Evaluation of Hair and Scalp Condition Based on Microscopy Image Analysis

Conference Paper · February 2017

DOI: 10.1109/PlatCon.2017.7883708

6 authors, including:

Hyungjoon Kim
Korea University
13 PUBLICATIONS **34** CITATIONS
SEE PROFILE

Seungmin Rho
Sungkyul University
212 PUBLICATIONS **2,981** CITATIONS
SEE PROFILE

Jisoo Park
Ewha Womans University
16 PUBLICATIONS **49** CITATIONS
SEE PROFILE

Evalution of hair and scalp condition based on microscopy image analysis

Hyungjoon Kim, Woogeol Kim, Jeheok Rew,
Jisoo Park and Eenjun Hwang*
School of Electrical Engineering
Korea University, Seoul, Republic of Korea
{hyungjun89, woogulzzang, rjh1026, jisoo_park,
ehwang04}@korea.ac.kr

Seungmin Rho
Department of Media software
Sungkyul University
Anyang, Republic of Korea
smrho@sungkyul.edu

***Abstract*— Due to the rapid deployment of IT technology, health care service has entered a new era. Some services such as cardiac monitoring are critical for life and have contributed to saving lives. On the other hand, monitoring hair loss is another interesting health care service. Even though it is not critical for life, people tend to pay much attention to their hair condition. Hair loss is one of the major issues related to the hair condition since excessive and uncared hair loss might lead to bald head. Hair care can be done professionally at the hair care shop but it requires much time and cost. Recently, due to inexpensive smart devices, self-diagnosis on the hair condition has become possible. Still, few applications have been developed to evaluate hair condition. In this paper, we propose a new scheme to evaluate the condition of hair and scalp by extracting diverse features from their microscopy image. The features include hair thickness, hair density and scalp blotch. We show the effectiveness of our scheme by extensive experiments on the prototype system.**

Keywords—scalp analysis; microscopy image analysis; feature extraction;

I. INTRODUCTION

Hair loss can occur due to diverse factors, which include genetics, stress, abuse of hair products and poor nutrition. Even environmental changes are reported to cause hair loss [1]. Since excessive and uncared hair loss could lead to bald head, many efforts have been made to remedy or prevent the hair loss. Such efforts include visiting professional hair care shop or using special hair or scalp care products. Since they are usually expensive and inconvenient to the users, there has been an increasing demand for inexpensive and convenient way to monitor hair and scalp condition.

On the other hand, with the popularity of smartphones with decent computational power, various smartphone-based applications have been developed for health care purpose. Their focus was fast diagnosis using cheap equipment. Even though their performance was not that satisfactory compared to the professional services, still they are gaining more popularity due to the convenience and cost effectiveness.

Hence, in this paper, we propose an efficient scheme to automatically analyze hair and scalp condition using cheap microscopy camera. To do that, we first extract three critical features from the hair image, which are hair thickness, hair density and scalp blotch. By performing chronological analysis on the accumulated feature data, we can evaluate the user's hair and scalp condition. The remainder of this paper is organized as follows. In Section 2, we introduce several related works for hair and scalp image analysis. Detailed techniques for hair/scalp image analysis are described in Section 3 and then we explain our prototype system and experiment in Section 4. We conclude this paper in Section 5.

II. RELATED WORKS

In order to analyze the scalp image, hair and scalp should be separated from each other. The most noticeable difference between the two is their color; the scalp is relatively bright, and the hair is relatively dark. Hence, in many studies, hair and scalp areas were classified based on color, and image analysis was done based on this separation.

In [2], Huang addressed three critical issues of hair segmentation and counting and then proposed a new hair-counting algorithm. He showed the algorithm is substantially more accurate than the Hough-based one and robust to curls, oily scalp, noise corruption, and overlapping hairs, under various white balance. In [3], Hayashi et al. developed a quantitative method for measuring hair growth using optical microscopy and image analysis. The hairs were cut from an area 7-8 mm in diameter and 24 h and 72 h later, images of the areas were obtained using an optical microscope and were recorded on a video disc. Then, they measured regrowing hairs using the image analyzer. The length of each hair was measured on the monitor by designating two points with the digitizer. In [4], Hoffmann Rolf presented the TrichoScan as a method that combines epiluminescence microscopy with automatic digital image analysis for the measurement of human being, and potentially animal hair, in situ. The software was developed to analyze hair density, hair diameter, hair growth rate, and anagen/telogen ratio. In [5], Abbas et al. proposed hair detection and repair techniques. The proposed hair removal algorithm consists of hair detection, refinement by morphological techniques and hair repair by fast marching image inpainting technique.

* Corresponding author; Tel.: +82-02-3290-3256

978-1-5090-5140-3/17/$31.00 ©2017 IEEE

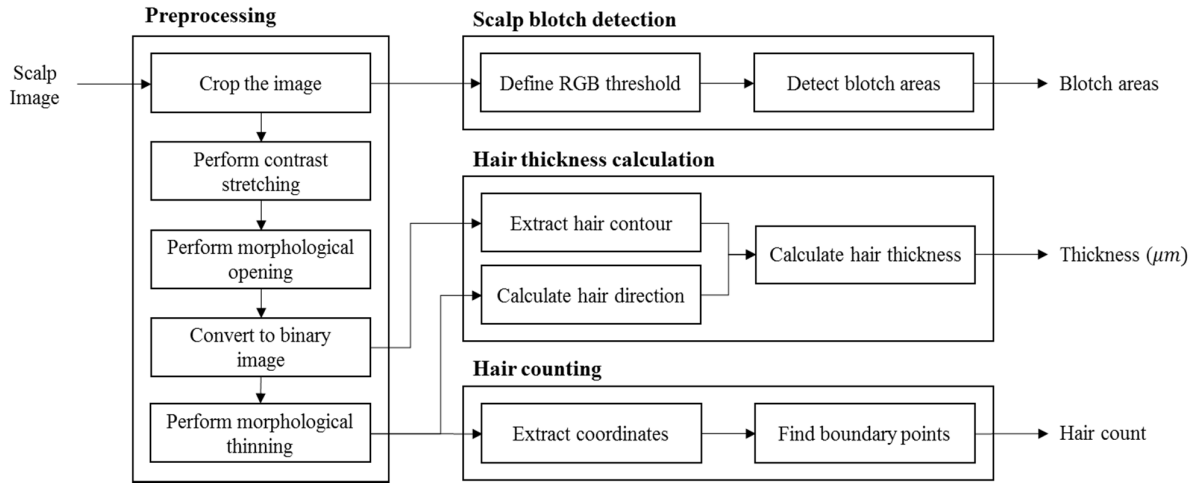


Fig. 1. Overall steps for feature extraction

III. Feature Extraction Scheme

In this section, we describe how to extract hair and scalp features from a microscopy image. To improve the accuracy of feature extraction, we first perform some pre-processing, and then analyze the resulting image for feature extraction. Fig.1 shows the overall steps for feature extraction.

A. Pre-processing

Since RGB-based color images are easily influenced by light source, it is not good to perform feature extraction for the scalp image directly. If so, the image could suffer from diverse problems such as vignetting effect, which could drop the quality of image analysis dramatically. To solve this, original image should be pre-processed appropriately before further processing. For the hair and scalp image, we perform the following pre-processing:

Cropping image: One of the typical problems caused by camera hardware limitation is vignetting effect. Due to the effect, the outer edges of an image is getting darker due to the reduced light in the periphery of camera lens. This problem can be solved by concentrating on the center of the image and cropping the boundary of the image out.

Contrast stretching: Hair area and scalp area can be effectively separately by utilizing their color contrast. However, in many cases, color contrast of original image leads to some ambiguity due to diverse noises such as moles, red blotches and wrinkles. This problem can be solved effectively by using contrast stretching, which expands the dynamic range of the intensity levels allowing it to span the color distance between hair and scalp.

Morphological opening: The oily and moist hair makes bright spots in its microscopy image. This is due to the light reflection of the microscopy camera. However, those bright spots would give incorrect result during the feature extraction. This problem can be solved by using morphological opening approach, which is derived from the fundamental operations of erosion and dilation.

Binarization: After aforementioned pre-processing, the resulting image is converted into gray-scale image, and then into binary image based on Otsu threshold [6]. In the binary image, '0' and '1' denote hair pixel and scalp pixel, respectively.

B. hair/scalp image analysis

Hair detection: Hair contour can be acquired from binary image by using Canny edge detection algorithm [7]. Fig.2 shows all the steps for detecting and modeling hairs. For the original microscopy image in Fig.2 (a), we can calculate hair contour and skeleton. In particular, hair skeleton is calculated by using the thinning operation on the binary image. Thinning [8] is a morphological operation that removes foreground in overall binary image. Fig.2 (d) shows the final image by superimposing hair contour and skeleton.

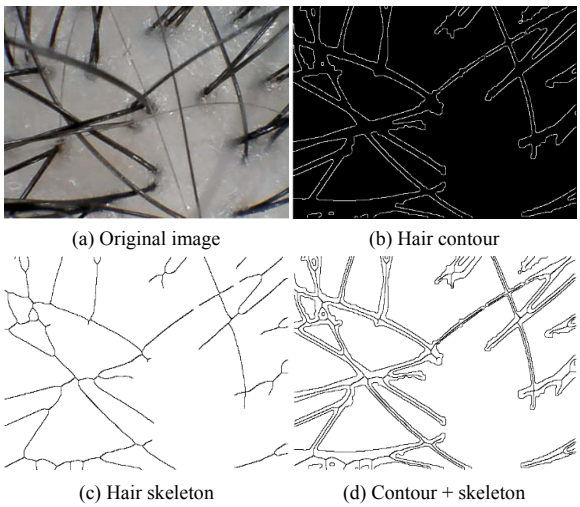


Fig. 2. Example of hair detection

Hair thickness calculation: Hair thickness can be defined by the length of perpendicular line to the hair. To get the perpendicular line, we first need to calculate the hair direction.

We calculate the direction of each pixel by considering its neighboring pixels and applying PCA (Principal Component Analysis) algorithm [9].

When the direction is calculated for all the points on the hair skeleton, the perpendicular line for each point can be calculated. Then, the distance between the intersection points of the perpendicular line and the hair boundary is the thickness of the hair and can be calculated by using Euclidean distance as shown in Eq. (1). Based on the distance, we can calculate average hair thickness using Eq. (2).

$$Thickness_{avg} = \frac{1}{n}\sum_{i=1}^{n}\sqrt{(x_{i1}-x_{i2})^2+(y_{i1}-y_{i2})^2} \quad (1)$$

Here, the unit of $Thickness_{avg}$ is pixel thus it needs to be changed into the meter unit using Eq. (2) as shown below.

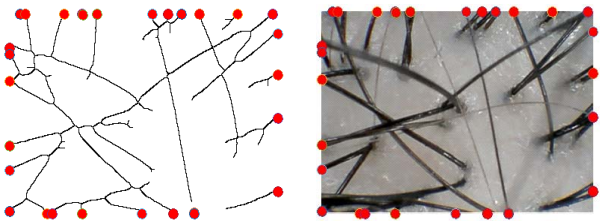
$$Thickness_{actual}(um) = \frac{Thickness_{avg}(px)\times UL(um/px)}{mf} \quad (2)$$

Where mf is the magnification of camera and UL is the unit length which indicates the micrometer length of one pixel.

Hair counting: Typical portable microscope camera generally covers a rectangle of 5mm x 5mm. Thus, if a hair is longer than 5mm, it must go beyond the rectangle. Based on this observation, we made two assumptions for hair counting.

1. Each hair is represented by one start point and one end point.
2. The start point is positioned inside the rectangle, and the end point is positioned on the boundary of the image.

For hair counting, we use the skeleton image that was obtained by thinning operation. Based on the assumptions, we count the hair if one point of its skeleton line is inside the rectangle and the other point is on the boundary. Fig.3 shows an example of hair counting. In the figure, the counted pixels are marked with red dots and those dots are superposed onto the original image. Then, hair density can be calculated by dividing the number of counted pixels by the image dimension.



(a) Counted hairs (b) Superposed onto image

Fig. 3. Example of hair counting

Scalp blotch detection: Blotches on the scalp are usually reddish. In the dermoscopy image, their R values are larger than those of G or B. Therefore, if points in a specific region have largest R value, the region might represent a blotch region. Fig.4 (b) shows an example of scalp blotch. However, the fact that R value is largest doesn't necessarily represent a blotch. For instance, Asians have a scalp with a relatively large R value in the microscopy image even though they don't have blotches as shown in Fig.4 (a). Therefore, it is necessary to establish a guideline by which the reddish area can be counted as a blotch.

(a) Normal scalp (b) Scalp blotch

Fig. 4. RGB values vs red blotch

First, a blotch region is always on the scalp, thus we only consider scalp in the original image for blotch detection. To do that, we consider coordinates of the original image and binary image together. For instance, if a point in the binary image is 0, the point is considered to correspond to a hair. If the point is 1, then it belongs to a scalp. Based on this, we can extract scalp area from the original image. Secondly, since each pixel of the original color image has R, G, B values, we can calculate the average of R values, R_{avg}. Third, for all the points in the image, if the R value of a pixel (i, j) is bigger than R_{avg} and the point is not in the hair area, then the point is considered as a blotch candidate. Lastly, for the candidate points, we calculate the ratio of R and G and test if G/R < 0.85. Likewise, we calculate the ratio of R and B and test if B/R < 0.8. If the point satisfies these two conditions, then the point is considered to be in the blotch area. Two threshold values 0.85 and 0.8 are decided experimentally. For instance, in Fig.4 (a), R and G, B values of marked points have no significant difference, and their ratios are bigger than 0.9. Whereas, as in the Fig.4 (b), R values of pixels in the blotch area are bigger than their G or B values.

IV. Experiment

In order to evaluate the performance of our proposed scheme, we built a prototype system based on the scheme. The system is implemented using Matlab R2013a. The test images were made using x50 microscopy camera compatible with smartphone as shown in Fig.5 (a), Fig.5 (b) shows the electron microscope for measuring actual hair thickness.

(a) Portable camera (b) Electronic microscope

Fig. 5. Equipments for experiment

We constructed a dataset of scalp images from 50 subjects aging from 20s to 50s. To measure the accuracy of our hair thickness evaluation method, we pulled out 4 hairs per persons and took 3 microscopy partial images of start, middle and end portion of each hair. So, thickness was calculated for a total of 600 hair portions. For hair counting, 4 scalp images were captured per person, so total 200 samples were tested.

A. Thickness

To evaluate the accuracy of our hair thickness evaluation method, we measured actual hair thickness using electronic microscope. The accuracy of hair thickness measurement is shown in Table 1. The average hair thickness of Koreans is reported to be 84.9μm [10]. Compared with this, our result of 90.29μm is reasonably good. There is small difference between actual (calculated by electron microscope) and estimated values. One possible reason is the shadow effect. Another possible reason is the camera lens distortion. The image has 640*480 size. However, the real shape of the area covered by the camera is almost an ellipse. Thus, camera magnification has difference between rows and columns. Depending on the shot angle, magnification could be different.

TABLE I. AVERAGE HAIR THICKNESS AND ERROR RATE

	Actual	Estimated	Error rate	Accuracy
Average	85.91 μm	90.29 μm	5.10%	94.90%

B. Hair Counting

In order to evaluate our hair counting algorithm, we performed an experiment for the dataset of 200 scalp images. Table 2 shows the result of precision/recall between actual number of hairs and estimated number of hairs calculated by our algorithm. The average precision and recall were 91.35% and 92.01%, respectively. Even though the performance is quite good, the precision/recall can be improved further. One critical reason for the error is preprocessing and the quality of original image. In our experiment, once the image has a blurred spot in the image, it is not possible to remove all the noises in the preprocessing step. Therefore, considering the camera noise, the accuracy is very good. Similarly, we tested our hair pore counting algorithm, and the result shows about 90% of average accuracy rate.

TABLE II. PRECISION AND RECALL OF HAIR RECOGNITION

Precision	Recall
91.35%	92.01%

C. Scalp blotch detection

To measure the accuracy of detecting reddish blotches on the scalp, we performed an experiment for 150 blotch images from 30 subjects and 200 normal images from 40 subjects. As shown in the Table 3, most of scalp blotches in the images were detected. Relatively low recall score was caused by a few subjects with reddish scalp even though they didn't have blotches. This phenomenon happens frequently for reddish scalp image. Since our method is based on R, G, B values, subjects with comparatively red skin color tend to have higher R value.

TABLE III. PRECISION AND RECALL OF DETECTING SCALP BLOTCH

Precision	Recall
93%	87.5%

V. CONCLUSION

In this paper, we proposed an efficient scheme for extracting hair/scalp features from microscopy images. The features include average hair thickness, hair density, and scalp blotches. In order to improve the quality of hair/scalp image for feature extraction, extra works were carried out during the pre-processing.

To measure the performance of our proposed scheme, we implemented a prototype system and carried out several experiments for the images collected from subjects using cheap microscopy camera attachable to smartphone. We measured the performance of our feature extraction scheme by calculating error rate and precision/recall. Overall, our scheme showed very good performance.

ACKNOWLEDGMENT

This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (No. R0190-16-2012, High Performance Big Data Analytics Platform Performance Acceleration Technologies Development).

REFERENCES

[1] ″Alopecia Market Analysis By Treatment (Oral, Topical, Injectable), By Gender (Men, Women) And Segment Forecasts To 2024," Market Research Report, 6. 2016.

[2] H. Chia, "An Unsupervised Hair Segmentation and Counting System in Microscopy Images," IEEE Sensors Journal, Vol. 15, No. 6, pp. 3565-3572. 2015.

[3] S. Hayashi et al. "Measurement of human hair growth by optical microscopy and image analysis," British Journal of Dermatology, Vol. 125, No. 2, pp. 123-129, 1991.

[4] H. Rolf, "TrichoScan: a novel tool for the analysis of hair growth in vivo," Journal of Investigative Dermatology Symposium, Vol. 8, No. 1, pp. 109-115, 2003.

[5] A. Qaisar et al. "Hair removal methods: a comparative study for dermoscopy images," Biomedical Signal Processing and Control, Vol. 6, No. 4, pp. 395-404, 2011.

[6] N. Otsu, "A threshold selection method from gray-level histograms," Automatica, Vol. 11, No. 23-27, pp. 285-296, 1975.

[7] J. Canny, "A computational approach to edge detection," IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 8, No. 6, pp. 679-698, 1986.

[8] L. Lam, "Thinning Methodologies-A Comprehensive Survey," IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 14, No. 9, pp. 869-885, 1992.

[9] Y. S. Lee et al. "A straight line detection using principal component analysis," Pattern Recognition Letters, Vol. 27, No. 14, pp. 1744-1754, 2006.

[10] G. S. Choi, "Hair characteristics and androgenetic alopecia in Koreans," Journal of the Korean Medical Association/Taehan Uisa Hyophoe Chi, Vol. 57, No. 1, 2014