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Research Article

A Color Spot Extraction Method Based on the Multifused Enhancement Algorithm

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The color spot can reflect the skin status and the physiological change. It has been used in the evaluation of skin quality and medical diagnosis. However, the gray level of the color spot is very similar to that of normal skin. Because the shape, size, and position of the color spots are irregular. It is difficult to extract the accurate region of the color spot with the traditional methods. In order to extract the region of the color spot, we propose a multifused enhancement algorithm to enhance the feature of the color spot and extract the accurate region. The multifused enhancement algorithm mainly includes three components: the polarized image acquirement, the color model transformation, and the wavelet transform and enhancement. The color spot, which is in the intraepidermal basal cell, is captured by the polarized camera with the polarized light. The acquired method can remove the reflective light, covering the color spot. To further enhance the feature of the color spot, we use saturation instead of the gray level to characterize the color spot. The color spot is more conspicuous in the saturation image. Then, the wavelet transform and enhancement are used to enhance the feature of the color spot and reduce the effect of uneven illumination. The color spot is extracted by the proposed self-adaptive segmentation method. In addition, we discuss the performance with the different wavelets to choose the optimal wavelet. The actual reason for removing uneven illumination in the proposed algorithm is also analyzed in this work. The experimental results indicate that the proposed algorithm achieves the best accuracy among all the algorithms compared.

1. Introduction

The skin is the largest organ of humans. It protects the body from external harm. The functions of thermoregulation, tactile sensation, and excretion are also realized by the skin of humans [1–3]. The skin's water content occupies 15% of the body weight, and the skin is one of the most important organs in the body. With the change in age and the health status, the skin will have a physiological change [4–6]. The evaluation of the skin has attracted much attention by the doctors and the beauty and skin care industries [7–9]. Due to the importance and complexity of the skin, the analysis of the skin has some challenges. The traditional analysis and diagnosis of the skin are based on the subjective observation of the doctors. The subjective evaluation cannot provide the quantitative analysis results of the skin. Furthermore, some features of the skin cannot be observed by the naked eyes of the doctors. Thus, an objective evaluation method of the skin is required by current medical diagnosis and cosmetology.

Some indicators can reflect the change of the skin, such as pore [10], wrinkle [11, 12], roughness [13], and the color spot [14] of the skin. The pore is the porous structure in which the pelage is deciduous. The wrinkle is the small microgroove generated by the free radical that breaks the collagen and active substance of the normal cells. The roughness is used to evaluate the texture of the skin. The color spot caused by the accumulation of melanin is the spot in which the color is different from that of the surrounding skin [3, 15]. These features of the skin can reflect the change of the skin due to the aging process [16]. The research of the skin indicators has an important meaning in the objective evaluation.

The color spot is one of the most important indicators in skin evaluation. It includes freckle [17, 18], black spot [19], chloasma [20, 21], and age pigment [22]. The color spot is a pigmentary skin disorder caused by the increasing melanin of the skin [23, 24]. The main reason for the freckle generation is the hereditary factor. Enough exposure to ultraviolet radiation and the metabolism of the broken skin also lead to the freckle. Except for the ultraviolet radiation, an unhealthy lifestyle may result in the black spot. The imbalance of the healthy condition of the body and the increase of the male progesterone after the pregnancy may cause chloasma. In addition, some chronic diseases, such as chronic hepatitis and tuberculosis, may multiply the melanin [25, 26]. When the melanin cannot be eliminated from the body, the melanin may turn into chloasma. Cosmetics misuse is also the important reason for the black spot and chloasma. The seborrheic keratosis, which is also called age pigment, is a benign skin tumor. The generated reason is the cell proliferation of the corneum. According to medical statistics, melanoma's morbidity and mortality rate constantly improve. The melanoma comes from the pigmented spot that is easy to be ignored by humans. The melanoma may be diagnosed earlier if the color spots can be quantitatively and objectively analyzed. The traditional diagnosis method of the color spot is based on the visual inspection of the doctors. Hence, the inspected accuracy relies on the experience of the doctors. The subjective and manual method is not only inefficient but also inaccurate. It is difficult for a doctor to quantify the size of the area of the color spot precisely.

There are some challenges for the color spot extraction: (1) the gray-level difference between the color spot and the normal skin is too small. This problem may cause that the color spot is difficult to be recognized in the spatial and frequency domains; (2) the illumination is uneven. The uneven illumination may cause the gray-level distribution to be uneven in the skin. The region of the weak illumination can be falsely recognized as the color spot, and (3) the captured image cannot obtain the conspicuous information of the color spot because the images of the color spots are captured by the camera with a macrolens. The obtained image is fuzzy and cannot provide a conspicuous color spot. Hence, the color spot is in the intraepidermal basal cell. The camera cannot capture an image that contrasts the color spot under the normal light. Thus, we propose the multifused enhancement algorithm to obtain the conspicuous color spot.

Due to the challenges of color spot extraction, many existing segmentation algorithms may not work well for segmenting this type of image. Some methods can be used to detect and quantify the color spot but cannot achieve good performance. The threshold segmentation [27, 28] is the most traditional method for image segmentation. However, the gray level is very similar between the normal skin and the color spot, and the method cannot achieve good performance. According to the characteristic of the color spot, the method based on HSV [29, 30] can be used to segment the color spot. Although the performance is better than the threshold segmentation, the performance is limited by the uneven illumination of the image. In order to enhance the color spot from the background in the image, homomorphic filtering [31–33] is used to enhance the color spot. The method weakens the low-frequency signal and enhances the high frequency for improving the image detail. However, the method cannot achieve the preferable performance in complex circumstances. The method of wavelet transform [34–36], which can obtain the multilevel signal with the decomposition algorithm, is used to enhance the color spot. Due to the multivariable parameters used, it is not easy to obtain stable performance.

In this work, we propose the multifused enhancement algorithm to extract the color spot. To obtain conspicuous features of the color spot, we propose three methods to enhance the weak features of the color spot. The polarized image acquirement, the HSV model, and the wavelet transform are fused to extract the conspicuous features of the color spot. The experimental results indicate that the proposed algorithm can achieve excellent performance for color spot enhancement.

The remainder of this article is organized as follows: Section 2 introduces the proposed methods for color spot enhancement and segmentation. Section 3 shows the experimental results and analysis of the proposed methods. Section 4 discusses the significance of the color spot extraction and its possible improvement. The conclusion then follows.

2. Methods

The key issue of color spot extraction is how to enhance the color spot. In order to enhance the difference between the color spot and the normal skin, the three methods are proposed to obtain the conspicuous color spot. First, we use the polarized camera with the polarized light to obtain the conspicuous feature of the color spot. Secondly, the saturation features of the image are used to express the color spot. Thirdly, the wavelet transform is used to enhance the feature of the color spot. Finally, the color spot is extracted by the proposed self-adaptive threshold segmentation. The schematic diagram of the proposed method is shown in Figure 1.

3. Polarized Image Acquirement

Generally, the color spot is in the intraepidermal basal cell. The reflective light of the epidermis will cover the texture of the color spot. Thus, we adopt the polarized light to remove the reflective light of the epidermis. The horizontally polarized light provides the lighting source, and the camera with a vertically polarized glass is used to capture the image of the color spot. The experimental result is shown in Figure 2. It is difficult to recognize the color spot in the ordinary image. But the color spot is conspicuous in the polarized image.

Under ordinary light, the surface of the skin reflects a large number of reflective lights, and the captured image has a large number of reflective lights. When the light is transformed to the horizontally polarized light, and a vertically polarized glass covers the lens of the camera, the reflective light from the skin surface is eliminated. The

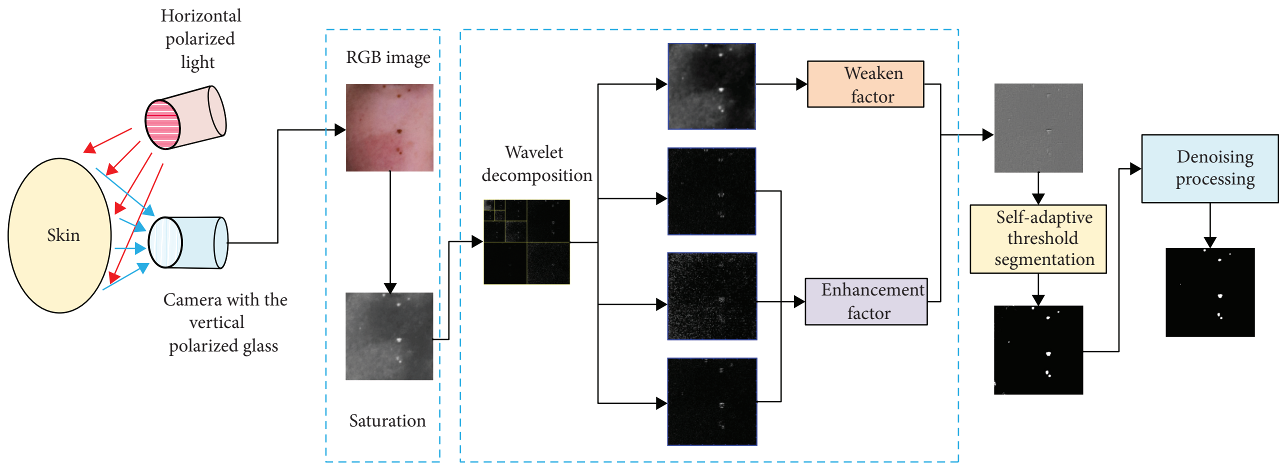
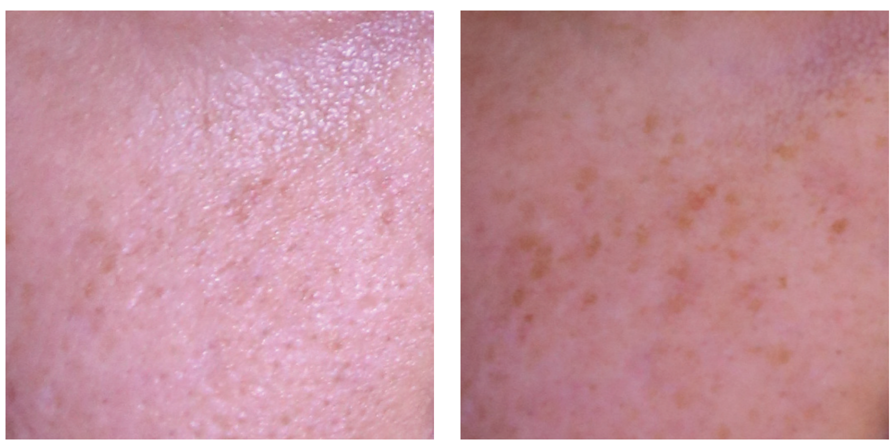


Figure 1: The schematic diagram of the proposed method.



(a)

(b)

Figure 2: The image acquirement with the polarized light. (a) Ordinary image. (b) Polarized image.

captured light mainly comes from the subepidermal light, and the camera can obtain the conspicuous color spot.

4. Color Model Transformation

Although the contrast of the color spot is improved by the polarized image acquirement, the color spot is still tricky to be segment. In the gray-level space, the gray-level difference between the color spot and the normal skin is too little. By analyzing the different color models, we find that the saturation feature of the color spot is more visible. In our work, the captured image is transformed to the HSV (hue, saturation, and value) model before processing the image, and we use the saturation to express the feature of the color spot.

Based on the transformation principle between RGB and HSV, the conspicuousness of the saturation can be explained. The saturation is obtained by the following equation:

$$\text{saturation} = 1 - 3 * \min(r, g, b), \tag{1}$$

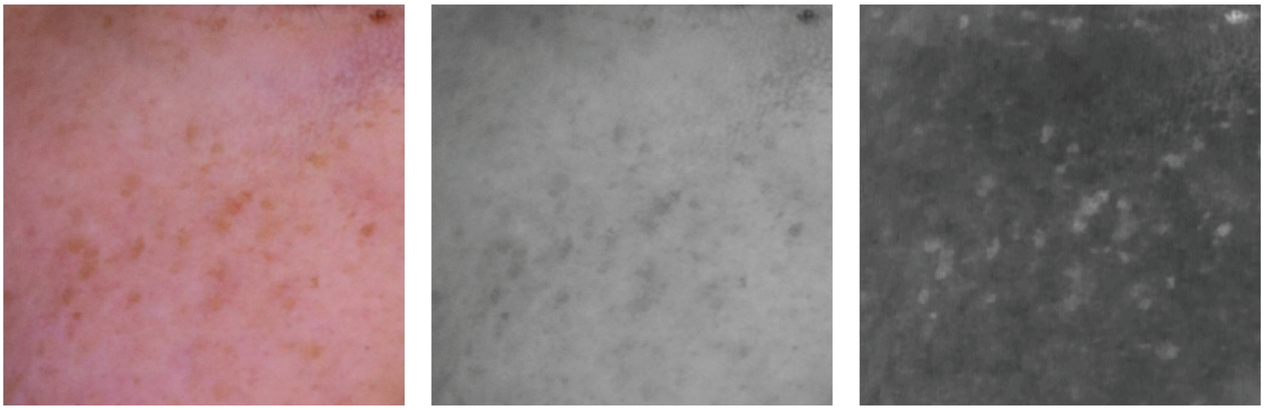
where r, g, and b are the normalized value of the R, G, and B value in the RGB model, respectively. The saturation is the maximum of (1), and the conspicuousness of the saturation is larger than the gray level.

From Figure 3, the original image, gray-level image, and saturation image are given. We can obviously observe that the contrast of the saturation is better than the gray-level image. The result also can be used to verify Equation (1).

5. Wavelet Transform and Enhancement

The information of the color spot is usually included in the high frequency of the image. The other information except the color spot is in the low frequency. The color spot may be enhanced if we enhance the high frequency and waken the low frequency. In this work, we use the wavelet transform algorithm to achieve this goal.

Suppose the given image with the size of $m \times n$ is $f(x, y)$, the wavelet decomposition is shown as follows:



(a) (b) (c)

Figure 3: The comparison of different lights. (a) Original image. (b) Gray-level image. (c) Saturation image.

$$f_{k+1}(x,y) = f_k(x,y) + g_k(x,y),$$
$$g_k = g_k^H + g_k^V + g_k^D, \tag{2}$$

where $f_k(x,y)$ is the low-frequency component, and the high frequency is indicated by $g_k(x,y)$. The horizontal, vertical, and diagonal components of the high frequency are indicated by the g_k^H, g_k^V, and g_k^D, respectively. k is the decomposition level.

According to the principle of the multiresolution analysis, it has $f_k(x,y) \in V_k$ and $g_k^I(x,y) \in W_k$. And $\varphi(2^k x - m, \ 2^k y - n)$ and $\psi^I(2^k x - m, \ 2^k y - n)$ are the Riesz base of the space V_k and W_k, respectively. The W_k is the complementary set of V_k. The $f_k(x,y)$ and $g_k^I(x,y)$ can be described as follows:

$$f_k(x,y) = \sum_{m,n} \varepsilon_{k;m,n} \varphi\left(2^k x - m, 2^k y - n\right),$$
$$g_k^I(x,y) = \sum_{m,n} \eta_{k;m,n}^I \psi^I\left(2^k x - m, 2^k y - n\right), \tag{3}$$

where φ and ψ are scaling function and wavelet function, respectively. In addition, $I \in (H,V,D)$. The coefficients of the $\varepsilon_{k;m,n}$ and $\eta_{k;m,n}^I$ can be described as the following equation based on the decomposition algorithm:

$$\varepsilon_{k;m,n} = \sum_{l,j} \gamma_{l-2m,j-2n} \varepsilon_{k+1;m,n},$$
$$\eta_{k;m,n}^I = \sum_{l,j} \delta_{l-2m,j-2n}^I \varepsilon_{k+1;m,n}, \tag{4}$$

where $\gamma_{k;m,n}$ and $\delta_{k;m,n}^I$ are the binary decomposition sequences that is generated from the unary decomposition sequences.

To enhance the color spot and weaken other information, we use (5) to enhance the high-frequency information and weaken the low-frequency information.

$$\Phi_{k;m,n} = \alpha * \varepsilon_{k;m,n}, \tag{5}$$

$$\Psi_{k;m,n}^I = \beta * \eta_{k;m,n}^I, \tag{6}$$

where the weaken factor is α and the β is the enhancement factor.

Suppose the $\mu_{l,j}$ and $\nu_{l,j}^I$ are the binary decomposition sequences generated from two unary decomposition sequences. The reconstruction algorithm is shown in the following:

$$\varepsilon_{k+1;m,n} = \sum_{l,j} \left(\mu_{m-2l,n-2j} \Phi_{k;l,j} + \sum_{i=1}^{3} \nu_{m-2l,n-2j}^i \Psi_{k;l,j}^I \right). \tag{7}$$

6. Self-Adaptive Threshold Segmentation

By the enhancement methods, we can obtain the more conspicuous color spot. To extract the accurate region of the color spot, we propose the self-adaptive threshold segmentation. First, we calculate the maximum and minimum of $\varepsilon_{k+1;m,n}$, and the self-adaptive threshold is obtained as shown in the following equation:

$$\text{MAX} = \max\left(\varepsilon_{k+1;m,n}\right), \tag{8}$$

$$\text{MIN} = \min\left(\varepsilon_{k+1;m,n}\right), \tag{9}$$

$$\text{THRESHOLD} = \frac{\text{MAX} + \text{MIN}}{2}. \tag{10}$$

The self-adaptive threshold method can obtain the threshold without manual adjustment. The segmented region is indicated by the REGION, and the value is the gray level of the reconstructed image. The segmentation algorithm can be described in the following:

$$\text{REGION} = \begin{cases} 255, & \text{if value} \geqslant \text{THRESHOLD}, \\ 0, & \text{if value} < \text{THRESHOLD}. \end{cases} \tag{11}$$

The segmented result may include a small amount of noises, and we use the median filter to process the segmented image as shown below:

$$\text{SPOT} = \text{median}\left(\text{REGION}, [P,Q]\right), \tag{12}$$

where the SPOT indicates the final region of the color spot, and $[P, Q]$ is the template of the median filter.

7. Results

To evaluate the performance of the proposed multifused enhancement algorithm, we design an experimental platform and verify the proposed algorithm. We use the camera of the Canon EOS 750D with the lens of the Tamron 18–200 mm to capture the face images. Among the images captured, the 100 images with the size 512×512 are selected for the evaluation of the proposed algorithm. The 50 images are randomly selected for the performance evaluation.

There are some common criteria for evaluating the segmented accuracy [37]. We choose the true positive rate (TPR, also called sensitivity, recall, and hit rate), positive predictive value (PPV, also called precision), accuracy (ACC), and F_1score (is the harmonic mean of precision and sensitivity) to evaluate the performance of segmented accuracy. These metrics are defined as follows:

$$\begin{aligned}
\mathrm{TPR} &= \frac{TP}{TP + FN},\\
\mathrm{PPV} &= \frac{TP}{TP + FP},\\
\mathrm{ACC} &= \frac{TP + TN}{TP + TN + FP + FN},\\
F_1 &= \frac{2TP}{2TP + FP + FN},
\end{aligned} \tag{13}$$

where TP is the intersection between ground truth and segmentation result. TN is the whole image except ground truth and segmentation result. FP is the segmentation except the TP. FN is the ground truth except the TP.

8. The Performance of the Different Methods

In order to evaluate the performance of the proposed algorithm, we compare the algorithm with the threshold segmentation, edge extraction, homomorphic filtering, and Gabor filtering methods. The experimental results are shown in Figure 4.

We use two kinds of images to evaluate the performance. The first is the conspicuous and straightforward image of the color spot, the second has the color spot of large, and the third is more complicated color spots with many and large regions. In the simple and conspicuous image, the methods of edge extraction, Gabor filtering, and our proposed algorithm can extract or indicate the accurate position of the color spot. Because the gray-level difference between the color spot and the normal skin is very small, the uneven illumination is the main problem for the wrong segmentation as shown in Figures 4(d) and 4(l). The edge extraction only obtains the edge of the color spot. Although the edge extraction method can extract the accurate position of the color spot in this sample (Figure 4(e)), the method has poor robustness in the complex image (Figure 4(m)). Homomorphic filtering is the classical filter method that reduces the low-frequency component and enhances the high-frequency component. It can reduce the effect of varying illumination and enhance the detail of the image. In the image of the color spot, the gray-level difference between the color spot and the normal skin is very small, and the homomorphic filtering is also hard to recognize the precise region of the color spot. The Gabor filtering [38, 39] is a short-time Fourier transformation that provides the selections of the orientation and scales. From Figures 4(g) and 4(o), the selection of the orientation may cause the deformation of the extracted color spot. And that the performance is worse in the complex image. The proposed multifused enhancement algorithm achieves the accurate position of the color spot not only in the simple circumstance but also in the complex image.

To further evaluate the accuracy and robustness of the proposed algorithm, we randomly selected 50 images from the skin dataset built by our group. The images include simple and complex samples of the color spot. The segmented accuracy of the color spot is evaluated by TPR, PPV, ACC, and F1, and the experimental results are shown in Figure 5.

The mean values of TPR, PPV, ACC, and F1 are 0.591, 0.625, 0.995, and 0.581, respectively. The segmented results indicate that all the color spots can be mainly segmented by the proposed method. Some factors may reduce the segmentation accuracy: (1) the region of color spot occupies a small proportion in the whole image, the small inaccurate segmentation may cause a great influence on the TPR, PPV, and F1, and (2) the denoising algorithm may reduce the accuracy of the segmented results. Excessive denoising and insufficient denoising also lead to a large error, (3) some color spots are difficult to recognize. The color spot is generated by the melanin accumulation, and the accumulation of some region may not reach the standard of the real color spot, and (4) the region, shape, and size of the color spots are varied and irregular, and the feature of the color spots is not discriminative, so the extraction of the color spot is still a great challenge.

9. The Wavelet Transform with Different Parameters

In this work, we use the wavelet transform to enhance the color spot. The wavelet is the key factor that should effect the enhanced performance of the color spot. There are some wavelets that can be used in the wavelet transformation, such as haar, daubechies, symlets, coiflets, biorthogonal, reverseBior, dmeyer, and fk. We use these wavelets to evaluate the performance to choose the optimal wavelet. The main experimental results are shown in Figure 6.

From the experimental results, we can learn that haar, bior1.1, and rbio1.1 may be the optimal choices in our work. While choosing the optimum wavelet, we should consider the support width, symmetry, vanishing moment, regularity, and similarity of the wavelet.

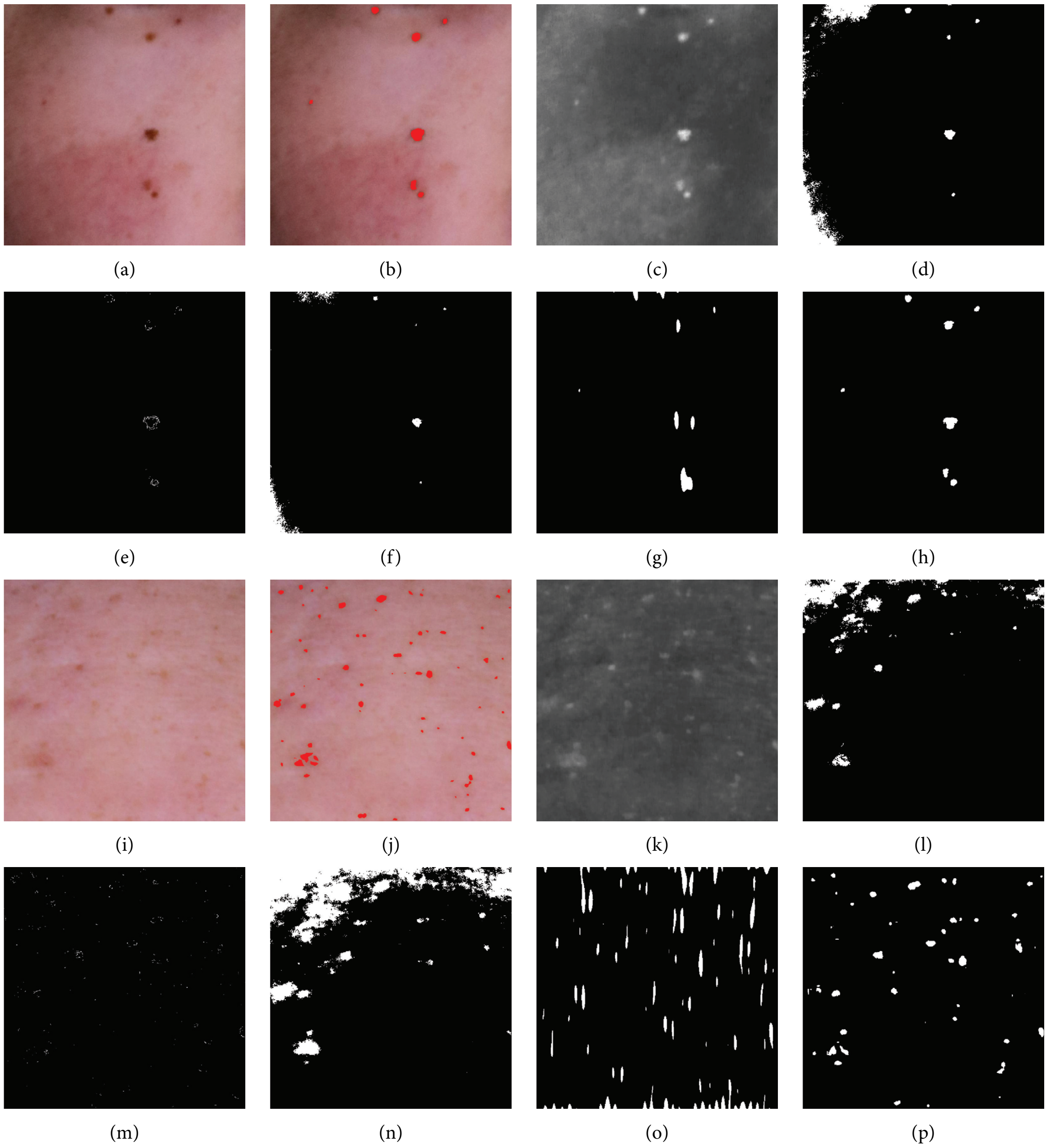


Figure 4: The comparison of different methods. (a) Simple image. (b) Ground truth. (c) Saturation. (d) Threshold. (e) Edge. (f) Homomorphic filtering. (g) Gabor filtering. (h) Our proposed algorithm. (i) Complex image. (j) Ground truth. (k) Saturation. (l) Threshold. (m) Edge. (n) Homomorphic filtering. (o) Gabor filtering. (p) Our proposed algorithm.

10. The Reduction of the Uneven Illumination

The uneven illumination is one of the main reasons that caused the gray level to be uneven in the captured image. In Figure 7(a), the image includes the conspicuous color spot, but the region with the low illumination may have a similar gray level to the color spot. The phenomenon is a little bit difficult for the segmentation of the color spot. In order to reduce the effect, we use saturation instead of the gray level to reduce the effect caused by the uneven illumination. Although the uneven effect is reduced in Figure 7(b), the features of the color spot for the discrimination are also reduced. The proposed method uses the wavelet transform to enhance the features of the color spot. The final enhanced image is shown in Figure 7(c). The final result not only eliminates the uneven effect but also enhances the features of the color spot.

11. Discussion

The article proposes a multifused enhancement algorithm for color spot extraction. We use the imaging technology of the polarized light to obtain the conspicuous color spot information and adopt the saturation component instead of the traditional gray-level image to analyze the color spot. Finally, the wavelet transform algorithm enhances the color spot information and reduces the influence of normal skin information. The experimental results indicate that the

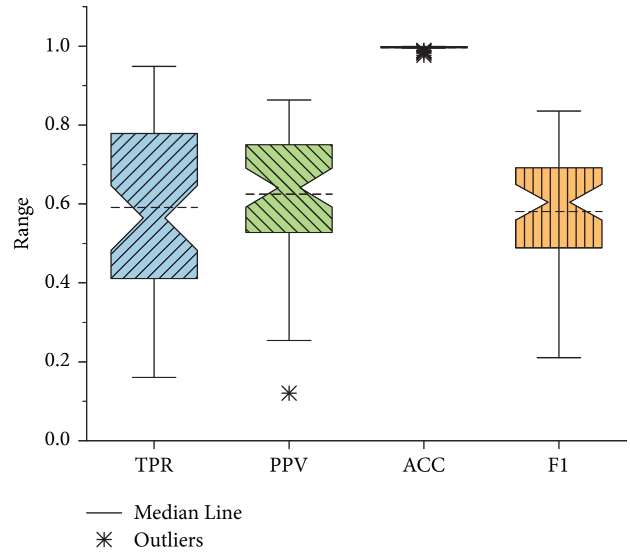


FIGURE 5: The accuracy of the proposed algorithm.

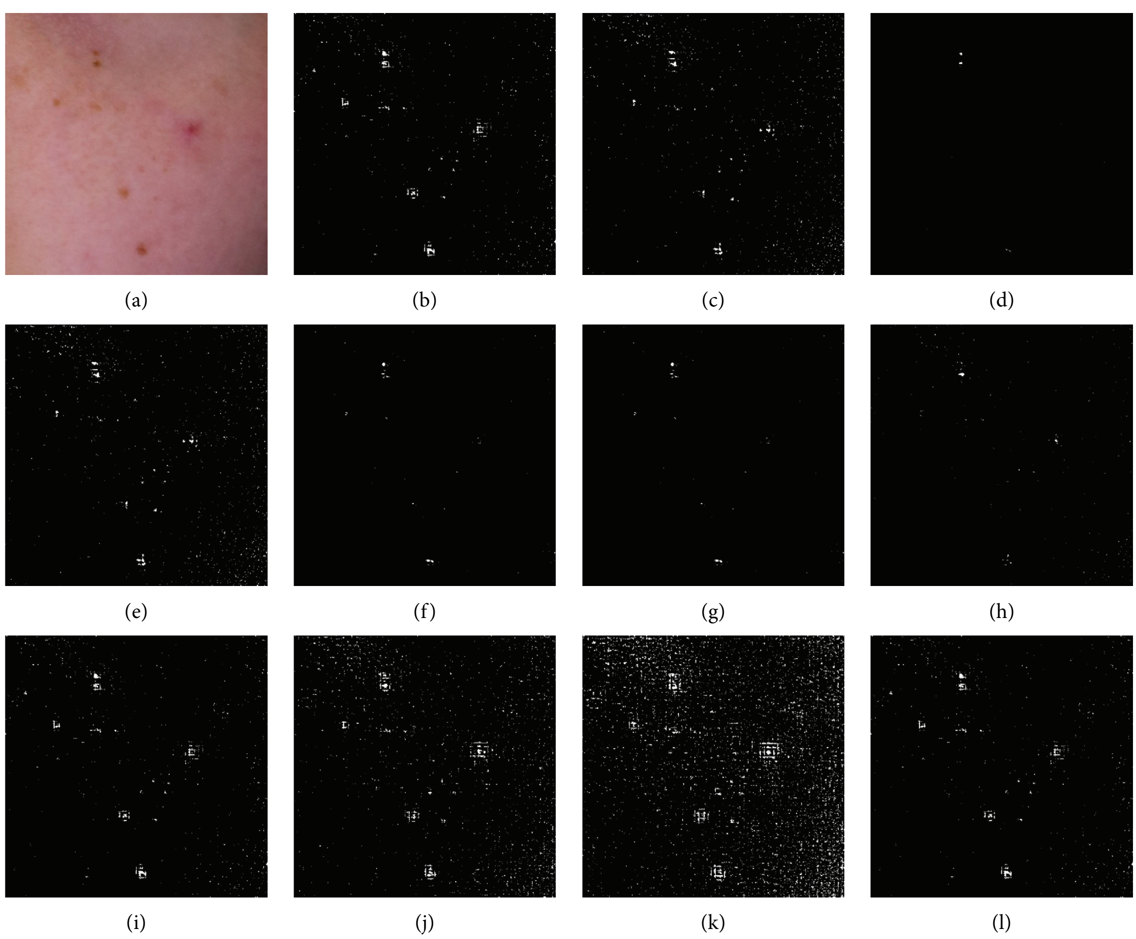
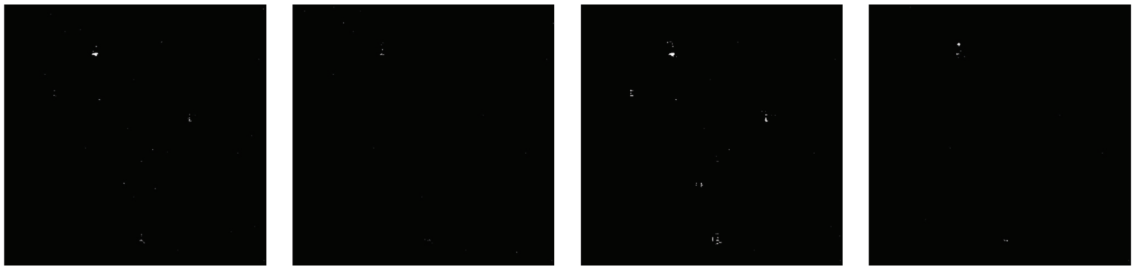


FIGURE 6: Continued.



(m) (n) (o) (p)

Figure 6: The image enhancement with the different wavelets. (a) Original image. (b) Haar. (c) db2. (d) db3. (e) sym2. (f) sym3. (g) coif1. (h) coif2. (i) bior1.1. (j) bior1.3. (k) bior1.5. (l) rbio1.1. (m) rbio1.3. (n) dmey. (o) fk4. (p) fk6.

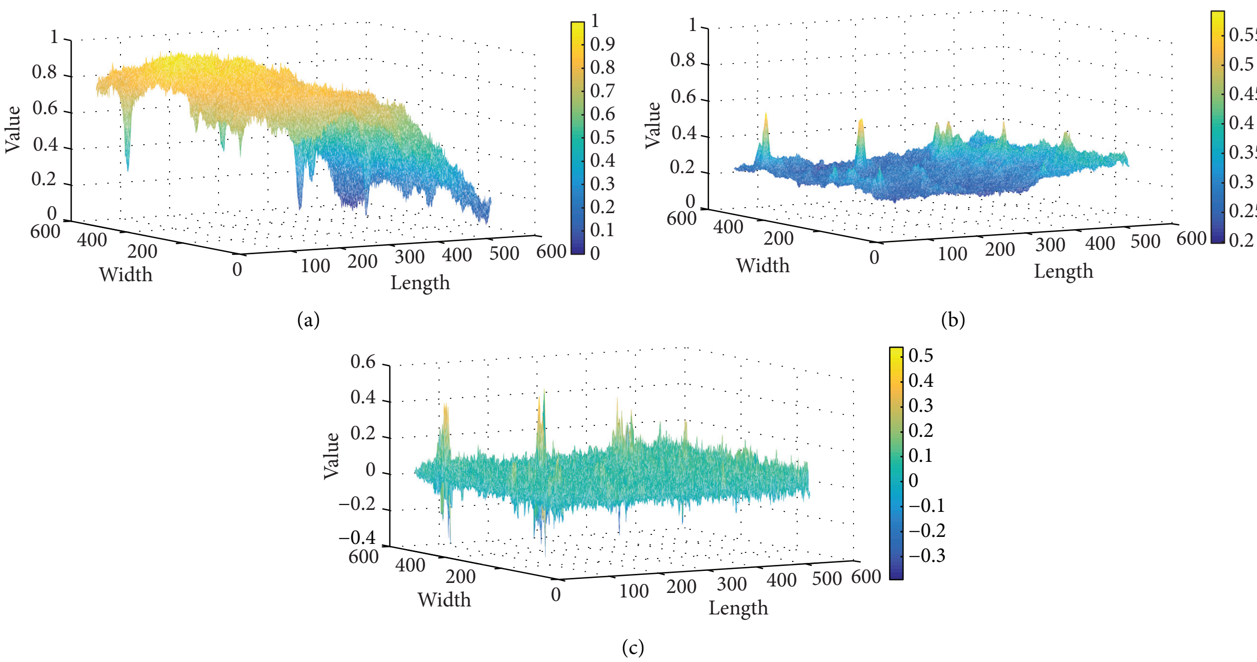


Figure 7: The reduction of the uneven illumination. (a) Gray-level image. (b) Saturation image. (c) Enhanced image.

proposed algorithm can accurately and robustly extract the color spot. In comparison with the traditional methods, the proposed algorithm can obtain the more conspicuous color spot with the enhanced methods. The algorithm also can reduce the effect of the uneven illumination by the method with the polarized light and wavelet transform. In addition, the proposed algorithm can achieve robust performance on both simple and complex color spots.

The key issue of the color spot extraction is how to solve the nonobviousness of the color spot. The traditional threshold segmentation extracts the color spot without the color spot enhancement. Hence, the results are noisy and not accurate. Although the edge extraction does not enhance the color spot, the obtained positions of the color spots are accurate in simple circumstances. The reason is that the edge extraction is based on the local gradient feature, and the uneven gray level cannot influence the performance in simple circumstances. However, because of the heavy noise in the complex circumstance, the performance of the edge extraction is not efficient. Except for the method of the spatial domain, the method based on the frequency domain is the primary enhancement method, such as homomorphic filtering and Gabor filtering. Due to the gray level of the captured images being uneven, the homomorphic filtering cannot achieve the preferable performance. The Gabor filtering can achieve the accurate color spot in the simple circumstance, but the obtained shape is distorted on account of the orientation selection in the algorithm. When the color spot is complex, the algorithm is also challenging to achieve the preferable performance. The proposed algorithm is the multifused enhancement algorithm. To reduce the effect of the uneven illumination and enhance the conspicuousness of the color spot, we use the polarized image acquirement, color model transformation, and wavelet transform. The proposed algorithm considers not only the effect of the uneven illumination but also the local features based on the wavelet transform. Thus, the proposed algorithm can achieve better performance.

The color spot has a significant meaning in medical diagnosis and skin evaluation. The pathological features of the color spots can be used in skin diagnosis. The color, size, and position of the color spots are also used in Chinese medical diagnoses. With the development of the living standard, more and more people focus on skin care. The status of the color spot can represent the skin quality. In addition, the skin quality of the different periods can be used for the evaluation of skin care products.

It is still a challenge for the precise extraction of the color spot still has some challenges. A more accurate algorithm of the color spot should be studied in future work. Although the proposed algorithm can achieve the preferable performance, the extracted region should be further improved. In addition, as far as we know, it does not exist any intelligent imaging software to recognize and analyze the spot automatically. A more intelligent algorithm should be studied.

12. Conclusions

The article proposes a multifused enhancement algorithm for color spot extraction. In order to extract the accurate color spot, we use the vertically polarized camera with the horizontally polarized light to capture the conspicuous information of the color spot. The saturation of the image is also used to enhance the color spot. Finally, the wavelet transform is used to enhance the high frequency, which indicates the information of the color spot. In comparison with the threshold method, edge extraction, homomorphic filter, and Gabor filter, the proposed algorithm can achieve the best accurate and robust performance in simple and complex circumstances. The experimental results indicate that the proposed algorithm achieves 59.1% and 62.5% accuracy in terms of TPR and PPV, respectively. In future work, the larger dataset should be used to verify and improve the performance of the proposed algorithm.

Data Availability

All data used during the study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] J. A. Savin, "The hidden face of dermatology," *Clinical and Experimental Dermatology*, vol. 18, no. 5, pp. 393–395, 2010.

[2] E. Foley, A. Robinson, and M. Maloney, "Skin substitutes and dermatology: a review," *Current Dermatology Reports*, vol. 2, no. 2, pp. 101–112, 2013.

[3] R. E. Ashton, "Teaching non-dermatologists to examine the skin: a review of the literature and some recommendations," *British Journal of Dermatology*, vol. 132, no. 2, pp. 221–225, 2010.

[4] M. Nematy, A. Mehdizadeh, and F. Razmpour, "Short review iranian journal of dermatology a review on nutrition and skin aging," *Iranian Journal of Dermatology*, vol. 18, no. 71, pp. 20–24, 2015.

[5] A. L. S. Chang, J. W. Wong, J. O. Endo, and R. A. Norman, "Geriatric dermatology review: major changes in skin function in older patients and their contribution to common clinical challenges," *Journal of the American Medical Directors Association*, vol. 14, no. 10, pp. 724–730, 2013.

[6] J. H. Dunn and J. Koo, "Psychological stress and skin aging: a review of possible mechanisms and potential therapies," *Dermatology Online Journal*, vol. 19, no. 6, Article ID 18561, 2013.

[7] M. Nematy, A. Mehdizadeh, and F. Razmpour, "A review on nutrition and skin aging," *Iranian Journal of Dermatology*, vol. 18, no. 71, pp. 20–24, 2015.

[8] A. Sparavigna, B. Tenconi, and I. De Ponti, "Antiaging, photoprotective, and brightening activity in biorevitalization: a new solution for aging skin," *Clinical, Cosmetic and Investigational Dermatology*, vol. 8, pp. 57–65, 2015.

[9] Y. Al-Nuaimi, M. J. Sherratt, and C. E. M. Griffiths, "Skin health in older age," *Maturitas*, vol. 79, no. 3, pp. 256–264, 2014.

[10] E. Uhoda, C. Piérard-Franchimont, L. Petit, and G. E. Piérard, "The conundrum of skin pores in dermocosmetology," *Dermatology*, vol. 210, no. 1, pp. 3–7, 2005.

[11] A. K. Langton, M. J. Sherratt, C. E. M. Griffiths, and R. E. B. Watson, "Review Article: a new wrinkle on old skin: the role of elastic fibres in skin ageing," *International Journal of Cosmetic Science*, vol. 32, no. 5, pp. 330–339, 2010.

[12] M. A. Hamer, L. M. Pardo, L. C. Jacobs et al., "Lifestyle and physiological factors associated with facial wrinkling in men and women," *Journal of Investigative Dermatology*, vol. 137, no. 8, pp. 1692–1699, 2017.

[13] J. M. Lagarde, C. Rouvrais, and D. Black, "Topography and anisotropy of the skin surface with ageing," *Skin Research and Technology*, vol. 11, no. 2, pp. 110–119, 2010.

[14] Y. Tian, T. Hoshino, C. J. Chen, S. Yabe, and W. Liu, "The evaluation of whitening efficacy of cosmetic products using a human skin pigmentation spot model," *Skin Research and Technology*, vol. 15, no. 2, pp. 218–223, 2010.

[15] U. Blume-Peytavi, J. Kottner, W. Sterry et al., "Age-associated skin conditions and diseases: current perspectives and future options," *The Gerontologist*, vol. 56, 2016.

[16] A. Mamalis, D. Ho, and J. Jagdeo, "Optical coherence tomography imaging of normal, chronologically aged, photoaged and photodamaged skin," *Dermatologic Surgery*, vol. 41, no. 9, pp. 993–1005, 2015.

[17] C. Praetorius, R. A. Sturm, and E. Steingrimsson, "Sun-induced freckling: ephelides and solar lentigines," *Pigment Cell & Melanoma Research*, vol. 27, no. 3, pp. 339–350, 2014.

[18] B. Hernando, M. V. Ibaez, J. A. Deseriocuesta, R. Sorianavarro, I. Vilarsastre, and C. Martinezcadenas, "Genetic determinants of freckle occurrence in the Spanish population: towards ephelides prediction from human dna samples," *Forensic Science International Genetics*, vol. 33, p. 38, 2017.

[19] C. T. Paniagua and A. S. Bean, "Black-spot poison ivy: a rare phenomenon," *Journal of the American Academy of Nurse Practitioners*, vol. 23, no. 6, pp. 275–277, 2011.

[20] M. Rodrigues and A. G. Pandya, "Melasma: clinical diagnosis and management options," *Australasian Journal of Dermatology*, vol. 56, no. 3, pp. 151–163, 2015.

[21] R Sarkar, P Ailawadi, and S Garg, "Melasma in men: a review of clinical, etiological, and management issues," *The Journal of*

clinical and aesthetic dermatology, vol. 11, no. 2, pp. 53–59, 2018.
[22] L. Ai-Young, "Recent progress in melasma pathogenesis," *Pigment Cell Melanoma Res*, vol. 28, no. 6, pp. 648–660, 2015.
[23] A. Skoczyska, E. Budzisz, E. Trznadel-Grodzka, and H. Rotsztejn, "Melanin and lipofuscin as hallmarks of skin aging," *Advances in Dermatology Allergology/postpy Dermatologii I Alergologii*, vol. 34, no. 2, pp. 97–103, 2017.
[24] H. Sakai, Y. Ando, K. Ikinaga, and M. Tanaka, "Estimating melanin location in the pigmented skin lesions by hue-saturation-lightness color space values of dermoscopic images," *The Journal of Dermatology*, vol. 44, no. 5, pp. 490–498, 2017.
[25] N. Joly-Tonetti, J. I. D. Wibawa, M. Bell, and D. Tobin, "Melanin fate in the human epidermis: a reassessment of how best to detect and analyse histologically," *Experimental Dermatology*, vol. 25, no. 7, pp. 501–504, 2016.
[26] M. D'Ischia, K. Wakamatsu, F. Cicoira et al., "Melanins and melanogenesis: from pigment cells to human health and technological applications," *Pigment Cell Melanoma Res*, vol. 28, no. 5, pp. 520–544, 2015.
[27] L. Liu, N. Yang, J. Lan, and J. Li, "Image segmentation based on gray stretch and threshold algorithm," *Optik*, vol. 126, no. 6, pp. 626–629, 2015.
[28] E. Hamuda, M. Glavin, and E. Jones, "A survey of image processing techniques for plant extraction and segmentation in the field," *Computers and Electronics in Agriculture*, vol. 125, pp. 184–199, 2016.
[29] A. Ferone, S. K. Pal, and A. Petrosino, "A rough-fuzzy hsv color histogram for image segmentation," *Image Analysis and Processing - ICIAP 2011*, vol. 6978, no. 1, pp. 29–37, 2011.
[30] C. Lu and T. Wu, "[segmentation and cavity filling of color image from stained trabecular sections based on hsv space]," *Journal of Biomedical Engineering*, vol. 29, no. 2, p. 260, 2012.
[31] A. M. Grigoryan, E. R. Dougherty, and S. S. Agaian, "Optimal wiener and homomorphic filtration: Review," *Signal Processing*, vol. 121, pp. 111–138, 2016.
[32] N. Biradar, M. L. Dewal, and M. K. Rohit, "A novel hybrid homomorphic fuzzy filter for speckle noise reduction," *Biomedical Engineering Letters*, vol. 4, no. 2, pp. 176–185, 2014.
[33] L. Xiao, C. Li, Z. Wu, and T. Wang, "An enhancement method for x-ray image via fuzzy noise removal and homomorphic filtering," *Neurocomputing*, vol. 195, pp. 56–64, 2016.
[34] X. Ma, K. Xu, J. Jiang, R. Liu, and X. Yu, "Layered vasculature segmentation of color conjunctival image based on wavelet transform," *Biomedical Signal Processing and Control*, vol. 42, pp. 9–17, 2018.
[35] S. Liu, "Study on medical image enhancement based on wavelet transform fusion algorithm," *Journal of Medical Imaging and Health Informatics*, vol. 7, no. 2, pp. 388–392, 2017.
[36] K. Thiruvenkadam and N. Perumal, "Fully automatic method for segmentation of brain tumor from multimodal magnetic resonance images using wavelet transformation and clustering technique," *International Journal of Imaging Systems and Technology*, vol. 26, no. 4, pp. 305–314, 2016.
[37] Y. Feng, E. Song, L. Hong, Y. Li, Z. Jun, and C. C. Hung, "An augmented reality endoscope system for ureter position detection," *Journal of Medical Systems*, vol. 42, no. 8, p. 138, 2018.
[38] S. Thilagamani and N. Shanthi, "Gaussian and gabor filter approach for object segmentation," in *Proceedings of the International Conference on Optical Imaging Sensor and Security*, pp. 1–6, IEEE, Coimbatore, India, July 2013.
[39] F. Farokhian, C. Yang, H. Demirel, S. Wu, and I. Beheshti, "Automatic parameters selection of gabor filters with the imperialism competitive algorithm with application to retinal vessel segmentation," *Biocybernetics and Biomedical Engineering*, vol. 37, no. 1, pp. 246–254, 2017.