Multimodal data acquisition method for the classification of pigmented spots

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ABSTRACT

Introduction

The use of dermatological reference scales to document age-related features from digital photographs of women is essential to study age-related changes of skin based on a variety of parameters such as ethnicity, environment or lifestyle. Among these clinical signs, pigmented irregularities and, in particular, solar lentigines and seborrheic keratosis are sometimes difficult to characterize and differentiate. Lentigines are hyperpigmented maculae, commonly found after the age of 50 on photoexposed areas. They correspond to an epidermal hyperpigmentation with an increase in the number of melanocytes and a modification of the epidermal structure. The main differential diagnosis is flat seborrheic keratosis, common benign tumors, which are well-circumscribed, flat or slightly elevated lesions. Dermatological treatment of spots available on the market mainly target lentigines with whitening products which can soften their color. Differentiation between lentigines and keratosis is thus essential for clinical diagnosis and prescription of dermatologic care. This paper describes the development of a computer-aided tool for the detection, characterization and classification of these two types of spots on the back of the hands of Asian women.

Materials and methods

266 Asian women living in Paris aged from 20 to 78 years participated in this study. After a 30-minute resting period in a temperature- and humidity-controlled area (21°C ±2° and 50% ±5% respectively) pictures of the back of their right hands were taken using a specific camera system (see Figure 1).

Figure 1: The specific hand image acquisition system used in this study.

This system uses a Nikon D90 camera 12.3M pixels with a 28mm lens. It includes a uniform polarized light (based on white LED's) and a multimodalities filter wheel for taking pictures under a parallel and cross polarized configuration. Cross polarization filters out surface reflection and thus is very helpful to visualize and evaluate sub-surface details such as pigmented spots and telangiectasia, whereas parallel polarization passes only surface reflections, resulting in a superior visualization of topographical details. An example of hand pictures under these lighting conditions is given in Figure 2.

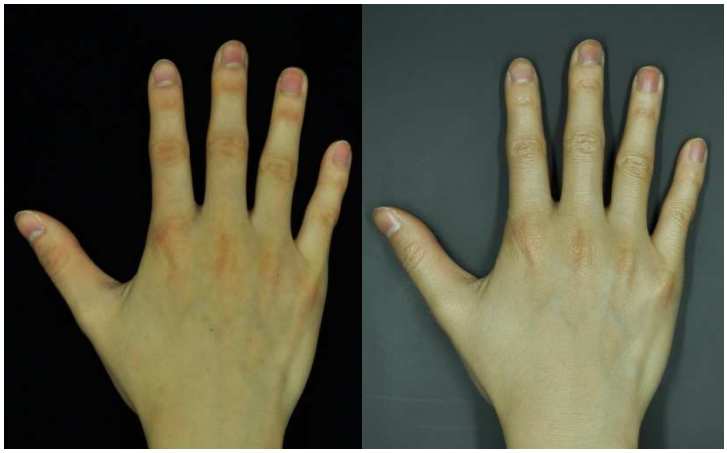

Figure 2: ***Hand pictures in cross polarized light (left) and parallel light (right)***

A color chart placed on the hand carrier allows color calibration using a specific color registration algorithm in each picture to ensure color stability of the images. Dedicated software (DigiCam) is used to take a sequence of images with identical acquisition parameters for each type of polarization (normal, cross and parallel), thus ensuring high stability of the acquired images.

To detect and segment the spots on the acquired images, an image processing protocol is applied as follows:

1. Firstable, a specific segmentation algorithm (Figure 3) based on colorimetric contrast analysis as well as shape (roundness and regularity of the contour), allows initial detection of pigmented spots present on the surface of the hand. This segmentation method is based on projection to a specific axis based on the colorimetric values of the spots.
2. Then a statistical threshold algorithm is applied to achieve an optimal two-class separation (spot or non spot) based on the image histogram. A mask is generated with white pixels for high spot probability and black for high background probability.

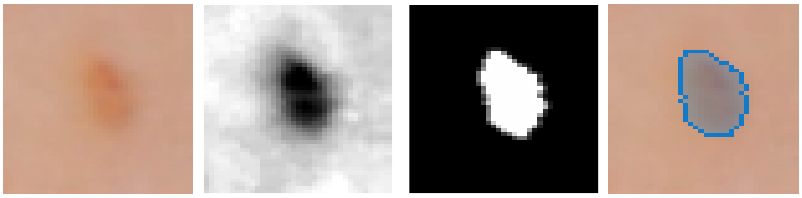

Figure 3: ***From left to right: Original image (cross polarized), Image encoded along the projection axis, Spot mask after application of statistical threshold algorithm and Final spot contour detection***

Once the detection process has been performed on the entire image, spatial filters are used to remove small or irregular contour objects. In this study all detected spots smaller than 300 pixels were removed because their surface is insufficient for clinical analysis.

A software (SpotViewer) developed specifically for this application (Figure 4) is then used by a dermatologist to complete the automated segmentation by removing or adding spots and classifying each spot as a solar lentigo or a seborrheic keratosis. This tool gives the investigator a simple, fast and intuitive display picture with two types of polarization for the same hand and an overlay color of the outlines of the detected spots. A total of 162 keratosis and 518 lentigines were thus detected and classified manually by the dermatologist.

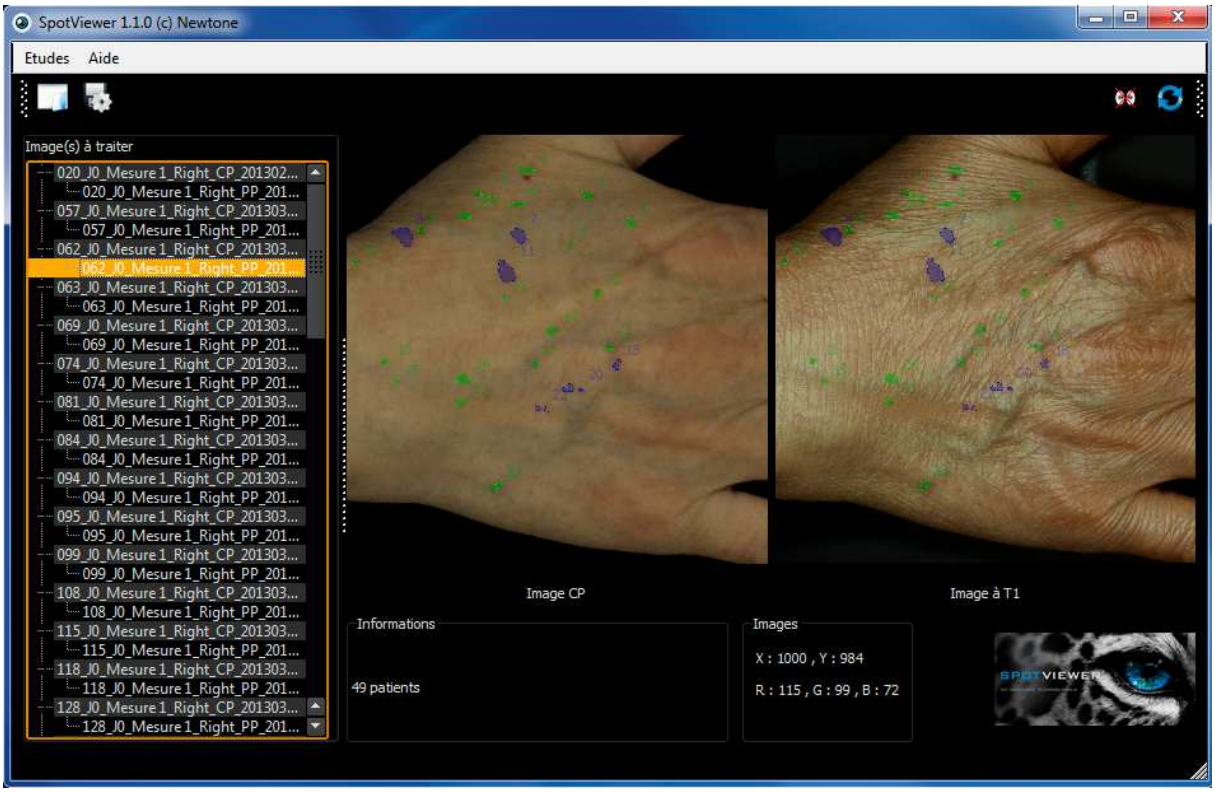

Figure 4: ***SpotViewer software for spot detection and classification***

Based on the spots detected and classified by the clinician, a specific learning machine algorithm was developed in order to automatically classify new spots.

For all the detected spots, several parameters are extracted with a specific algorithm based on the color and shape of the detected area:

- Mean and standard deviation on all the points in the analyzed surface for CIE colorimetric parameters: L*a*b* C h°
- Surface of the detected area
- Specific pigmentation index: ITA

$$ITA = \arctan\left(\frac{L^* - 50}{b^*}\right)$$

Where:

L* and b* are the three color components of the system defined by the International Commission of Lighting (CIELAB).

The parameter increases when spots are less pigmented.

- Specific whitening index: $IWA_{Newtone}$

$$IWA_{Newtone} = \arctan\left(\frac{L^*}{C}\right) = \arctan\left(\frac{L^*}{\sqrt{a^{*2} + b^{*2}}}\right)$$

Where:

L*, a* and b* are the three color components of the system defined by the International Commission of Lighting (CIELAB) [1].

C (Chroma) is the second component of the color defined by the International Commission of Lighting (CIELCH). This parameter increases when pigment spots are whiter.

- Homogeneity Index : $H76$

$$H_{76} = \frac{1}{N}\sum_i \sqrt{(L_i - \mu)^2 + (a_i - \mu)^2 + (b_i - \mu)^2} = \frac{1}{N}\sum_i \Delta E_{76}(i, \mu)$$

This parameter decreases with increasing homogeneity.

- Haralick texture features: Haralick indicators are calculated from the co-occurrence matrix. This statistical tool measures the distribution of gray levels in the image and highlights the frequency and regularity of a color into a gray level image from which a possible pattern can be detected. This matrix contains a large volume of information which is difficult to use in practice. 14 different parameters were proposed by Haralick [2]. In this study we have used the 12 following ones: Contrast, Entropy, Dissimilarity, Homogeneity, Second Moment, Uniformity, Direction, Maximum, Variance, Correlation, Proeminance and Nuance.

- Anisotropic index: The anisotropic index [3] is used to determine if a surface is perfectly isotropic and has the same physical properties in all directions.
To calculate the anisotropy, the first step is to calculate the tensor of each pixel to determine their direction. All directions are then grouped together in a common histogram.

The anisotropy index is calculated as follows:

$$A.I. = \frac{1}{2}\frac{\sum_{i=0}^{N-1}\left|R_i - {}^{S}/_{N}\right|}{S - {}^{S}/_{N}} \times 100$$

with:

- N, the number of directions of the histogram
- The R value of the histogram for the angle i
- S is the sum of the histogram values

The greater the increase in the Anisotropic Index parameter, the greater the anisotropy of the surface.

Thus, 93 parameters are extracted for each spot from the cross and parallel polarized images. After a statistical significance test to evaluate the correlations between these parameters, 58 were retained in our analysis. From these 58 parameters a linear classifier was established to differentiate lentigines and seborrheic keratosis. The classification algorithm is based on a data learning process to adjust the weighting coefficients of each parameter according to their relevance. With all the 58 parameters for all the detected spots and associated clinician classification, the classifier can automatically classify a new spot as a lentigo or seborrheic keratosis. The classifier can also provide values for the probability of spots falling in either class.

Results and discussion

To evaluate the efficiency of the automated spot detection a dermatologist has validated all the spots detected by our algorithm in the entire set of images. This validation process allowed us to study the number of spots considered to be false detections and therefore removed by the dermatologist and the number that went undetected and were therefore added by the dermatologist.

In a set of 305 spots automatically detected for all the subjects, 73 spots were removed and 174 spots added by the dermatologist. Thus, spot detection and clipping by the algorithm shows an overall efficiency of 57% (Figure 5), which represents a significant help for a dermatologist in the detection of spots.

Automated segmentation analysis				
Nb automated segmented spots	**Spots removed by expert**	**Spots added by expert**	**Nb good segmented spots**	**Good segmentation**
305	73	174	232	57%

***Figure 5.** Evaluation of automated segmentation and spot detection*

These results show that our detection algorithm has a tendency to underestimate the presence of spots. This method of spot detection may be optimized in the future through the use of a supervised segmentation learning algorithm.

The quality of the classifier is evaluated by studying the confusion matrix and ROC (Receiver Operating Characteristic) curve. From all the 58 parameters a correct classification of 86% (88% for keratosis and 82% for lentigines) was obtained. An analysis of the prediction coefficient by bootstrapping was also performed (80% of data was used as training data, 20% as validation data, 10 random draws). A prediction coefficient of 75% was found. This classification method is evolutive and can be optimized from new clinical data defined by investigators.

Factorial Discriminant Analysis (FDA)				
Nb Parameters for model description	**Sensitivity**	**Specificity**	**Good classification**	**Prediction coefficient**
58	90%	85%	86%	75%

Figure 6. ***Fractional Discriminant Analysis for classifier performance***

Another method to evaluate the relevance of automated classification was used: this was the subsequent validation by a dermatologist of a set of automated classified spots. The significance of this validation is that it takes into account the variability of the dermatologist's evaluation. For this validation 3 sets were created each consisting of 80 randomly drawn spots. The classifier automatically assigned a class for each of these spots. A dermatologist then confirmed or invalidated this class. Some spots are very difficult to classify and are considered as 'difficult to classify' by the clinician. The rate of spots held to fall into this category throughout our 3 validation sets is about 18%. That means that on the two images in cross polarization and parallel polarization, such spots are very difficult to evaluate and classify even by an experienced clinician. On the assumption that the classification algorithm always makes an incorrect decision about all these 'difficult to classify' spots, the correct classification rate is calculated to be 82%. On the other hand, if all these spots are properly considered by our classification algorithm, the correct classification rate is calculated to be 100%. Taking this into account, we can conclude that the correct classification rate of our algorithm is approximately 90%. To probe deeper into this validation, we studied the probability ratio as defined by the classification for each spot. A probability of 1 means that the spot has a 100% chance of being a lentigo, according to our classifier. A probability of 0 means that the spot has a 100% chance of being a seborrheic keratosis, and a probability of 0.5 means that the spot may equally be rated as a lentigo or a seborrheic keratosis. The above analysis shows that with a probability of greater than or equal to 50% the spot was considered as a lentigo, and with a probability of a less than 50% the spot was considered as a seborrheic keratosis. Further, given a probability range of between 0.24 and 0.76 wherein a spot is considered as unpredictable by our classifier, a correct classification rate of 86% is obtained in the worst case, with 27% of spots considered unpredictable. Such information of unpredictable spots may be very helpful for dermatologists in highlighting certain spots that require their particular attention.

Conclusions

These results demonstrate the potential of such a tool to assist clinical investigations. On the one hand, the segmentation of spots via a semi-supervised method with the help of dedicated software would simplify the clinician's observations procedures. On the other hand, the evaluation of parameters and automated classification improves the reproducibility of the assessment of pigmented irregularities. This approach to support clinical evaluation using simple and fast computational tools is particularly interesting and is surely essential for improving the clinical evaluation of age-related features. This current work may also be used to produce an automated skin severity grade based on spot analysis. Furthermore, this methodology is readily applicable to others

body areas. For example, the female face is an area deeply affected by pigmentation spots during aging, particularly in Asian women.

Keywords: Supervised Segmentation, aid diagnostic tool, standardized photographic system, colorimetric analysis, spots detection, classification method.

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