Preliminary experiments on quantification of skin condition

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ABSTRACT

In this study, we investigated a preliminary assessment method for skin conditions such as a moisturizing property and its fineness of the skin with an image analysis only. We captured a facial images from volunteer subjects aged between 30s and 60s by Pocket Micro® device (Scalar Co., Japan). This device has two image capturing modes; the normal mode and the non-reflection mode with the aid of the equipped polarization filter. We captured skin images from a total of 68 spots from subjects' face using both modes (i.e. total of 136 skin images). The moisture-retaining property of the skin and subjective evaluation score of the skin fineness in 5-point scale for each case were also obtained in advance as a gold standard (their mean and SD were 35.15±3.22 (μS) and 3.45±1.17, respectively). We extracted a total of 107 image features from each image and built linear regression models for estimating abovementioned criteria with a stepwise feature selection. The developed model for estimating the skin moisture achieved the MSE of 1.92 (μS) with 6 selected parameters, while the model for skin fineness achieved that of 0.51 scales with 7 parameters under the leave-one-out cross validation. We confirmed the developed models predicted the moisture-retaining property and fineness of the skin appropriately with only captured image.

Keywords: skin, image analysis, cosmetic, regression

1. INTRODUCTION

Quantification of severity of skin disease is diagnosed by dermatologist, but it is often subjective and troublesome. Most of skin diseases are not fatal, but they sometimes make not small deleterious changes on patient's appearances and decrease their QoL seriously. The "Psoriasis area and severity index" (PASI)[1] is commonly used as a semi-quantized criteria for evaluating the severity of psoriasis, one of very common chronic skin diseases. Severity score of each body region is diagnosed by dermatologist and the PASI is calculated by these weighted sums. It seems objective measure, however it highly depends on subjectivity of dermatologists and the score has a quite wide variety among them. Therefore, physicians cannot compare the severity among different patients with PASI and accordingly, it cannot be an absolute indicator for selection of therapy, dosage and so on. Currently, the "Dermatology life quality index" (DLQI)[2] or "Skindex"[3] is also commonly used for evaluating skin conditions in clinical. The DLQI and Skindex29 consists of 10 and 29 questions, respectively and the evaluation was made with their weighted scores of each item provided by patient. These criteria focus on patients' QoL and therefore, they are subjective and not intended to quantify the severity of disease. On the other hand, the evaluation of skin conditions for cosmetic purpose such as that of pigmented spot, fineness of skin, skin moisture etc. is sometimes done by experts. It is also still often subjective as well as mentioned above. In such a background, there is a call for development of objective evaluation criteria for skin condition not only for medical, but also for cosmetic purpose. Some engineering approaches to address these issues[45] . However, there have been no general solutions to address this issue so far due to mainly their accuracy, cost, and usability. In such backgrounds, we conducted preliminary experiments to develop a convenient and objective evaluation method of skin conditions such as the moisture-retaining property and the fineness of the skin for cosmetic purpose.

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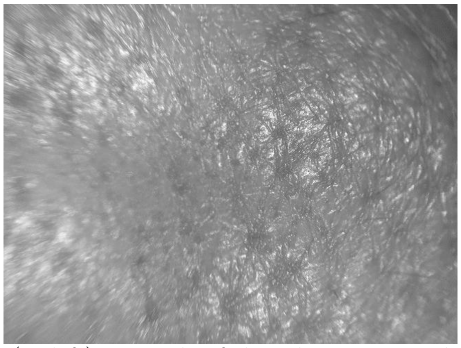
2. MATERIAL AND METHOD

In this study, we developed a new assessment method for skin conditions such as (A) moisture-retaining property of the skin and (B) fineness of the skin using only image analysis as a preliminary experiment. The proposed method investigated the effective image features to describe the relationship between objective features from facial images and the skin condition as the estimation targets. With the selected image features, the method built linear regression models to predict the relationship. These details are described in below.

2.1 Materials and definition of gold standard

In the experiments, we used the Pocket Micro® device (Scalar Co., Japan) (Figure 1) to capture skin images. It was designed to put on an iPhone® or an ipod touch® (Apple Co., USA). This device equips a uniform white light source and a polarization filter. With this device, we obtained two kinds of macrophotography images of the skin. The first one is a general enlarged image obtained without the polarization filter (Figure 2(a)). In this mode, we can observe the texture of skin surface. The other is the image obtained with the polarization filter (Figure 2(b)). Using the filter, scattered reflection which usually occurs at the skin surface is largely suppressed and it enables us to observe the structure of dermis while it loses the texture information at the skin surface. The idea of this modality is the same as dermoscopy, which is mainly used for diagnosing melanomas. We captured a total of 68 face spots (1cm below from bottom lid and mandibular regions) from volunteer subjects aged between 30s and 60s with this device. We captured images with and without the polarization filter for each spot and accordingly we obtained a total of 136 skin images. The resolution of the captured images was 3264×2448. In the experiments, the amount of skin moisture and subjective score of skin fineness provided by author in 5-point scale for each case were also obtained in advance and used them as a gold standard. Their mean and SD were 35.15 ± 3.22 (μS) and 3.46 ± 1.17, respectively.

Figure 1. Pocket Micro®



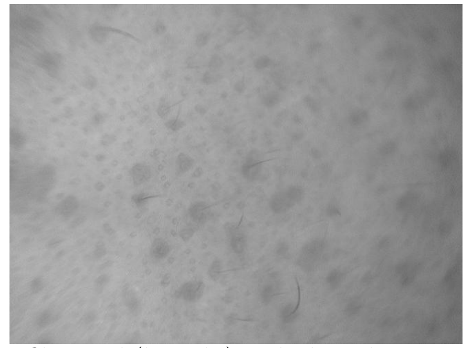


Figure 2. (a: left) Example of shot skin image without the polarization filter and (b: right) with the polarization filter

2.2 Feature extraction

When we observe our skin with magnification lens, we usually find several kinds of texture patterns. Figures 3(a) and 3(b) show examples of fine skin and rough skin. Skin images with periodical fine network-like pattern are generally considered as fine skin. Accordingly, we expect Fourier spectra and texture properties of the skin are good clue for quantification of skin conditions. In addition, we consider light reflection property of the skin surface should represent skin condition. Based on these assumptions, we extracted a total of 107 image features (Table 1) from each facial image as candidates of our estimation model. They are consisting of (1) Fourier 68 spectra, (2) 35 textures, and (3) 4 skin brightness features. In (1), (a) the mean of the power spectrum with the step of 10 Hz bandwidth P_n (average power between $n + 1$ Hz to $n + 10$ Hz in 1-200 Hz (subtotal 20)) and (b) the ratio of two power spectra P_i/P_j (subtotal 48 : See Table 2) were used. These ratio of Fourier spectra were introduced to describe the shape of each skin texture (i.e. ratio of its major and minor axes) obtained in enlarged skin images. In (2), (a) general texture features (energy, moment, entropy and correlation) based on the co-occurrence matrices with 7 kinds of different unit size δ (subtotal $4 \times 7 = 28$). Note here that we calculated four angle parameters (0°, 45°, 90°, and 135°) for each δ, but we averaged them, since we had no control for angle when capturing the image. In addition, we used (b) a total 7 high-dimensional moment features (ϕ_1-ϕ_7) developed by Hu.[6] These parameters were reported invariant under shift, rotation and scale changes. In (3), average and standard deviation of captured skin color in (a) luminance and (b) blue channel were used.

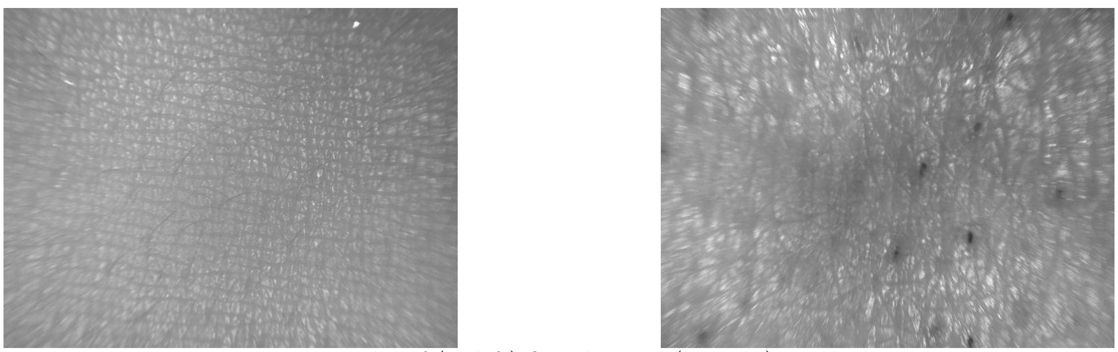


Figure 3. Examples of (a: left) fine skin and (b: right) rough skin

Table 1. Extracted image features for predicting skin conditions

Category		Features	Sub total
1	(a)	The power spectrum P_n (with the step of 10 Hz band width in 1-200 Hz)	20
	(b)	Ratio of the two power building P_i/P_j (See Table 2)	48
2	(a)	Texture parameters (energy, moment, entropy and correlation)	28
	(b)	High-dimensional moment parameters (Hu moment)[6]	7
3	(a)	Skin luminance (mean and SD)	2
	(b)	Skin color in blue channel (mean and SD)	2

2.3 Feature selection and estimating regression models

We built linear regression models for estimating (A) the degree of moisture-retaining of the skin and (b) the fineness of the skin using above-mentioned feature candidates. Here, we built models from the facial images captured without polarization filter (P−), with filters (P+), and both with and without filters (P+&−), respectively to investigate the effectiveness of introducing different modalities. In the development of each regression model, a stepwise feature selection[7] was performed to avoid overfitting. The developed models were evaluated with (i) correlation between estimation value and the gold standard, and (ii) the mean square error (MSE) under the leave-one-out cross validation strategy .

Table 2. Ratio of the two power spectra P_i/P_j used in this study

power spectrum P_j \ power spectrum P_i †	P_0	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
P_0											
P_{10}	$\star$										
P_{20}	$\star$	$\star$									
P_{30}	$\star$	$\star$	$\star$								
P_{40}	$\star$	$\star$	$\star$	$\star$							
P_{50}		$\star$	$\star$	$\star$	$\star$						
P_{60}		$\star$	$\star$	$\star$	$\star$	$\star$					
P_{70}		$\star$		$\star$	$\star$	$\star$	$\star$				
P_{80}		$\star$			$\star$	$\star$	$\star$	$\star$			
P_{90}		$\star$				$\star$	$\star$	$\star$	$\star$		
P_{100}							$\star$	$\star$	$\star$	$\star$	
P_{110}								$\star$	$\star$	$\star$	$\star$
P_{120}									$\star$	$\star$	$\star$
P_{130}										$\star$	$\star$
P_{140}											$\star$

† P_i : average power between $i + 1$ Hz to $i + 10$ Hz

3. RESULTS

The summary of the developed models for estimating (A) the degree of moisture-retaining of skin and (B) fineness of the skin are shown in Tables 3 and 4, respectively. Figures 4 and 5 show the scatter diagram in estimating those items with the regression models (P+&−).

Table 3. Summary of developed estimation model for (A) moisture-retaining of skin under the leave-one-out cross validation

types	# p	selected features	correlation	MSE
P−	5	·energy ($\delta = 100$) ·average skin color in blue channel ·entropy ($\delta = 50$) ·Hu moment (ϕ_5) ·ratio of spectrum (P_0/P_{10})	0.690	1.931
P+	3	·average luminance of the skin ·average color of skin in blue channel ·ratio of spectrum (P_{50}/P_{60})	0.534	2.245
P+&−	6	·energy ($\delta = 100$) (P−) ·entropy ($\delta = 50$) (P−) ·Hu moment (ϕ_5) (P−) ·average color of skin in blue channel (P−) ·ratio of spectrum (P_{50}/P_{90}) (P+) ·average skin luminance (P+)	0.715	1.924

4. DISCUSSION

From tables and figures, we confirmed that the developed model attained good estimation performance with relatively small number of parameters (A: MSE of 1.92 (μS) and correlation value of 0.69 with 6 selected parameters, B: MSE of 0.51 scales and correlation value of 0.89 with 7 parameters). In both cases, the developed model based on images captured without the polarization filter (P−) showed better results than those with (P+). We consider this is because the captured images with the polarization filter lost the important skin texture at the

Table 4. Summary for developed estimation model for (B) fineness of the skin under the leave-one-out cross validation

types	# p	selected parameters †	correlation	MSE
P−	3	·moment ($\delta = 200\sqrt{2}$) ·average skin luminance ·Hu moment (ϕ_5)	0.785	0.557
P+	6	·average skin luminance ·variance of skin luminance ·correlation ($\delta = 100$) ·correlation ($\delta = 400$) ·Hu moment (ϕ_5) ·ratio of spectrum (P_0/P_{10})	0.737	0.668
P+&−	7	·moment ($\delta = 200\sqrt{2}$) (P−) ·ratio of spectrum (P_0/P_{10}) (P+) ·ratio of spectrum (P_{50}/P_{60}) (P−) ·ratio of spectrum (P_{20}/P_{30}) (P−) ·average skin luminance (P−) ·Hu moment (ϕ_5) (P−) ·power spectrum (P_{10}) (P+)	0.888	0.507

#p : The number of selected parameters using stepwise method
† (P−) : Parameters from images captured without polarization filter
(P+) : Parameters from images captured with polarization filter

skin surface. On the other hand, however, the models developed with both features (P+&−) attained the best performance, especially in estimating the fineness of the skin. From these results, we confirmed that several no intuitive features improved the estimation performances and analysis of images obtained from different modalities was important. We found with these experiments that relatively detailed texture such as energy and entropy with smaller δ were selected as important features for estimating moisture-retaining property. On the other hand, the rough texture and the ratio of Fourier spectra were selected for doing fineness of the skin. In this study, the number of analysed cases was limited to 68 (136 images). We are going to investigate the relationship between image features and the skin properties with larger dataset and improve the estimation performance in the near future.

5. CONCLUSION

In this study, we investigated a preliminary experiment to develop a quantitative evaluation of skin conditions. We reached (i) estimation of the moisture-retaining property of the skin and the fineness of the skin were estimated appropriately by means of only captured skin image with simple image parameters and (ii) introducing different modalities improved the estimation performance. With this experiment, we confirmed that these simple image analyses had a potential to quantize the skin conditions.

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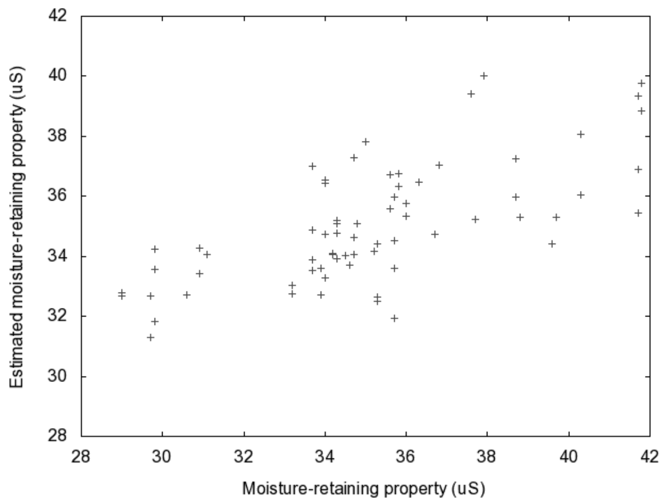

Figure 4. Scatter diagram in estimating (A) moisture-retaining property with regression model (P+&−) under the leave-one-out cross validation

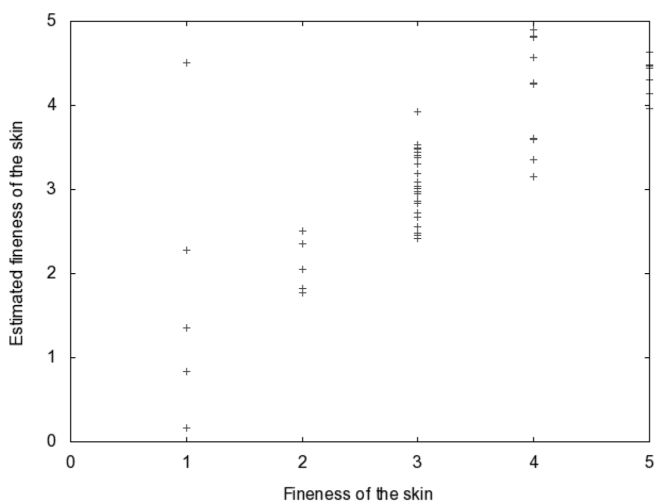

Figure 5. Scatter diagram in estimating (B) fineness of the skin with regression model (P+&−) under the leave-one-out cross validation