Saudi Journal of Biological Sciences (2017) 24, 514–518

King Saud University

Saudi Journal of Biological Sciences

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Quantitative evaluation methods of skin condition based on texture feature parameters

Hui Pang, Tianhua Chen *, Xiaoyi Wang, Zhineng Chang, Siqi Shao, Jing Zhao

School of Computer and Information Engineering, Beijing Technology and Business University, Beijing 100048, People's Republic of China

Received 7 December 2016; revised 25 December 2016; accepted 6 January 2017
Available online 26 January 2017

KEYWORDS

Skin beauty;
Cosmetic efficacy evaluation;
Quantitative evaluation of skin condition;
Skin texture feature;
Gray level co-occurrence matrix

Abstract In order to quantitatively evaluate the improvement of the skin condition after using skin care products and beauty, a quantitative evaluation method for skin surface state and texture is presented, which is convenient, fast and non-destructive. Human skin images were collected by image sensors. Firstly, the median filter of the 3×3 window is used and then the location of the hairy pixels on the skin is accurately detected according to the gray mean value and color information. The bilinear interpolation is used to modify the gray value of the hairy pixels in order to eliminate the negative effect of noise and tiny hairs on the texture. After the above pretreatment, the gray level co-occurrence matrix (GLCM) is calculated. On the basis of this, the four characteristic parameters, including the second moment, contrast, entropy and correlation, and their mean value are calculated at 45 ° intervals. The quantitative evaluation model of skin texture based on GLCM is established, which can calculate the comprehensive parameters of skin condition. Experiments show that using this method evaluates the skin condition, both based on biochemical indicators of skin evaluation methods in line, but also fully consistent with the human visual experience. This method overcomes the shortcomings of the biochemical evaluation method of skin damage and long waiting time, also the subjectivity and fuzziness of the visual evaluation, which achieves the non-destructive, rapid and quantitative evaluation of skin condition. It can be used for health assessment or classification of the skin condition, also can quantitatively evaluate the subtle improvement of skin condition after using skin care products or stage beauty.
© 2017 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

People are increasingly concerned about their own health and beauty in recent years. There is a direct link between the skin state and beauty of health. The surface of the skin condition depends on skin texture characterization. Every object with a physical form has its own unique texture. In other words, different objects have different texture, so the texture is a significant character for people to observe and identify objects

* Corresponding author.
E-mail address: cth188@sina.com (T. Chen).
Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.sjbs.2017.01.021
1319-562X © 2017 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University.
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

(Shan et al., 2015; Gao et al., 2011; Song and Li, 2014). Scientific assessment of skin texture is an important approach that could analyze image and evaluate effectiveness of cosmetics and cosmetology. The way of mechanical detection, uses a certain intensity probe to explore, and it is mainly adopted in early evaluation of skin texture and coarseness. As the probe may puncture the surface of the skin, the approach not only has a certain degree of risk but also its precision and sensitivity are not very ideal (Dong, 2011; Liu and Liu, 2010). In recent years, silicone film has been widely used to detect the shadow area of skin wrinkle formed by inclined light, and it could get texture index by conversion. This method still has limitations on the sensitivity and accuracy although it could reduce some risks (Xu et al., 2011a,b). The paper achieves objective quantitative assessment of skin texture state by acquiring skin image from the image sensor, calculating the Tamura feature and the GLCM of two-dimensional image and counting skin texture characteristic value in four different orientations.

2. Material and methods

Nowadays, there is no uniform definition of texture. The texture often refers to space distribution of regular and interdependent pixels' gray level in an image area. Texture can be also recognized as a partial basic mode unit which repeats itself in a method of closing to periodicity in a certain image area (Song et al., 2009). Currently, both in terms of health or skin cosmetic effects, there has been a particular need of scientific analysis and quantitative evaluation of texture state. In traditional medical cosmetology, skin is mainly judged by experimental knowledge of doctors or associated professional staff, which lacks scientific standards. In fact, there are many factors affecting skin quality including the skin surface sebum membrane, skin types, living habits, the application of cosmetics and so on. Furthermore, human skin is also affected by age, race, gender, personality and other factors. It shows diversity and has little differences among its shape, color and texture. Therefore, only using observation or traditional methods is easy to cause a diagnostic error. With the rapid development of computer and digital image processing techniques, image analysis can be used in quantitative analysis of skin texture features according to coarseness and texture measure theory, in order to achieve quantitative appraisal.

2.1. Texture feature of skin image

Currently, there are some main characters of skin texture which are GLCM, LBP (Local Binary Pattern) algorithm, texture spectrum and transform domain method. However, these features have a common shortage of which physical or visual characters are indefinite, having a great possibility to produce inconsistency between checking result and visual feeling. In 1980s, Tamura and others put forward an expression of texture character, according to the psychological research of human perception for texture. There are six components of Tamura texture character corresponding with the six properties in psychological field which are coarseness, contrast, directionality, linearity, regularity and roughness. According to the image process theory, the first three characters can describe the subtle visual features of texture in a better way. It can be used to evaluate skin texture and retrieve content-based image. For the sake of improving the description and identification, this paper proposes a modified Tamura texture features algorithm, using coarseness column chart instead of coarseness to express micro information of skin texture.

2.2. The calculation of GLCM

GLCM is one of the effective methods for quantitative analysis of skin texture. This concept is proposed by Haralick, and it focuses on transforming the gray level information to texture information conveniently, which has been proven both in theory and experiments. GLCM describes a frequency correlation matrix of two pixel points which have i and j gray values separately, s distance and in a θ angle direction (Bai et al., 2012; Xu et al., 2011a,b; Qi et al., 2012).

GLCM provides a supportive theory for the description of skin texture state. According to the principle of GLCM, if the image consists of pixel block, the diagonal element values of GLCM will be big (Schmidt et al., 2007). If the gray value of skin image pixel has a big change in some fields, the element values which keep away from the diagonal element will be big. As there is an internal mathematical relationship between GLCM and distribution of image texture, therefore GLCM has a good effect on skin texture analysis. It can evaluate skin texture, roughness and degree of consistency of skin condition. At present, the main characteristics parameters of GLCM include angular second moment, contrast, entropy, correlation and other indicators.

Texture c in total sets of value of omputing focuses on GLCM calculation. Take any point (x, y) in $N \times N$ image and another point $(x + dx, y + dy)$ which deviates a s distance to form point pair and we assume the gray value of the point pair is (g_1, g_2). To begin with, we move the point (x, y) on the whole image and we will acquire several different values of (g_1, g_2). Then the series of image gray values is supposed as k, and there will be k^2 sets of value of (g_1, g_2) in total. For the whole picture, we need to count the frequency of every (g_1, g_2) and arrange them in a matrix. Moreover, according to the total number of appearing (g_1, g_2), the matrix members need to be normalized transformed into the probability P (g_1, g_2). We call this matrix, the GLCM matrix. As can be seen from it, GLCM is a function of distance and direction whose order is determined by gray values of the image and it is a symmetrical matrix. We can obtain joint probability matrix in different situations when (dx, dy) has different values. The value of (dx, dy) should be chosen from distribution of texture. Small divided difference need to be acquired for the thinner texture, for example, (1, 0), (1, 1), (−1, 1), (2, 0). At the same time, calculating the four individual orientation (0, 45°, 90°, 135°) reflects the statistics features of skin texture comprehensively, according to the concept of pixel neighborhood.

Gray level co-occurrence matrix calculation mainly involves the choices of two key parameters. One is a series of gray levels which need to be confirmed generally by the gray level series of skin image. In order to reduce the amount of calculation, the number of gray values can be reduced properly. The other one is the choice of displacement. There is no consensus method of how to choose the distance S, and the optional range of incremental theory is from 1 to size (image). Various research aims have different selection methods for S.

For example, the incremental values of {0, 4, 8,. . ., 64} for skin texture calculation generally choose 1 or 2 in the horizonal and vertical direction.

2.3. The choices of feature parameters

Haralick supposed 14 kinds of texture features based on GLCM parameters (Schmidt et al., 2007; Barata et al., 2014). But there is redundancy between parameters. Theoretical studies and a large number of experiments show that the energy, contrast, correlation and entropy can reflect skin features from different levels.

Asm is the sum of squares of GLSM element values, so it can be called as energy. It is the uniformity measurement of texture gray distribution (the thickness measurement of the image texture). If all element values of co-occurrence matrix are equal, the asm is small. On the contrary, it is also true.

(1) Asm Angular Second Moment (asm). The definition of Angular Second Moment is

$$Asm = \sum_{g_1}\sum_{g_2}[p(g_1, g_2)]^2 \tag{1}$$

(2) Contrast (con). The definition of con is

$$con = \sum_{k}k^2\left[\sum_{g_1}\sum_{g_2}p(g_1, g_2)\right] \tag{2}$$

in the formula, $k = g_1 - g_2$.

Contrast is also called the moment of inertia which is a part gray level measure of change in the image. The contrast size reflects the sharpness, texture density and the depth extent of groove. The visual effect is clearer if image has deeper groove and bigger contrast. If the element values which are far away from the diagonal are bigger in GLCM, the contrast value will be bigger.

(3) Entropy (ent). The definition of ent is

$$ent = -\sum_{g_1}\sum_{g_2}p(g_1, g_2)\lg p(g_1, g_2) \tag{3}$$

Entropy, which is a measurement of information, describes the complexity of image texture, and it reflects the randomness of image texture gray distribution. When all elements of the co-occurrence matrix have the greatest randomness, the entropy will be big.

(4) Correlation (cor). Correlation is used to measure the similar extent of GLCM elements in a certain direction. Its definition of cor is

$$cor = \frac{\sum_{g_1}\sum_{g_2}g_1 g_2 p(g_1, g_2) - \mu_x\mu_y}{\sigma_x\sigma_y} \tag{4}$$

Correlation is the linear correlation measurement of texture image optical gray level. When elements are identical or uniform, the value of correlation is large. On the contrary, it is also true.

According to the properties of the human skin, the mathematical model of the comprehensive evaluation of the skin condition is as follows:

$$Rin = \frac{\sum_{g1}\sum_{g2}p(g_1 + g_2)\{p(g_1, g_2) + \lg[p(g_1, g_2)]\}}{\sum_k k^2\left[\sum_{g1}\sum_{g2}p(g_1, g_2)\right] \times cor} = \frac{Asm + ent}{con \times cor}$$

3. Results & discussion

3.1. Image acquisition and experiment

Use CCD image sensor to collect the image of 52 individuals in different ages, use LED as the light source, and the camera lens enlargement factor is 50 times. The parts of acquisitions include cheeks, forehead, canthus, chin, and there are 208 images in total. The image size is 640 × 480. Each person who is being collected images must wash face carefully with clean water, after which the image collection begins. Fig. 1 shows 8 images of Cheek part.

The experiment has calculated all images of 52 individuals, Fig. 2 expresses 8 cheek images in the sample. According to Fig. 1, the results of calculation can be shown at Table 1 (including angle second order moment, and contrast, and

(a) 1.bmp (b) 2.bmp (c) 3.bmp (d) 4.bmp (e) 5.bmp (f) 6.bmp (g) 7.bmp (h) 8.bmp

Figure 1 Texture image of face cheek.

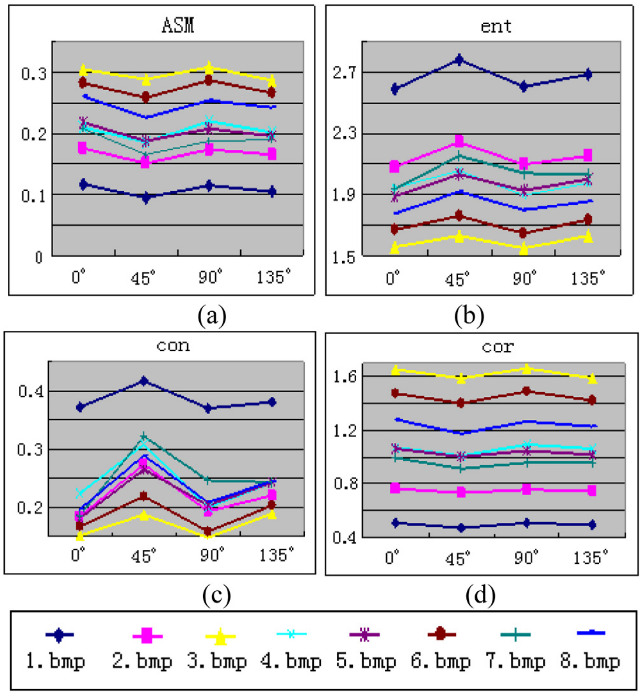

Figure 2 The relation of characteristic parameters.

entropy and correlation four features parameter and the standard poor). The angular second moment, entropy, contrast and correlation are related to the characteristic values at 0°, 45°, 90°, 135° four direction average of the characteristic values, the standard deviation (std) respective refers to the standard deviation in 4 directions. The last two columns are the Rin values based on Rin index and measured values of Geman CK instrument.

According to Fig. 1, image (c) is the best one of the skin situation among these eight images, followed by image (h) while the skin situation of image (a) is the worst. The results of calculation are consistent with the evaluative result of skin images in Fig. 1. It illustrates using the GLCM quantitative evaluation in accordance with real situation. The evaluation method can be regarded as objective, scientific and reasonable. The texture feature parameters reflect the characteristics of skin structure and physiology. The shortage of using GLCM is that its calculation value has great relevance with the scales and gray series of the skin image. For example, if an image at 256 gray level with 512×512 scales, the computation of GLCM will be approximately 2^{34} times multiplication. According to the results of experiment from Table 1, we use the texture coarseness theory to calculate human skin texture features, and then the evaluation of effect on the skin coarseness is consistent with human visual perception precisely. That is, using the proposed calculation method, the texture coarseness value is large for coarse texture image, while the value is small for delicate skin texture image.

3.2. The analysis of characteristic parameter

Fig. 2(a) shows the calculations of angular second moment, which are shown in the 8 images of Fig. 2 in the 0°, 45°, 90°, 135°directions. As can be seen Fig. 1(c) shows the maximum ASM value of which the skin texture situation is the best, while Fig. 1(a) shows the minimum ASM value of which the skin texture situation is the worst. Angular second moment (ASM) well reflects the uniformity of skin texture coarseness and gray distribution. Fig. 2(b) shows the calculation results of entropy in the directions of 0°, 45°, 90°, 135°. The entropy indicates the randomness of skin image gray distribution. The better skin condition is, the less value of entropy is. The results of calculation in Fig. 2(b) explain the concept precisely. The results of contrast and correlation are shown in Fig. 2(c)–(d). Correlation reflects the similarity of skin texture in a certain direction. The experiment shows that if the contrast of skin image is small, its correlation will be big. However, if contrast is big, its correlation will be small. Meanwhile, we can find that the variation of correlation is similar with the variation of energy. In fact, the change law of relativity is similar to that of Asm. Theoretical analysis and experiments show that the single feature value reflect the state of the skin only from one level, while the Rin index is a comprehensive characterization of state in texture, direction, consistency and other aspects of the skin, which fully reflects the comprehensive information of the state of skin texture.

4. Conclusion

The skin texture characteristic means the spatial traits of skin, and skin state analysis have received increasingly more attention in the field of Image Processing and Biomedical Engineering. A total of 208 skin texture images of four different parts from 52 individuals in different ages are collected, analyzed, processed and calculated in this project. Experimental results show that the image preprocessing method based on the median filter, gray mean value and color information can eliminate the influence of the image noise and the hair pixels on texture. The four main parameters including energy, contrast, entropy and correlation of the skin image were calculated by the gray

Table 1 Texture characteristic parameter computed result.

No.	asm	std	ent	std	con	std	cor	std	Rin	CK
1.bmp	0.1072	0.0102	2.6625	0.0903	0.3854	0.1166	0.4992	0.0208	73.751	0.1569
2.bmp	0.1659	0.0115	2.1426	0.0705	0.2183	0.0403	0.7538	0.0134	65.168	0.2265
3.bmp	0.2962	0.0112	1.5924	0.0436	0.1692	0.0225	1.6233	0.0411	35.146	0.1182
4.bmp	0.2032	0.0145	1.9655	0.0699	0.2443	0.0468	1.0612	0.0361	44.506	0.1587
5.bmp	0.2014	0.0133	1.9612	0.0661	0.2231	0.0383	1.0371	0.0271	48.602	0.1681
6.bmp	0.2721	0.0129	1.7006	0.0532	0.1867	0.0284	1.4501	0.0414	37.143	0.1367
7.bmp	0.1876	0.0172	2.0379	0.0891	0.2497	0.0561	0.9588	0.0343	48.811	0.2011
8.bmp	0.2446	0.0153	1.8376	0.0649	0.2354	0.0419	1.2362	0.0467	36.008	0.1355

level co-occurrence matrix method. Theoretical analysis and calculation results show that the above characteristic parameters reflect the texture and physical state of human skin from different aspects. However, due to the skin condition not being uniform and consistent, the same characteristic parameters, in different directions, its size are not same. In this paper, the average of four directions (0°, 45°, 90°, 135°) is taken as the eigenvalue, which eliminates the randomness of the characteristic parameters in different directions.

According to the basic theory of Image Engineering, although the four parameters of angular second moment, contrast, entropy, and correlation characterize the skin from different aspects, there is a limitation of any single index in the above indicators. The Angle Second Moment mainly reflects the gray distribution of skin texture, which is the thickness of skin texture; The Contrast demonstrates the skin image gray value of the local variation, that is, the clarity of skin texture and groove depth; The Entropy characterizes the randomness and complexity of skin texture distribution. The Correlation shows the local linear correlation of skin texture in gray image, which is the similarity of skin texture in one direction. Therefore, the individual features cannot fully reflect the skin's overall state. The comprehensive characteristic parameters proposed in this paper overcome the limitations of the single feature, and combine the advantages of the above four features, which could better represent the actual state of the skin surface and texture characteristics. The results of the evaluation are basically the same as those of CK instrument based on biochemical principle, which can evaluate the skin condition quickly, accurately and objectively. The method can be used to quantitatively analyze and evaluate the micro-state changes of the skin, to rapidly detect, evaluate and classify the skin condition, and can also be used for quantitative evaluation of skin-care products and cosmetic effects.

Acknowledgements

The Work was Science and Technology Development Program of Beijing Municipal Commission of Education (No. KZ201510011011), the National College Student's Scientific Research and Entrepreneurial Action Plan (No SJ201502084.), and comprehensive reform project for promoting personnel training of Beijing Technology and Business University-China cosmetics collaborative innovation research center construction project (No. 19005428069/007).

References

Bai, L., Fang, C., Ding, X.Q., 2012. High resolution face image recognition based on skin texture feature. Comput. Eng. 38 (1), 164–166.

Barata, C., Ruela, M., Francisco, M., 2014. Two systems for the detection of melanomas in dermoscopy images using texture and colour features. IEEE Syst. J. 8 (3), 965–979. 9.

Dong, X.Y., 2011. Study of Fingerprint Image Pre-processing Algorithm. Jilin University, Changchun, pp. 21–30.

Gao, Q., Hu, L.W., Wang, Y., 2011. Skin texture parameters of the dorsal hand in evaluating skin aging in China. Skin Res. Technol. 17 (4), 420–426.

Liu, H.B., Liu, Z.L., 2010. Recycling utilization patterns of coal mining waste in China. Resour. Conserv. Recycl. 54 (12), 1331–1340.

Qi, H.C., Peng, W.X., Wu, Y.Q., Wu, S.B., Xu, G.J., 2012. Effects of alkaline extraction on micro/nano particles of eucalyptus camaldulensis biology. J. Comput. Theor. Nanosci. 9 (9), 1525–1528.

Schmidt, S., Koch, B., Schulz, R., et al, 2007. Comparative analy-sis of the applicability of the skeletal age determination methods of Greuli-ch-Pyle and Thiemann-Nitz for forensic age estimation in living sects. Int. J. Legal Med. 121 (4), 293–296.

Shan, G.X., Gan, P., He, L., 2015. Study on objectively evaluating skin aging according to areas skin texture. J. Biomed. Eng. 32 (2), 142–145.

Song, Z.C., Li, T.Q., 2014. Enhancement of skin texture images based on gabor filter. Acta Laser Biol. Sin. 23 (5), 413–417.

Song, J.L., 2009. Extraction and Analysis of Skin Texture Image Features. Northeastern University, Shenyang, pp. 8–20.

Xu, S.C., Zhang, S.Y., Zhang, Y., 2011a. Robust algorithm for extracting skin pigment concentration from colour image. J. Zhejiang University (Engineering Science). 45 (2), 253–259.

Xu, S.F., Wu, S.L., Li, H., 2011b. An analysis on hu-man skin texture based on gray-level co-occurrence matrix. ACTA Laser Biol. Sin. 20 (3), 324–328.