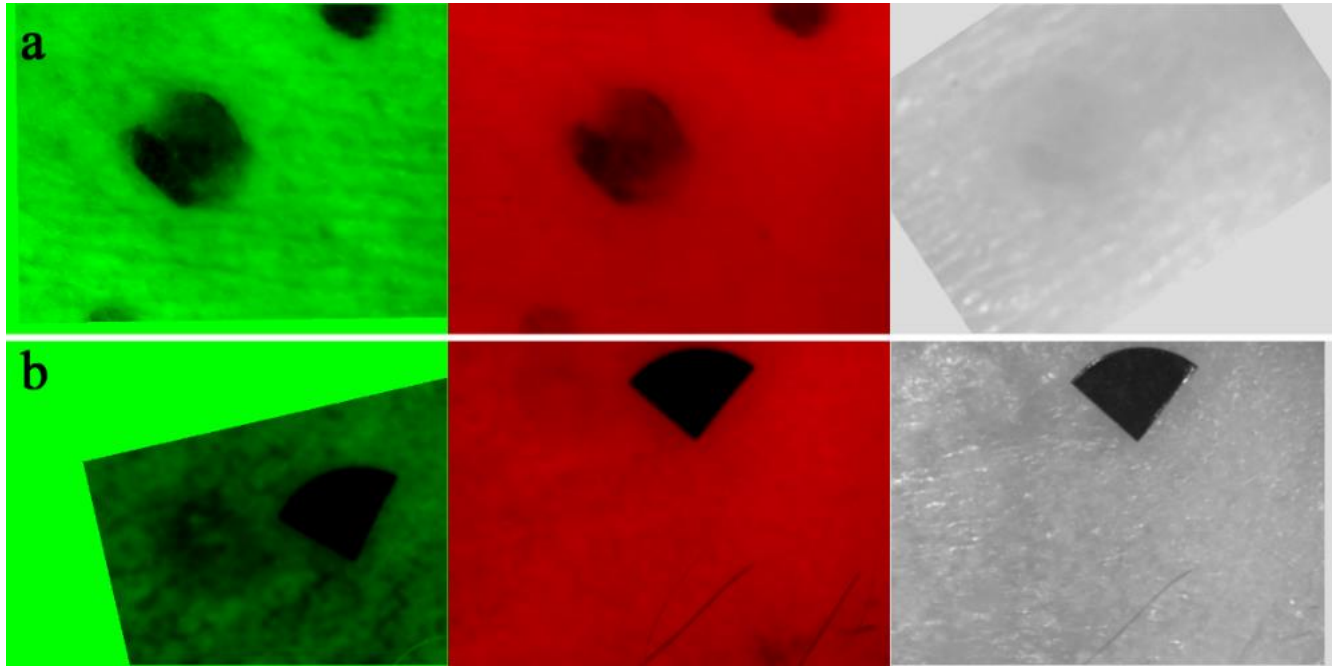


IMAGE ALIGNMENT

- Proposed method:
  - First register the marker on all three images by using the proposed marker registration method and then perform the image alignment using the marker data.
  - The transformation matrix T_{marker} used for marker image transformations is recorded and then implemented on the multispectral images:

$$img_{aligned} = img_{original} \times T_{marker}$$

IMAGE ALIGNMENT

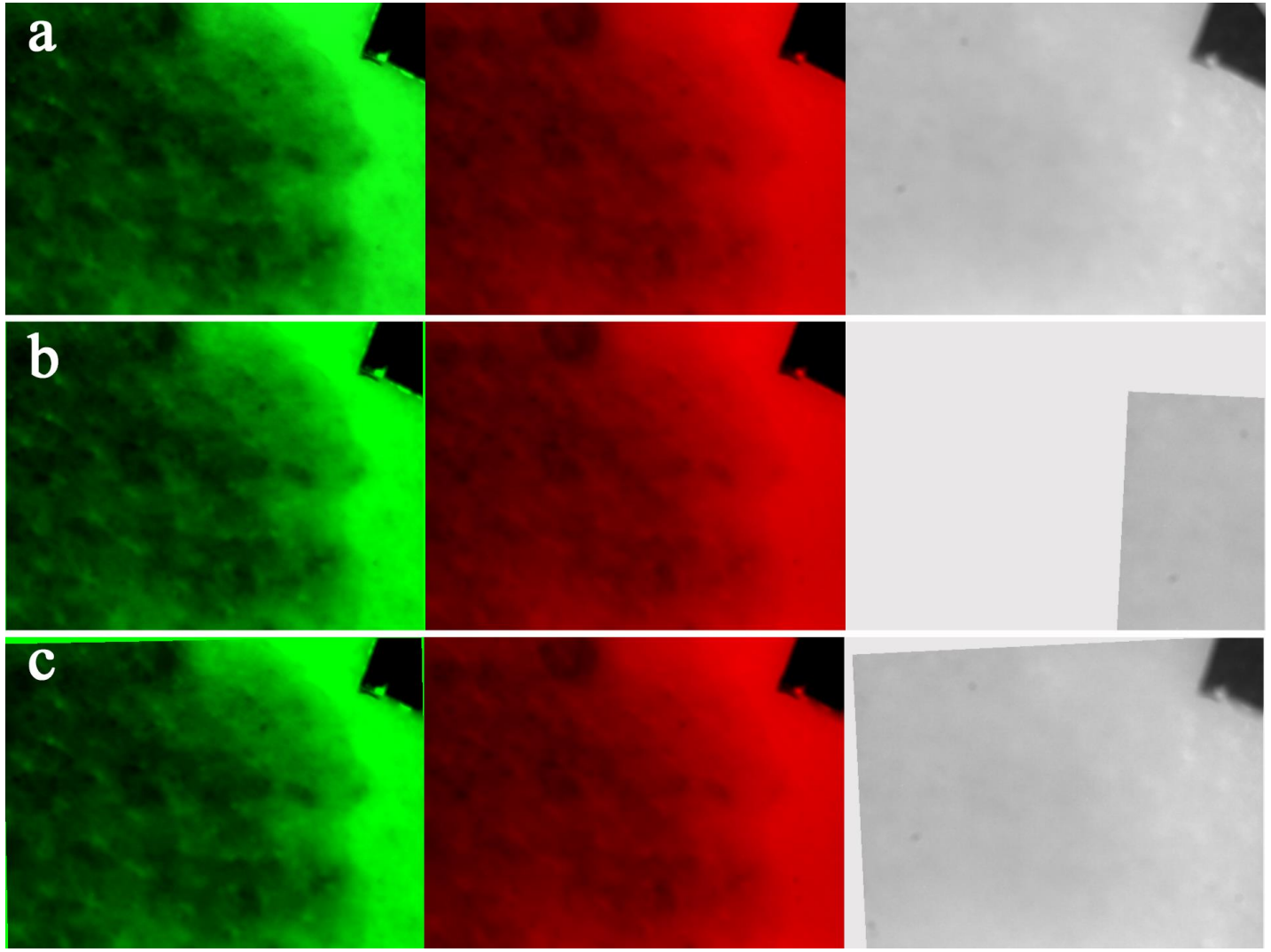
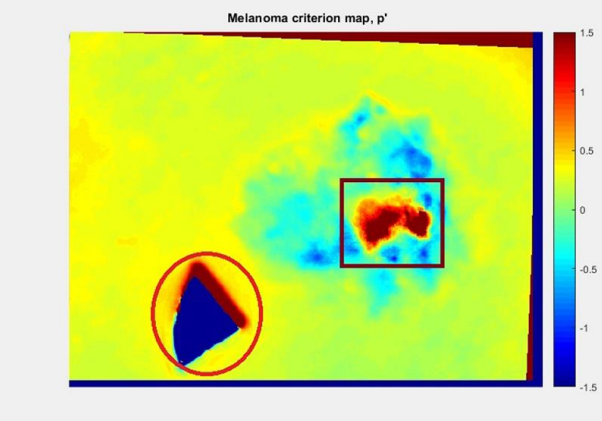
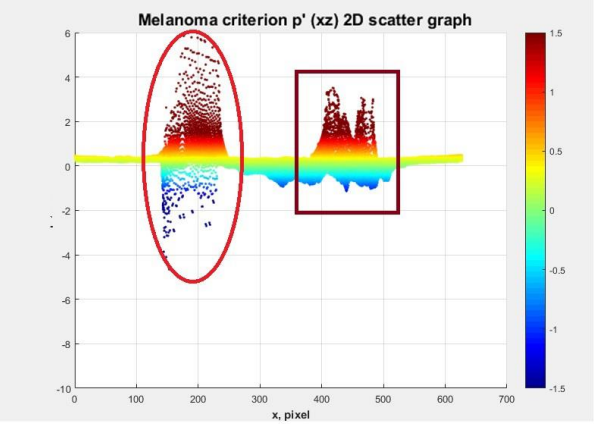
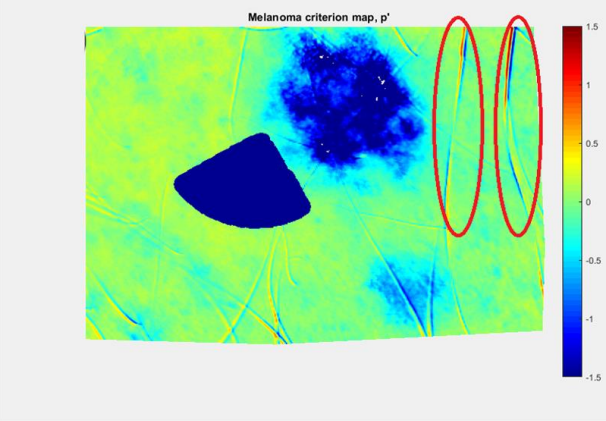
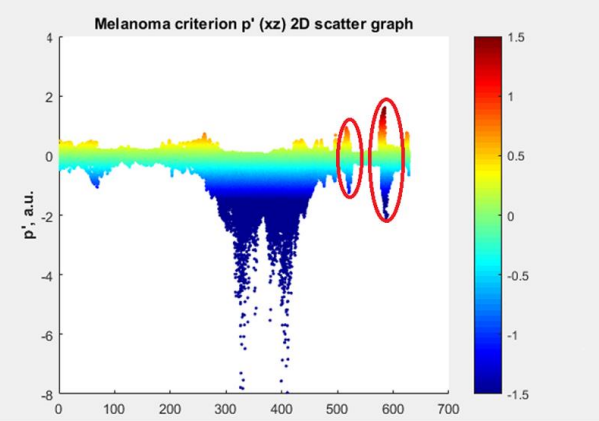


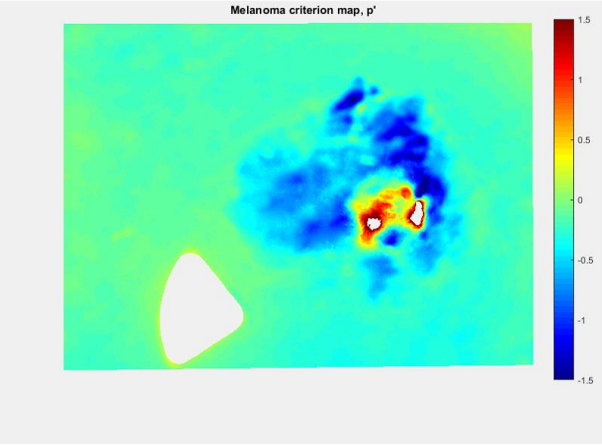
IMAGE PROCESSING METHODS COMBINED RESULTS

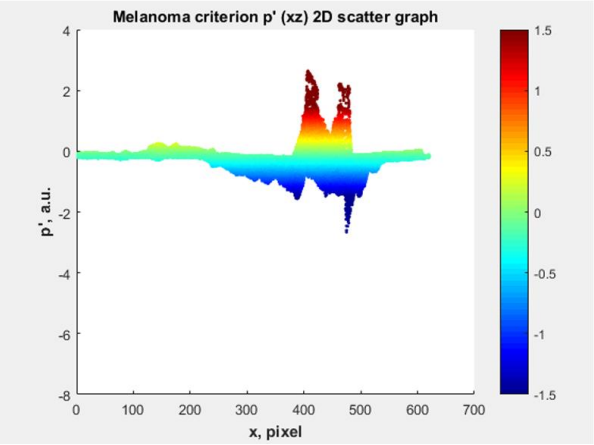


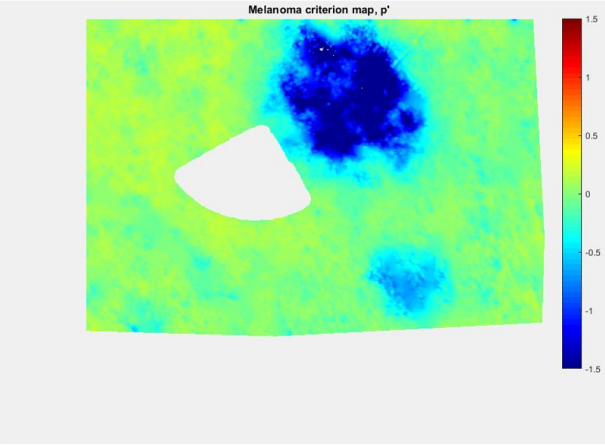


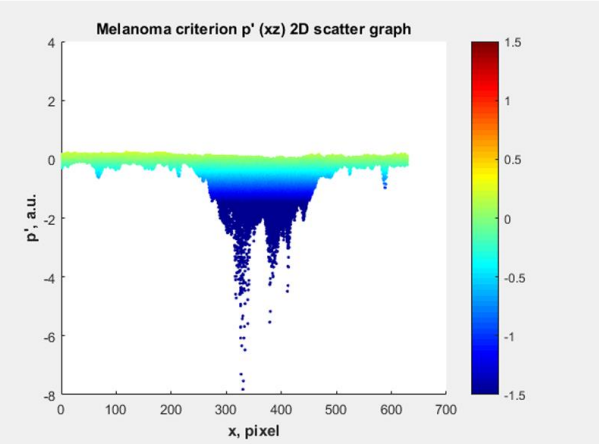












SUMMARY AND DISCUSSIONS

- The complex approach to image processing and quality enhancement was tested on multispectral images of different skin malformations with different image quality problems. The results show that this approach provides additional possibilities to automated multispectral image diagnostics:
  - The method can align the captured multispectral images to minimize the incorrect calculations of the melanoma criterion due to image displacement.
  - The approach allows to eliminate nonskin fragments like hair and marker from the multispectral images, which, in turn excludes different false results of automatic diagnostics, including incorrect registration of hairs and marker as a malign melanoma, due to high melanoma criterion values in these fragments.
  - The balance of lighting also allows to correct the cases where healthy skin is considered to be a malign malformation due to uneven lighting environment of the image.
- The approach did not impact any cases of melanoma in such a way that they would be considered benign malformations.

SUMMARY AND DISCUSSIONS

- Further studies will focus on testing proposed algorithms on larger set of multispectral images, to provide statistically accurate results. The methods of the complex image processing approach will also be enhanced, to improve the results in situations where the methods do not work as intended.
- For example, this includes the presence of extreme amount of hair on the multispectral images. The hair-extraction algorithm is not able to correctly register all the hair, as some hair fragments are visually merged into one region and the resulting segment cannot be correctly registered as long and thin region, a property that is typical to the hair.
- Some additional research is necessary to fully automate the uneven light balance using the high pass filter. Results show that incorrect parameters for the high pass filter may lead to additional distortions in the lighting environment. Further research is also needed to study the sharpening abilities of the high pass filter. The sharpening should be very useful when registering the marker on the image or aligning the images, because the multispectral images are often out of focus and the edges of the marker are blurred. Use of high pass filter may eliminate the blur on the marker and allow more accurate extraction of the marker as well as a more precise alignment of the multispectral images.

Thank you for your attention!

Acknowledgment

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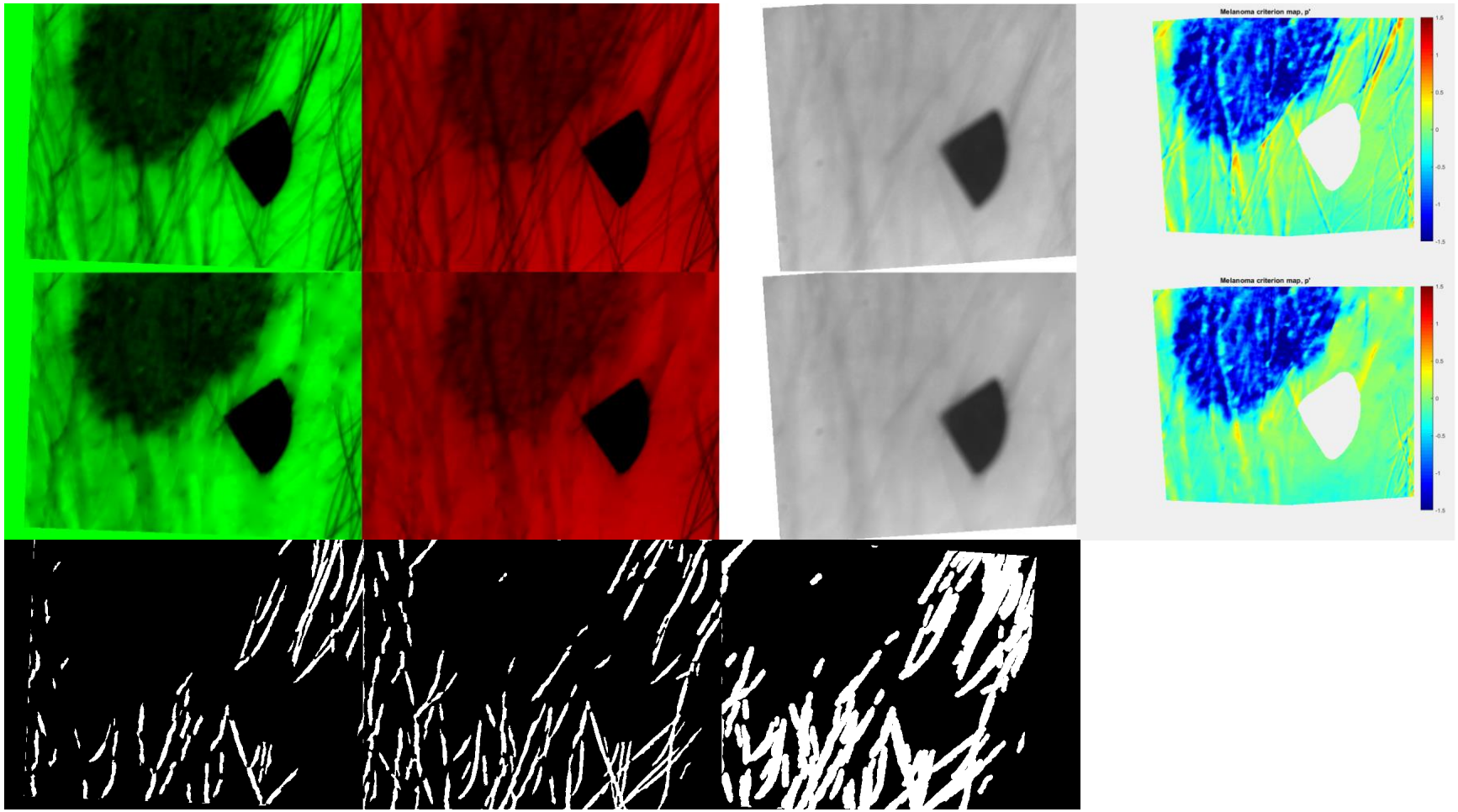
Additional slides for discussion

EXTRACTION OF NONSKIN FRAGMENTS (HAIR) POSSIBLE PROBLEMS DISCUSSION.



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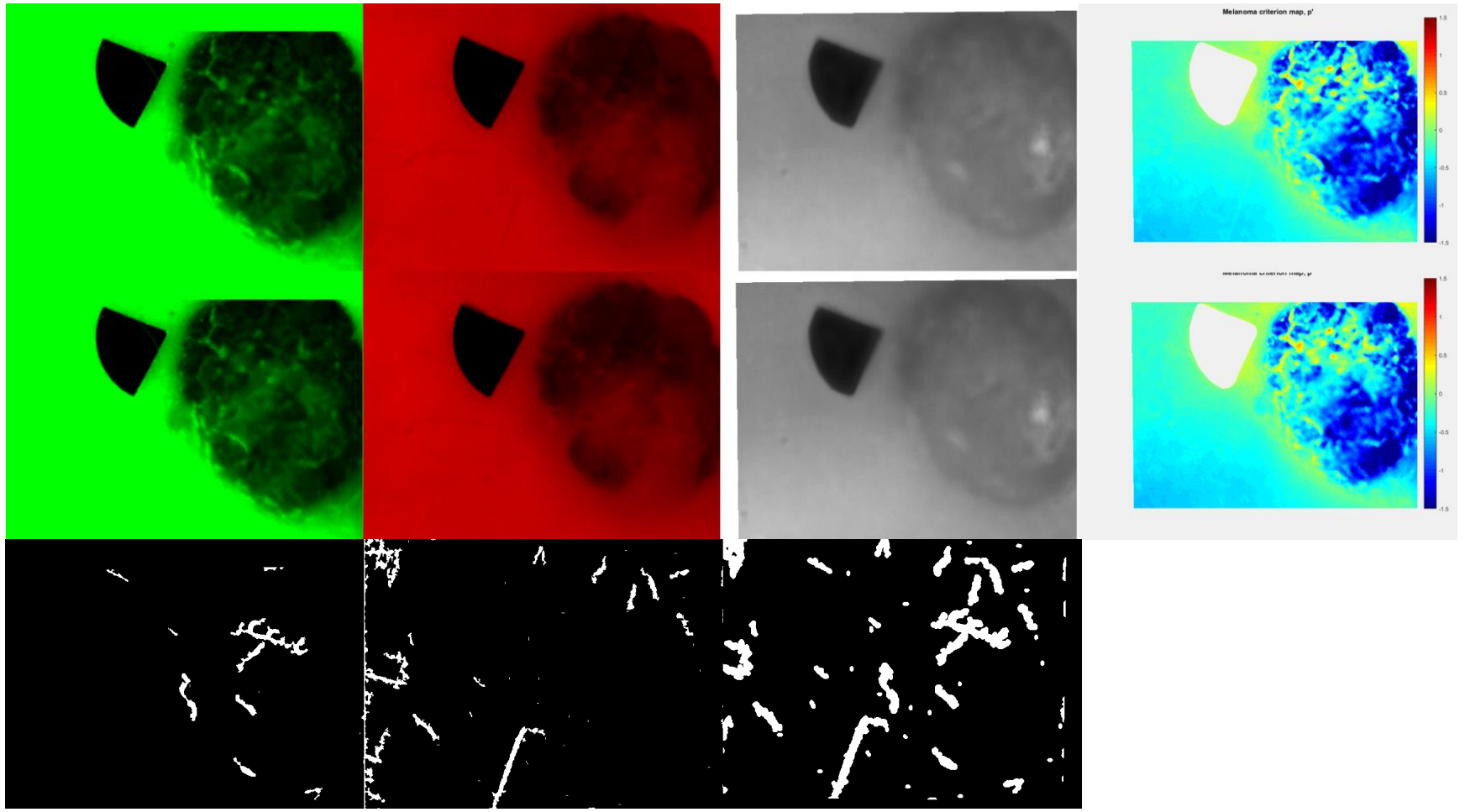

EXTRACTION OF NONSKIN FRAGMENTS (MARKER) POSSIBLE PROBLEMS DISCUSSION.