Quantitative assessment of female pattern hair loss

Pei-Kai Hung1, Chun-You Liu1, Chia-Yun Hsu1, Chien-Wei Kung1, Ren-Yeu Tsai2, Sung-Jan Lin1 and Chung-Ming Chen1,

1Institute of biomedical engineering, National Taiwan university, Taipei, Taiwan
2 Department of Dermatology and Skin Laser Center, Taipei Municipal Wan-Fang Hospital, Taipei Medical University, Taipei, Taiwan

Abstract - Conventional diagnosis of female pattern hair loss is based on visual inspection of the images exhibiting baldness scalp. However, different medical doctors may come up with different severity grading due to the inherently subjective decision process. In this study, the appearance of baldness area is summarized into a quantitative descriptor, i.e., baldness width, by applying a level-set scheme and the principal component analysis. This descriptor is extracted to estimate the baldness severity and its diagnostic accuracy (82.9%) is validated by using the leave-one-out cross-validation method. It is expected that by monitoring the changes in baldness width, both prognosis and follow-up study of female pattern hair loss treatment can be reasonably assessed.

Keywords: female pattern hair loss; baldness width; quantitative analysis;

1 Introduction

Female pattern hair loss (FPHL) is a common term for the decrease in central scalp hair density that occurs in many females. Typical features of FPHL are miniaturizations of affected hairs and decreases in central scalp (vertex, mid and frontal), bitemporal and parietal regions [1]. In FPHL patients, the baldness area, where poor hair coverage is found, is exhibited around the midline scalp. In clinical practice, the severity of FPHL is graded by visually inspecting the baldness area, including the exposed scalp and nearby non-vellus hair, which are fine, short, brittle, and may be the same color with pale skin or scalp,. By measuring the baldness area, the conventional grading method for severity of the FPHL is based on the Ludwig or Savin scales [2, 3]. Another important clue, hair loss at midline scalp, was discovered and applied in Olsen’s work [4]. It is also revealed that midline hair loss in “Christmas tree” pattern is unique for FPHL.

Although the Ludwig and Savin scales are widely accepted, there are still two unavoidable defects: (1) cameras may capture FPHL images with different photographic conditions, such as exposure rate, and (2) every single grading simply depends on the physician’s subjective decision. As a result, one single image may easily have diagnostic discrepancy among physicians. And, one camera operates in standard circumstance but captures images with different photography contrast and brightness. Therefore, normalization for all FPHL images is required to prevent inconsistent diagnosis of the FPHL images.

To build up an objective scaling of FPHL, in this paper, we propose a baldness width measure to characterize the baldness area. The goal of this study is to develop a lookup table that objectively describes and classifies the severity of FPHL in the hope of achieving adequate consistency and accuracy, both for diagnoses and follow-up assessments of treatment response.

2 Material and Method

2.1 Patient and Sampled Images

This study performs a retrospective analysis of 44 subjects, each with 4 to 7 photos amounting to 245 images in total. These 44 subjects, who suffer from FPHL, have been classified into stages I-2, I-3, I-4, II-1, and II-2 on Savin scale based on the consensus gradings of two experienced medical doctors. Note that stage I-1 represents “normal”.

2.2 Image acquisition, normalization and segmentation

For the assessment of hair loss, photos that clearly exhibit the midline scalp are taken by Nikon BM5. The camera configurations are aperture F-22, shutter speed 1/6400 sec., ISO 200, auto white-balance, 300 dpi and 3008*2000 in resolution. The flashlight of camera is fully charged before taking a new photo. For better distinctions between hair and normal scalp, a gray-scale transformation scheme, Hermite spline, is applied to regulate the exposure value for each photo.

To delineate the contour of the baldness area from the region of interest (ROI), the Chan and Vese level set method is employed (Fig.1.) [5]. The level set scheme is to generate and optimize a reasonable contour that maintains the homogenous intensity inside and outside the contour. The mean intensities inside and outside the contour are denoted as \( m_1 \) and \( m_2 \). With an arbitrarily given initial contour, the level set scheme will minimize the energy function as defined in Eq. (1):

\[
E(c, m_1, m_2) = u * \text{length}(c) + v * \text{area}(\text{inside}(c)) + \lambda_1 * F1 + \lambda_2 * F2
\]  

where

\[
F1 = \int_{\text{inside}(c)} |l(x, y) - m_1|^2 \, dx \, dy
\]

\[
F2 = \int_{\text{outside}(c)} |l(x, y) - m_2|^2 \, dx \, dy
\]  

For the assessment of hair loss, the appearance of baldness around the midline scalp are taken by Nikon BM5. The camera configurations are aperture F-22, shutter speed 1/6400 sec., ISO 200, auto white-balance, 300 dpi and 3008*2000 in resolution. The flashlight of camera is fully charged before taking a new photo. For better distinctions between hair and normal scalp, a gray-scale transformation scheme, Hermite spline, is applied to regulate the exposure value for each photo.

To delineate the contour of the baldness area from the region of interest (ROI), the Chan and Vese level set method is employed (Fig.1.) [5]. The level set scheme is to generate and optimize a reasonable contour that maintains the homogenous intensity inside and outside the contour. The mean intensities inside and outside the contour are denoted as \( m_1 \) and \( m_2 \). With an arbitrarily given initial contour, the level set scheme will minimize the energy function as defined in Eq. (1):

\[
E(c, m_1, m_2) = u * \text{length}(c) + v * \text{area}(\text{inside}(c)) + \lambda_1 * F1 + \lambda_2 * F2
\]  

where

\[
F1 = \int_{\text{inside}(c)} |l(x, y) - m_1|^2 \, dx \, dy
\]

\[
F2 = \int_{\text{outside}(c)} |l(x, y) - m_2|^2 \, dx \, dy
\]  

For the assessment of hair loss, photos that clearly exhibit the midline scalp are taken by Nikon BM5. The camera configurations are aperture F-22, shutter speed 1/6400 sec., ISO 200, auto white-balance, 300 dpi and 3008*2000 in resolution. The flashlight of camera is fully charged before taking a new photo. For better distinctions between hair and normal scalp, a gray-scale transformation scheme, Hermite spline, is applied to regulate the exposure value for each photo.

To delineate the contour of the baldness area from the region of interest (ROI), the Chan and Vese level set method is employed (Fig.1.) [5]. The level set scheme is to generate and optimize a reasonable contour that maintains the homogenous intensity inside and outside the contour. The mean intensities inside and outside the contour are denoted as \( m_1 \) and \( m_2 \). With an arbitrarily given initial contour, the level set scheme will minimize the energy function as defined in Eq. (1):

\[
E(c, m_1, m_2) = u * \text{length}(c) + v * \text{area}(\text{inside}(c)) + \lambda_1 * F1 + \lambda_2 * F2
\]  

where

\[
F1 = \int_{\text{inside}(c)} |l(x, y) - m_1|^2 \, dx \, dy
\]

\[
F2 = \int_{\text{outside}(c)} |l(x, y) - m_2|^2 \, dx \, dy
\]
In these equations, $I(x,y)$ is the color depth of pixel $(x,y)$, $\text{length}(c)$ the circumference and $\text{area}(\text{inside}(c))$ the area inside the contour, where $u$, $v$, $\lambda_1$ and $\lambda_2$ are weighting factors. Minimization of energy function $E$ results in a reasonable contour that characterizes the baldness area.

2.3 Feature extraction

Based on the demarcated baldness area, we propose to characterize the severity of FPHL by the width of the baldness area regardless of its irregular contour and fragments. The width of the baldness area is defined as the length of the minor axis of the equivalent ellipse of the baldness area. The equivalent ellipse of the baldness is an ellipse with the same size and center of mass as the baldness area. The equivalent ellipse is derived by using the principal component analysis (PCA) is employed [6].

3 Result

Two-hundred and forty-five images from 44 subjects have been tested in this study. All images are pre-processed by using the Hermite spline to regulate the exposure values before delineation of the baldness areas. With the transformed images, the widths of the baldness areas of all 245 images are derived automatically. As an examples, Fig. 1 demonstrates the results for a subject of stage I-3, in which (A) is the image after Hermite spline, (B) the zero-level set, and (C) the baldness area derived from the zero-level set (green contour) and its equivalent ellipse (red contour). The width of the baldness area is then defined as the length of the minor axis of the equivalent ellipse.

Based on the widths of the baldness areas of the 245 images, a five-class Gaussian Bayes classifier may be constructed for classification of each image into a baldness stage according to Savin scale. Table 1 lists the means and standard deviations computed from the 245 images for these five classes. The effectiveness of using the width of baldness area to characterize FPHL has been validated by the leave-one-out cross-validation method, in which a five-class Gaussian Bayes classifier is constructed for each set of training data (244 images). With the Savin scale as the standard, the classification accuracy is 82.9% for the 245 images used in this study.

4 Discussion

The proposed baldness descriptor, i.e., the width of the baldness area, is shown to be promising for characterization of the severity of the FPHL. Based on the leave-one-out cross-validation method, the accuracy rate is about 82.9% when using Savin scale as the standard. The classification performance may be further improved if second descriptor, such as a descriptor characterizing the condition of the baldness area, is included and a more sophisticated classifier, e.g., SVM or neural network, is employed.

5 Conclusion

In this paper, we present an automated approach to classifying the severity of the FPHL. A baldness descriptor, i.e., the width of the baldness area, has been proposed to characterize the severity of the FPHL. By using 245 images, the proposed descriptor may achieve an accuracy of 82.9% using the leave-one-out cross-validation method.

6 References


Table-1. The model parameters of the 5-class Gaussian Bayes classifier for the widths of the baldness areas (computed from all 245 images) in correspondence to the severity of FPHL defined by Savin scale. (unit: pixel)

<table>
<thead>
<tr>
<th>Savin scale</th>
<th>I-2</th>
<th>I-3</th>
<th>I-4</th>
<th>II-1</th>
<th>II-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>28.187</td>
<td>41.183</td>
<td>61.188</td>
<td>79.686</td>
<td>98.127</td>
</tr>
<tr>
<td>S.D.</td>
<td>2.822</td>
<td>5.090</td>
<td>7.537</td>
<td>6.552</td>
<td>4.889</td>
</tr>
</tbody>
</table>