A Survey on Low-Light Image Enhancement via Retinex Model with implemetation and comparsion of LIME and robust retinex model

Ng Ho Hin, MSc in Information Technology (HKPolyU)

20019711g@connect.polyu.hk

Abstract- This report aims on studying the topic of low light image enhancement via retinex model. The target is to implement the Low-light image enhancement methodology (LIME) and robust retinex model. The detail of LIME and robust retinex model would be introduced. Also, an experiment of implementation LIME and robust retinex model will be implemented that to show the results.

Keywords- Image enhancement, Retinex model

I. INTRODUCTION

Low-light image makes people hard to see the picture details, especially the photo taken in a dark environment. The information in the photo could not been delivered to the readers by an effective and efficiency way. This study was to show that image enhancement techniques can change the poor condition of image to an acceptable quality for reading.

II. RETINEX MODEL

Retinex theory is mentioned by Land, E. H. [1] which is divided in two parts, reflectance component and illumination component. This method is the basic theory for human understand the colour perception system. All objects can reflect red, green and blue light although human cannot physically see that specific colour. Normally, human may have objective judgement of the colour for two objects which reflected the same colour wavelength.

Both LIME and robust retinex model are using retinex model that estimated the illumination map in dealing low-light issue.

III. ARCHITECTURE OF LIME

Lime is a low-light image enhancement methodology developed by Guo, X [2]. The major findings were that this methodology could definitely improve the low-light image issue. This method included several processes which are illumination map, gamma correction, BM3D method. The detail for each part will discuss in the following.

A. Illumination map

Illumination map is one of the decomposed components under retinex theory. When sensor records the image in low light environment, it makes the images less intensity. The illumination component mainly controls the shading effect. The reflectance component mainly deals with how the object reflects the light. [3]

In mathematics expression, let L be the image. We can represent it by the formula:

$$L = R \times T$$

where T is the illumination map and R is reflectance component.

In LIME, illumination map will have several processes to refine and then output the final image result.

B. Gamma correction

Gamma correction is an operator technique, which usually accomplished by incorporating the nonlinear transfer function into a framebuffer's lookup table [4]. It involves a power function to encode and decode the tri-stimulus value of the image.

The tri-stimulus values are a particular colour form by the amount of blue, green and red. After maximum the value of RGB in illumination map, gramma correction helps find out the noise hiding in the dark pixel. This step can denoise and recomposite the image.

C. BM3D Method

Block-matching 3D (BM3D) is a novel image denoising strategy proposed by Dabov, K [5]. The main purpose for this method is to reduce the noise of the image.

Technically, it involves threes steps, 1. 3-D transformation of a group. In this step, the 3-D grouping transform aims to gather all the similar blocks to formula a 3-D array. 2. Shrinkage of the transform spectrum. The noise can be separated. 3. Inverse 3-D transformation. that produce all fragments which are grouped. [5]

This process only run when the denoising and recomposing needed. This method mainly used in reflectance component under LIME algorithm.

Therefore, the LIME algorithm is that we firstly have an input image. We represent the image as a matrix so we can estimate the illumination map T and reflectance component R. After we refine the illumination map T by a solver equation [2], we apply gamma correction on the illumination map T. We then can generate the image by using new illumination map. If needed, the denoising technique BM3D would also be used to reduce the noise in the dark pixel. Finally, we can obtain the final enhanced images.

IV. ROBUST RETINEX MODEL

Robust retinex model is proposed by Li, M [6]. Compared with LIME, robust retinex model is more status of art method to handle low-Light Image Enhancement issues. This method put more emphasised on the illumination map. Moreover, the illumination map would become a little bit different.

In mathematics expression, let L be the image and desired recovery.

$$L = R \times T + N$$

where T is the illumination map, R is reflectance and N is noise term.

The effect of the noise term is that the noise in illumination map or reflectance can be disturbed to the noise item. Also, Li, M [6] do not use logarithmic transformation in this method. The major idea of the next step is to perform the enhancement of the visibility of low-light images and mitigation the effect of noise in a joint optimization function at the same time. Li, M [6] call this framework as structure-revealing. This process introduced a term, l_1 norm, to limit the piece-wise smoothness in illumination map. Finally, the illumination map could be enhanced to a better denoising result.

V. EXPERIMENTS AND RESULTS

In this part, the LIME model and Robust retinex model are implemented to see how the models can enhance the low light images.

The detail of programming code can be refered to the readme file. The LIME demo code is developed by Guo, X [7]. The Robust retinex model demo code is also designed by Li, M [6]. Both demo codes are running in Matlab.

To apply in this experiment, there are some minor adjustments of their programme that make it easier to reflect the result. There also have two programmes, a programme can process PSNP calculation, a programme of image results representation is developed. Finally, a statistics measurement, PSNR, will be used to make analysis in this section.

A. Dataset

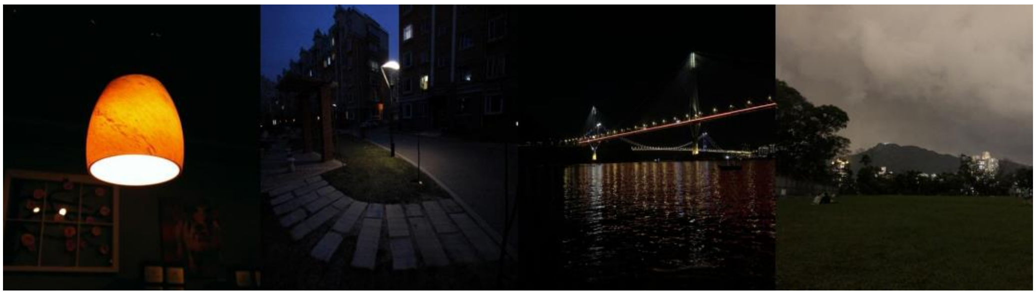

Fig. 1 shows all image file used in experiment. Image1, Image2, Image3 and Image4 (From left to right)

There are four images that be used to test. All images are taken in the dark light environment. Two image is come from internet which are commonly used in some literatures. The other two images are taken in Hong Kong which are new for performing test.

All images are in .jpg formal. Image1 and Image2 are attained from internet source. Image3 is about Ting Kau Bridge. This image is nearly all dark in most of pixel. Image4 is taken in Lok Fu Service Reservoir Rest Garden. This photo captured the lion rock.

B. Image Results

After performing the LIME method and robust retinex model. We attained the results.

Fig. 2 shows Image1, the original photo (left), LIME (centre) and robust retinex model (right).

Fig. 3 shows Image2, the original photo (left), LIME (centre) and robust retinex model (right).

Fig. 4 shows Image3, the original photo (left), LIME (centre) and robust retinex model (right).

Fig. 5 shows Image4, the original photo (left), LIME (centre) and robust retinex model (right).

In Fig. 2, the enhanced image1 by LIME and robust retinex model seems very similar. LIME seems give a clearer details on the wall decoration stuffs.

In Fig. 3, we can see some noise reflect on the street and sky under processing LIME. The textile seems rougher. When we looked on the robust retinex model, the textile is smoother.

In Fig. 4, we can see the enhanced images generally show more information. When comparing all images, we can see there are a boat on the sea which cannot be observed in the original image. Therefore, we can also say that these two methods can help displaying more detail information on the image.

However, when go flow the image after LIME and retinex model, we can see more noise surrounding on the dark image pixel on LIME while retinex model do not. Robust retinex model seems provided better quality for enhancing the dark environment image. However, we cannot see the hill on the left in the photo in a clear way.

Under Fig. 5, after the LIME algorithm, the photo can also be view in a more detail way. More information show on the image. The people can be figured out directly. Generally, this photo become a clearer and brightness photo. The photo quality can be maintained after the process of LIME. The detail of grass and green wavelength are clear.

After comparing all 4 images, LIME normally provided a brightness and clear image but with more noise, especially the image taken in a nearly dark environment. Robust retinex model can enhance the low-light issue that we can see more details. The denoising effect is better than LIME. Based on objectively perception, it seems Robust retinex model perform better than LIME by the trade-off of quality and brightness.

C. PSNR result

Peak signal-to-noise ratio (PSNR) is a method to measure the quality between the original and the represented image. PSNR is used to evaluate the two methods in a quantity way. It can provide the figures to compare the results more objectively. The higher the PSNR, the better the quality of the represented image.

Table 1. shows the figure of PSNR of all images.

	LIME	Robust retinex model
Image 1	13.6673	16.2742
Image 2	9.5198	12.8978
Image 3	12.7374	17.4370
Image 4	10.2576	13.1008

Table 1. result shows that robust retinex model normally have a higher PSNR. Image3 with robust retinex model has the highest PSNR. Robust retinex model seems perform well, especially in a nearly dark image. Therefore, we can conclude that robust retinex model provided a better low-light enhancement than LIME.

VI. CONCLUSION

In conclusion, LIME and Robust retinex model are briefly introduced. An experiment also had performed to compare the result of both algorithms.

Based on our experiment, LIME can improve the visibility of the image which provided a brightness and more details photos. However, LIME have limitation. This method cannot output a high-resolution image that the denoising effect is not in a perfect way. Robust retinex model can address this issue. In addition, based on the statistics of PSNR, robust retinex model generally provided a better quality of enhanced image. Besides, this experiment is based on four images that may exist bias and the dataset cannot draw a comprehensive result. A large dataset is needed to support our conclusion.

Last but not least, to create more effective image enhancement, Xu et al. [8] give a new method which is a retinex method with deep learning to address the low light image issue. It is the status-of-art method of low-light enhancement technique.

REFERENCES

[1] Land, E. H. (1977). The retinex theory of color vision. Scientific american, 237(6), 108-129.

[2] Guo, X., Li, Y., & Ling, H. (2016). LIME: Low-light image enhancement via illumination map estimation. *IEEE Transactions on image processing*, *26*(2), 982-993.

[3] Grosse, R., Johnson, M. K., Adelson, E. H., & Freeman, W. T. (2009, September). Ground truth dataset and baseline evaluations for intrinsic image algorithms. In 2009 IEEE 12th International Conference on Computer Vision (pp. 2335-2342). IEEE.

[4] Poynton, C. (2012). *Digital video and HD: Algorithms and Interfaces*. Elsevier. 259-260

[5] Dabov, K., Foi, A., Katkovnik, V., & Egiazarian, K. (2007). Image denoising by sparse 3-D transform-domain collaborative filtering. IEEE Transactions on image processing, 16(8), 2080-2095.

[6] Li, M., Liu, J., Yang, W., Sun, X., & Guo, Z. (2018). Structure-revealing low-light image enhancement via robust retinex model. IEEE Transactions on Image Processing, 27(6), 2828-2841.

[7] Guo, X. (2016). LIME demo code. Google Sites. https://sites.google.com/view/xjguo/lime.

[8] Xu, K., Yang, X., Yin, B., & Lau, R. W. (2020). Learning to restore low-light images via decomposition-and-enhancement. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (pp. 2281-2290).