Enhanced Retinex Deep Learning Method for Low light Image Enhancement

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Abstract

At present days most the researchers are carried out a lot of color enhancement of gray images in diverse fields. It is commonly used methods mainly include density layering method gray scale color transformation method pixel self-transformation method rainbow coding, method, metal coding as well as pseudo color enhancement algorithm based on frequency domain. In current centuries signal as well as image processing is based on fractional calculus has attracted extensive attention. Color Enhancement is realized by utilizing the constructed high gray scale enhancement algorithm. Combined with the convolution neural network, extract the features of the multiscale image utilizing the compact learning method. The research acquisition show that the compared with the traditional image enhancement image proposed method give better comprehensive performance in subjective vision besides objective indicators in dealing with low light image enhancement. The brightness distribution of the enhanced image can well restore the brightness distribution of the real shooting environment in addition to higher robustness. In this research paper the Retinex Hetergenous equalization Feature Fusion Scale Image Enhancement method for content based deep learning enhancement system. The proposed method effectively with traditional jet coding as well as HSV pseudo color methods as well as find out the brightness of image, brightness of the distortion, blocking can well restore the brightness besides preserves the values of the RGB color components of each pixel of the image in addition to estimates the reflectance distribution of the real shooting environment has higher robustness

Keywords: Low Light Enhancement, Hybrid Deep learning, Color Distortion, RGB, Retinex Heterogeneous.

1. Introduction

In low light image enhancement the image shooting will be affected by the environment or the equipment used, subsequent in the incapability to imprisonment clear as well as high quality images. In a backlight, night or dim indoor as well as other special environment, even the images taken with standard equipment will appear blurry as well as have low brightness loss of detail, high noise, poor visual quality etc. therefore low light moreover dim images image enhancement is very important.

The development of digital data makes image enhancement refers to accentuation otherwise sharpening of image features of the edges, boundaries or dissimilarity to create a graphic presentation more useful for display moreover exploration. The improvement procedure does not growth the intrinsic information comfortable in the data development and the retinex image variety of the preferred features can be distinguished certainly. Image enhancement includes gray level and contrast manipulation pseudo colouring and so on. Image enhancement is utilized to improve the equality of an image for visual perception of human eyes. It is also utilized for low level vision applications. This is the assignment in which the usual of pixel standards of unique image is distorted to a novel set of pixel values sot that the new image formed is perceptibly appealing as well as remains more appropriate aimed at examination. Hue, saturation as well as intensity are the attributes of color decides what kinds of color it is specially preferred red or an orange. In the variety every colour remains at the extreme clarity that the eye can terminate the appreciated image as well as the spectrum of colors is described as fully saturated. If a saturated color is diluted by being mixed with other colors or with white light its richness or saturation is decreased. For this purpose of enhancing a color image is to be seen that hue should not alteration aimed at several pixel. If hue is changed then the color gets changed by misrepresenting the image. Improvement of pictorial information for human perception means whatever image user set that want to enhance the quality of the image that the image will have a better look and it will be much improved as look at them. Image processing for autonomous deep learning applications industries particularly for quality control in assembly automation as well as many such applications. Efficient storage as well as transmission and want to store an image on a computer then this image need a certain amount of disk space. It is possible to process the image using certain image property. The disk space required for storing an image will be less and to have transmitted the image otherwise a video signal over a transmission media and if the bandwidth if the transmission medium is very low and how to process the image can be transmitted over low bandwidth communication channel.

Noise Filtering: The images get have some very noisy and to filter those images so that the noise present in the image can be removed and the image appears much better. In some other kind of applications to enhance certain characteristics of the image. The dissimilar kind of applications to enhance certain characteristics of the image. There is some other kind of application under this category is contrast Enhancement.

Contrast Enhancement: It covers diverse type of techniques such as contrast Enhancement and Deblurring. Sometimes the image may very poor contrast as well as to enhance the contrast of the image for enhanced chromatic. In particular additional belongings, the images might be blurred and the image is blurring might be occur outstanding to numerous purpose such as may be CCTV camera sitting is not proper or the lens is not focus properly that leads to one kind of blurring. The other kind of blurring can be take a picture from a moving train or moving a car might have observed the image to get a blurred image or not cleared image. Remote sensing: The type of image which are used in the aerial images. So that most of the aerial images are taken from satellite images.

Deep learning constructed low light image restoration methods consume compensations as well as disadvantages contingent on their structural characteristics as well as to apply the same architecture to the RGB channels. The correlation between the R, G, B channels is very low so diverse architectures are suitable to each channel or diverse color spaces would be more desirable to obtain more satisfactory results.

2. RELATED WORK

The developed pseudo color image enhancement, are described the tough schedule of cloud image as well as crack space image. The numerical image examination displays that the method is more effective for analyzing and understanding the fracture characteristics of rocks. [JIN20]. Chiang et al used HSV Zhang *et al.* Studied the rough point cloud image and crack space image. The numerical results show that the method is effective for studying and understanding the fracture characteristics of rocks [WAN20]. Relevant scholars have also applied the pseudo color enhancement algorithm of gray image to medical image fusion and remote sensing image processing.

The innovative palmprint image frequently consumes certain difficulties, such as the texture is not strong, the palmprint image has an unlimited revolution approach, as well as the image consumes noise. Therefore, it is necessary to enhance the original palmprint image acquired by the device and extract the region of interest (ROI). The existing palm print pretreatment methods generally have some problems, such as high time cost and dependency between methods. With the rapid development of neural network has attained excessive achievement in traffic vehicles, and recognition, license plate recognition and other fields. Neural network is a mathematical model that simulates biological neural network for information processing. Its purpose is to simulate some mechanisms and mechanisms of the brain to achieve some specific functions [YEN20]. It has a high degree of parallel structure and parallel implementation ability, can give full play to the high-speed computing ability of the computer, and can quickly and the optimal solution. Based on the transform domain image enhancement method, the image information is transformed into the frequency province space, and the image is enhanced by changing the components of the image with dissimilar frequencies. This kind of algorithm mostly customs low-pass strainer, high pass filter and homomorphic filter to improve the image.

The enhancement algorithms are able to classified into above working in the spatial field as well as in the transformation field. The enhancement can also be performed using several filtering techniques and to be the transform the domain techniques are over again classified into wavelet domain has to be curvelet domain algorithms depends on the domain.

Tian et al. [TIE21] adjusted multi-scale wavelet coefficients by utilizing the contrast of visual statistical characteristics to correct the global and local contrast of the image. The color of the image enhanced by this algorithm is more in line with human visual characteristics. [GUI22] used the brightness masking characteristics and contrasts masking gradient characteristics of HSV model to enhance the image contrast besides the adjustment of the image brightness in the secure wave helps to transform field as well as the dual tree composite. The wave transform field by utilizing the nonlinear contrast mapping is more coefficient value. The typical frequency domain enhancement algorithm is also the Retinax based enhancement algorithm proposed by land Peng et al. [PEN20].

In order to make the brightness of the enhanced image more consistent with human vision, separates the optical signal received by the human eye into incoming light and reflected light through transform domain filtering, and enhances the image quality by reducing the incident light and enhancing the reflected light that transmits the real information of the object. and then used the weighted variation model to estimate the incident light image and the reflected light image of the image to enhance the image brightness. This kind of algorithm can enhance the details of the image well, but the enhancement process is complex, and the enhancement algorithm based on deep learning can solve this problem.

3. METHODOLOGY

Retinex model-based method decomposes the low-light images helps to reflection as well as the illumination components of a low-light image *S*, it can be decomposed into S=R⊙I, where *S* denotes the low-light image, *R is the values that can be* signifies the reflectance, *I* values are denotes as the lighting map, besides ⊙ signifies the dot produce operation. In adding, frequent enhanced varieties of Retinex models must remained imitative consequently the Retinex theory, counting the single scale Retinex model.

In under water image enhancement low light images were usually enhancement methods for low light images the datasets as well as commonly used evaluation indicators in the deep learning enhancement methods. The problems as well as development of deep learning enhancement methods for low light images. The deep learning and machine learning methods are used to implement image enhancement methods are respectively introduced according to the neural network structure.

In calculation, the chroma-net is individually recycled to decrease color misrepresentation. Additionally, a mixed-norm loss function Utilized in the preparation procedure of every network is nominated to growth the immovability as well as eliminate distorting in the reassembled image by replicating the belongings of reflectance, illuminance, as well as chroma.

The wavelet transform should use diverse strategies on grayscale images and RGB images. In the grayscale images, these image enhancement algorithms can act on the gray channel. Nevertheless in the RGB images, it is erroneous to reinforce the RGB channels, since the unique color dissemination of the images. It is effective to convert the RGB image into hue-saturation-value. (HSV) channel and enhances the image by retaining the H channel, S channel and changing the V channel [XUM21]. In order to prevent the influence of the conversion from RGB images to HSV channels and from HSV channels to RGB channels, all the image data sets including the original images will be converted from RGB channels to HSV and convert back to RGB channels.

3.1 PROPOSED METHOD FOR RETINEX HETEROGENEOUS

The special transmission property of the light in the water and the light interacts with the water medium through two processes absorption and scattering. Engagement is the damage of influence as light travels in the intermediate as well as it be determined by on the catalogue of diversion of the medium. Scattering denotes to several refraction since a straight-line proliferation path. In low light environment, deflections can be due to particles of size comparable to the wavelengths of travelling light (diffraction) or to particulate matter with refraction index changed from that of the water refraction. Figure 1.1 signifies the retinex heterogeneous scale method on behalf of Image contrast enhancement utilizing luminance weight and Design detail weight.

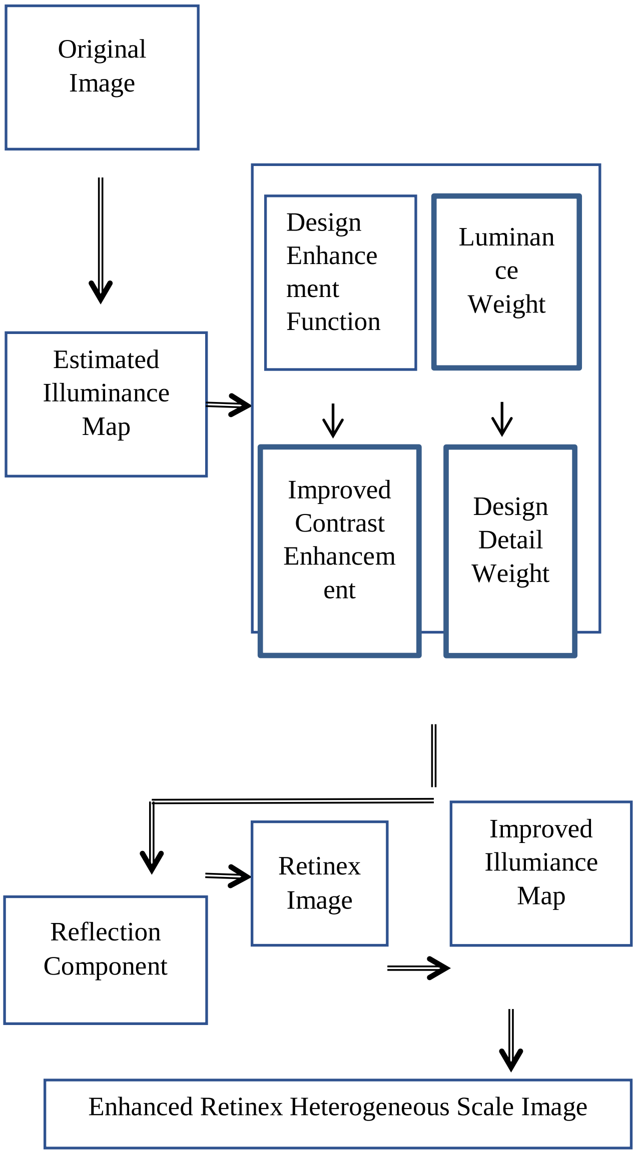

Fig.1.1 Retinex Heterogeneous Scale method for Image Enhancement

The differentiation of Retinex model based on the L2-norm, the hybrid L2-Lp of the model with bright channel prior, as well as the maximum-entropy-based on the Retinex model. Image remained occupied beneath low light otherwise dim backlight conditions frequently force inadequate brightness, low contrast besides poor visual quality of the image that leads to enlarged difficulty in computer vision as well as human gratitude of images the low illumination enhancement is very imperative in computer vision applications.

In this approach, it uses Retinex methodology to separate an image into illumination and reflectance layer so that on the illumination layer the luminance adaptation can be applied to handle it which cause detail loss. It uses the gauss filter for filtering the image so that the halo effects can be removed from it. In this approach, it uses to remove the illumination from the illumination layer during MSR in an adaptive manner so that data loss does not occur and hence details can be preserved for the image. After removing the illumination from the illumination layer it uses to perform the MSR for the results with the contrast enhanced output. Retinex is the approach which was introduced to remove the effect of light and get the true colors for the image after image enhancement. The reflectance layer is taken as the intrinsic feature of the image after removing the illumination from the image on the basis of Retinex theory. But it can lead to having the noise increment in the region with low light or dark region. So, to stop doing so this method uses a control factor on the basis of the luminance adaptation to remove the illumination artifacts adaptive.

The regularization-based algorithms show suboptimal presentation arranged the Set12 besides LOL since those approaches disregard the sound misrepresentation in augmenting images. Associated to the regularization-based methods, learning-based models achieve better results. Since the performance of pure learning-based methods relies heavily on the number of training samples, and this dataset only has limited data, their results are not completely satisfactory. Finally between all the image enhancement models, proposed method attains the greatest arithmetical scores in light of all metrics. To further test the effectiveness of the proposed method in noise suppression, here we specifically compare it with five competitors that also consider noise suppression in image enhancement.

3.2 DATASET

Implementation Details and Data sets to evaluate the performance of our proposed method train and test our model on LOL dataset [NAN21], which contains 500 low/normal-light image pairs, and is captured at various exposure times from the real world.

This module builds a reflection estimation network based on a variant of the Retinex model, utilizing the weighted feature maps to generate the reflection component of a low-light image. Equation 1 taking the reflection component as an enhanced wellexposed image.

$$sc = Fex(zc , \omega) = \sigma(g(zc , \omega)) = \sigma(\omega 2\delta(\omega 1zc)) \text{ ------(1)}$$

In the formula, ω 1, ω 2 represent the two fully connected layers, σ, δ represent the Sigmoid activation function and the ReLU activation function, and sc signifies the weight of the production of the position of the c-th channel. The consideration machinery component creates the network model further accomplished of classifying the types of each channel, consequently that the model can highlight the channel structures that are favourable to the improvement consequences.

3.3 RECURSIVE MATRIX ALGORITHM

A recursive matrix contrast method is utilized as an alternate to the innovative path addition. This algorithm significantly is depending on the control of the optimal number of iterations. Therefore, it is measured as a constraint subsequently and this parameter is hard to be determined and can essentially affect the final result [CIU04]. The complexity of generating a path that consist of a quantity of tracks to be utilized, as well as their distance are essentially resolved in the Recursive Matrix Algorithm. Although, ultimate results of the algorithm extremely be contingent on repetition that designates the time pixel limitations in the image as well as regulate the quantity of the neighbors to be measured. Therefore, the impartial of image enhancement is exposed to this critical stricture which enhances extra complication to the improvement assignment itself.

For a more convincing comparison, extend our model to SICE dataset [CHE18], which contains 589 natural scenes with multi-level exposure, and randomly select 108 under/normal exposure image pairs from it. Furthermore, adopt MEF dataset [YUN19] for visual comparison to demonstrate the efficiency of our proposed method.

3.4 DATASET AND METRICS

Apprehending real-world low-light images with ground certainty is challenging. e a large set of low-light images via synthesis based on the PASCAL VOC images dataset.

Low-light image synthesis

Low-light images are mostly different as of regular images because of two most important salient features: low brightness besides the presence of noise. Relate a random gamma adjustment to each channel of the conjoint images to yield the low-light images, This procedure can be communicated as I out = A×I γ in, where A is a constant determined by the maximum pixel intensity in the image and γ obeys a uniform distribution U(2,3.5). The noises, of the silent images are taken it into an account. In certain, normally add the Poisson noise with the peak value is defined as 200 and to the low light image. Preferred the 23714 images in the VOC dataset to production the training set, 156 images for the validation set, and 174 images for the test set.

Low-light video synthesis

Chose e-Lab Video Data Set (e-VDS) to synthesize low-light videos. Cut the original videos into video clips (31×255×255×3) to build a dataset of around 20000 samples, 95% of which form the training set and the rest for test.

Most excellent works based on the guided filter have indicated their outstanding efficiency in estimating the transformation model between low-resolution images in addition to delivering high-resolution images by applying the transformation model in various domains. Typically, an intuitive linear transformation model between input images I input and output image I out can be identified as Equation 2, where α is a real-valued scaling factor known as gain, and β is a real-valued offset known as the bias.

I out = α ∗ I input + β -------------------(2)

I i out = A k ∗ I i input + B k , ∀i ∈ ωk --------(3)

ωk is the k-th local square window on I input, and I i input is the i-th pixel inside ωk. By applying this Equation 2 on me as low and me o low, the corresponding A low and B low can be estimated by minimizing a reconstruction error between I low and I o low. Then the high-resolution output I o high can be approximately generated by the linear transformation model:

I o high = A high ∗ I in height + B high. -------------(4)

Based on procedures of estimating transformation model, present the module for generating high-resolution, edge-preserving outputs with much lower computational costs.

Algorithm of Retinex Heterogeneous Scale Method

Step 1: ***Input : Low light image S_0***

Step 2: ***The image I is taken, along with guidance image G, iteration number K=10 and parameter with values λ=0.3, α=0.5, g*=1e-3, h*=0.075, r*=2, I0, ⇓I, with * ∈{dt, sm}***

Step 3: ***for loop k= 0 to K do***

Step 4: ***Using Ik , calculate (∇* m,n) k , update (l*m,n) k***

Step 5: ***$Z_{i\,->}N(0,\partial^2)$, i= 1.2,3***

Step 6: ***With the value of (l*m,n) k update (μ* m,n) k***

Step 7: ***while (Input 6= ∅) do***
Step 8: ***Update mean(g) by mean(g) = γ × g(I) + (1 − γ) × mean(g)***
Step 9: ***if (I is normal illumination image) then***
Step 9: ***Update meanmid Idayby mean(mid Iday) = γ × mid(I) + (1 − γ) × mean(mid(Iday));***
Step 10: ***else***
Step 11: ***Estimate initial illumination L***
Step 12: ***Estimate reflectance R(IMSR)***
Step 13: ***Calculate weight parameters β(IHE)***
Step 14: ***Calculate weight parameters α(I)***
Step 15: ***Using (l*m,n) k and (μ* m,n) k solve Ik+1***
Step 16: ***for loop k= 0 to K-1 do***
Step 17: ***Updating Ik+1***
Step 18: ***end if***
Step 19: ***End for loop***
Step 20: ***Compute Enhanced Image §= C Ě{R,G,B)***
Step 21: ***Output §***

The proposed method Retinex Heterogeneous Scale method to filtering the content based system is in the pre-process method. So, CCTV camera sitting to test in this image pre-processing will add to yield the NIQE, and VIF values of the method used. The investigational consequences validate that the future technique hints to encouraging particular as well as detached developments terminated state-of-the-art image enhancement of deep-learning approaches.

4. RESULTS AND DISCUSSIONS

The method that has been proposed in this research has shown to have performed better than all the previous methods that exist for Low Light Image Improvement Models. For the sake of simplicity, decided a few of them these are the original images. Similarity, use SIRE, WME, RRM, and LIME [MAL22] as metrics. The developed the PNSR as well as SSIM values, the enhanced the image excellence. On the contrary, the worse the WME and SICE values, the better the image quality. Quantitative consequences on LOL dataset are exposed in the above Table 1.1. It is understandable to acquire that our technique overtakes others on greatest of the metrics excluding somewhat inferior scheduled MAE than KinD as well as KinD++. Perform much better results than all other methods in terms of RRM, Star, SSIM and SIRE, indicating the effectiveness of the proposed method. To validate the generalisation performance of the proposed URetinex-Net, further evaluate on SICE dataset without retraining or fine-tuning.

Fig.1.2 Low Light Image Retinex Heterogeneous Method

From Fig 1.2 aiming at the problems of low illumination images, this paper proposes a low illumination enhancement method based on attention mechanism, residual dense blocks and generation of counter measure.

Natural Image Quality Evaluator (NIQE): The inspiration for NIQE is based on constructing a series of features used to measure image quality and utilizing these features to fit a multivariate. The distance between the image feature model parameters and the pre-established model parameters is used to determine the image quality are analysed in this process. An inferior NIQE groove designates healthier conservation of spontaneity.

Qualitative and Quantitative Results in Dataset for the LLNet dataset, reserve 300 images (1440*1080 resolution) for validation and testing, and train on the remaining 2700. As the evaluation metrics, employed Peak Signal-to-Noise Ratio (PSNR) and Structural SIMilarity (SSIM) to quantitatively evaluate the performance of our solution in terms of the color and structure similarity between the predicted results and the corresponding long-exposure images. They are not absolutely indicative, but still use PSNR and SSIM values to conclude whether proposed solutions could generate reasonably promising results.

Table 1.1 Quantitative Comparison diverse down sampling levels for various metrics

METHODS	NIQE	PSNR	SSIM	VIF
Original Image	**3.75**	**12.78**	**0.50**	**1.03**
SIRE	**3.05**	**16.56**	**0.26**	**2.09**
WME	**2.99**	**13.43**	**0.67**	**2.23**
LIME	**3.45**	**14.46**	**0.63**	**2.89**
RRM	**3.09**	**16.74**	**0.63**	**2.97**
Star	**2.93**	**20.l5**	**0.65**	**2.96**
Retinex Heterogenous Feature Method	**2.95**	**24.31**	**0.6**	**3.13**

Various levels of features extracted by CRM and card are fused to obtain more detailed information. A generative countermeasure network is proposed to transform the low light image into the image of low light environment as truly as possible. The proposed method deeply to be considers the problematic of feature loss of deep struggle network, besides the advancing, a novel clarification to the delinquent of low light image color distortion. Peak Signal to Noise Ratio as well as Mean Squared Error is the furthermost widely utilized objective image quality/distortion metrics. To propose a Structural Similarity Index that does not treat the image degradation as an error measurement but as a structural distortion measurement.

The objective image quality metrics are classified in three groups: full references are exists an original image with which the distorted image is to be compared, not any orientation or "blind" excellence valuation further reduced orientation excellence assessment the position image is only moderately available, in the procedure of a set of extracted features. To end with, the enhanced image was acquired recognized on retinex theory. Images from different datasets were utilized to verify the usefulness of method from both subjective besides the objective aspects, that is, our method can not only expand the brightness, however similarly preserve additional exhaustive information.

5. CONCLUSION

In the present case of low light image processing, not any innovative image is obtainable to be associated, metrics are necessary. Inside the exceeding cited methods for improvement as well as re-establishment, many of the authors utilize subjective quality capacities to appraise the presentation of their approaches. The experiments established that the proposed method presented acceptable presentation in numerous quantitative assessments associated with other reasonable deep-learning methods. It is predictable that the proposed method can be applied to various intelligent imaging systems to obtain a high-quality image. Utilizing deep learning method the low light image enhancement is identified utilizing Retinex Heterogeneous Scale Method. Compare to existing Pseudo code Algorithm the proposed method utilizing metrics such as NIQE, SSIM, PSNR and VIF metrics, Retinex Heterogeneous Method find out the brightness of image, brightness of the distortion, blocking can well restore the brightness distribution. The contribution of noise creates the image further real, deteriorates the coupling association among the mechanisms, outflows overfitting, as well as magnifies generalization. Retinex Recursive preserves the values of the RGB color mechanisms of each pixel of the image as well as assessments the reflectance of each point.

References

[1] Dr.S.Brindha, Dr.S.Sukumaran, "Enhanced Pattern Classification Methods for Text Categorization Mining", International Journal of All Research Education and Scientific Methods (IJARESM), ISSN: 2455-6211 Volume 10, Issue 10, October-2022, Impact Factor: 7.429, Available online at: www.ijaresm.com.

[2] Dr.S.Brindha, Dr.S.Sukumaran, "Comparative Study of Term Based Pattern Taxonomy Deploying Algorithms", International Journal for Innovative Research In Multidisciplinary Field (IJIRMF), ISSN: 2455-0620 Volume-6, Issue -4, Apr-2020.

[3] Chen Wei, Wenjing Wang, Wenhan Yang, and Jiaying Liu. Deep retinex decomposition for low-light enhancement. arXiv preprint arXiv:1808.04560, 2018.

[4] F. Ciurea and B. Funt, "Tuning retinex parameters," Journal of Electronic Imaging, vol. 13, pp. 58-64, 2004.

[5] J. Gujoseph and G. W. Shaofeng, ``Quality evaluation data set for real underwater image enhancement," Chin. J. Image Graph., vol. 27, no. 5, pp. 1467_1480, 2022.

[6] Z. Yi, W. Haifeng, L. Liang, and C. Jiashu, ``Image enhancement based on wavelet coef_cient interpolation of human visual fitting function," J. Terahertz Sci. Electron. Inf., vol. 17, no. 6, pp. 1071_1077, 2019.

[7] Jianrui Cai, Shuhang Gu, and Lei Zhang. Learning a deep single image contrast enhancer from multi-exposure images. IEEE Transactions on Image Processing, 27(4):2049–2062, 2018. 6.

[8] N. Jirong, ``Research on color image enhancement based on his model," China Standardization, vol. 2019, no. 24, pp. 225_226, 2019.

[9] L. Jinchao, Y. Guang, W. Huiqian, P. Yu, L. Jinhua, C. Zhu, and Y. Chongyuan, ``Endoscope image enhancement algorithm based on quadratic improved weighted steering _lter," Life Sci. Instrum., vol. 18, no. 6, pp. 82_85, 2020.

[10] Z. Jie, L. Yipeng, Dalu, and L. Xueyan, ``NSCT enhancement of low brightness image based on quantum harmony search fuzzy set," Prog. Laser Optoelectron., vol. 58, no. 24, pp. 371_382, 2021.

[11] C. Li, C. Guo, W. Ren, R. Cong, J. Hou, S. Kwong, and D. Tao, ``An underwater image enhancement benchmark dataset and beyond," IEEE Trans. Image Process., vol. 29, pp. 4376_4389, 2019.

[12] M. T. Malone, ``Overview of low illumination image enhancement algorithms," Chin. J. Image Graph., vol. 27, no. 5, pp. 1392_1409, 2022.

[13] A. maitusun, I. ilkham, and T. abduklimu, ``An image enhancement method based on wavelet domain," Electron. Des. Eng., vol. 29, no. 24, pp. 24_33, 2021.

[14] W. Nan, L. Yiming, Z. Rui, Z. Jiao, and X. Yi, ``Image enhancement algorithm of material orGANization based on generation of countermeasure network," Inf. Technol., vol. 2021, no. 12, pp. 1_7, 2021.

[15] M. F. Pangyingna, ``A non reference optical remote sensing image enhancement algorithm based on lightweight depth network," Aerosp Return Remote Sens., vol. 43, no. 2, pp. 74_81, 2022.

[16] J. Peng and L. Bo, ``Improved Retinex underwater image enhancement algorithm based on HSI," Lab. Res. Explor., vol. 39, no. 12, pp. 1_4 and 14, 2020.

[17] C. Liaojuan, W. Yao, and Z. Shun, ``Seedling image enhancement algorithm based on double gamma correction," Jiangsu Agricult. J., vol. 36, no. 6, pp. 1411_1418, 2020.

[18] C. Luwanshun, L. Hui, and C. Xin, ``A fusion method based on clipping transform and image enhancement," J. Guangxi Univ., vol. 46, no. 6, pp. 1602_1609, 2021.

[19] P. Tian, ``Research on low quality image enhancement technology of airport monitoring based on a priori and depth neural network," Ph.D. dissertation, Sichuan Univ. Electron. Sci. Technol., Chengdu, China, Apr. 15, 2021.

[20] Z.Wang, R. Li, and J. Li, ``Image enhancement algorithm based on homomorphic _ltering and histogram equalization," Electron. Meas. Technol.,vol. 43, no. 24, pp. 75_80, 2020.

[21] W. Wang, Z. Chen, and X. Yuan, ``Simple low-light image enhancement based on Weber_Fechner law in logarithmic space," Signal Process., Image Commun., vol. 106, Aug. 2022, Art. no. 116742.

[22] Z. Xuminmin, L. Zhang, and W. Bo, ``Research on the application of police low

illumination image enhancement technology based on PCNN," J. Armed Police College, vol. 37, no. 12, pp. 57_62, 2021.

[23] M. Yang, J. Hu, C. Li, G. Rohde, Y. Du, and K. Hu, ``An in-depth survey of underwater image enhancement and restoration," IEEE Access, vol. 7, pp. 123638_123657, 2019.

[24] W. Yan, ``Research on design and implementation of medical image enhancement based on wavelet analysis," J. Central Univ. Nationalities, vol. 31, no. 2, pp. 52_56, 2022.

[25] Yonghua Zhang, Jiawan Zhang, and Xiaojie Guo. Kindling the darkness: A practical low-light image enhancer. In Proceedings of the 27th ACM international conference on multimedia, pages 1632–1640, 2019.

[26] Y. Yun and L. Yu, ``An adaptive intensity transformation method for color remote sensing image enhancement," Remote Sens. Inf., vol. 34, no. 6, pp. 39_44, 2019.

[27] L. Yeyunying, ``Mine image enhancement algorithm basd on rough set theory," J. Liaoning Teachers' College, vol. 22, no. 4, pp. 78_81 and 108, 2020.

[28] Z. Zhaominghua, D. Shuangli, and S. Zhenghao, ``Single backlight image enhancement based on virtual exposure method," Comput. Sci., vol. 49, no. S1, pp. 384_389, 2022.

[29] Z. Zhao, B. Xiong, L. Wang, Q. Ou, L. Yu, and F. Kuang, ``RetinexDIP:A uni_ed deep framework for low-light image enhancement," IEEE Trans.Circuits Syst. Video Technol., vol. 32, no. 3, pp. 1076_1088, Mar. 2022.

[30] T. Zhiyong, Z. Lei, and L. Sen, ``Low-illuminance texture image enhancement method based on SCBSO algorithm," Laser Optoelectron. Prog., vol. 56, no. 24, 2019, Art. no. 241002.