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Non-Uniform Illumination and Low Light Image Enhancement Techniques: An Exhaustive Study

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Abstract: Different kinds of Images captured are an important medium to represent meaningful information. It can be problematic for artificial intelligence, computer vision techniques and detection algorithms to extract valuable information from those images with poor lighting. In this paper, a study of low illumination-based low-light night image enhancement techniques are presented which work on reflectance, degradation, unsatisfactory lightings, noise, limited range visibility, low contrast, color variations, illumination, color distortion, and quality is reduced. Improving the images in low light conditions is a prerequisite in many fields, such as surveillance systems, road safety and inland waterway transport, object tracking, scientific research, the detection system, the counting system and the navigation system. Low-illumination or night image enhancement algorithms can advance the visual quality of low-light images and these images can be used in many practical application's artificial intelligence and computer vision techniques. The methods used for enhancement of low illumination must perform, preserving details, contrast improvement, color correction, noise reduction, image enhancement, restoration, etc.

Keywords: Image Enhancement, Low Illumination, Reflectance, Low Contrast, Low Light Images, Night Time Images, Low Visibility Images.

I. INTRODUCTION

Image enhancement is an important field in image processing. It is used to improve image quality for specific applications. This technology has been evolved and been used in many areas of technology science, engineering and civil, images of biomedicine, astrophotography, satellite imagery, computer vision, surveillance systems, civil cameras, underwater, researches, weather forecast, etc.

In everyday life, we receive many information from images and videos. And we try to identify and effectively process this visual information. Today's era smartphones where social networks are so widespread, lot of people are interested in capturing and sharing photos. Pictures taken with professional cameras or mobile phones are affected by many weather conditions, that affect quality of images. Therefore, many times the important contents of the captured images are not always visible clearly. These conditions that sometimes lead to the degradation in quality of image includes bad weather, poor lighting and moving objects, etc.

The impact of these conditions on quality of image can make it problematic for computer vision applications to clearly identify the image content. The clearly visible images represent more details and useful contents can be identified easily. Enhancement techniques can make the hidden content of images visible and facilitate the usability of valuable information for computer. The elimination of darkness and the extraction of meaningful information are important in applications such as medical imaging, object tracking, face detection, facial attraction and object detection, road safety.

In low-light conditions, quality of images and videos captured by optical imaging cameras frequently deteriorates. This can decrease the performance of some systems, which are used in intelligent traffic analysis, visual surveillance and consumer electronics. Low-light conditions in night-time can produce images and videos with low contrast, reducing visibility, absence of natural colors. No backlighting, where the details of the object's sand cannot be captured simultaneously in bright regions in background and dark regions in foreground due to limitations in exposure of many imaging systems.

Since objects and details cannot be clearly seen in very dark regions due to uneven illumination, backlit images have similar degradation with backlighting. However, unlike normal images in low light conditions, backlit images have a wide dynamic range that contains very dark and bright regions in the same scene. To improve normal images with unwanted lighting, many image enhancement algorithms have been proposed.

These low light conditions do not have an auxiliary light source, the images obtained on rainy days, at night or in the mine generally have poor quality and blurred details, these images do not apply to the recognition of the machine and to the objective tracking, so the result cannot be used for practical applications. Since image acquisition systems are necessary to operate in night limited light conditions, it is very desirable to improve the image and reduce noise.

II. LITERATURE REVIEW

Pictures captured in limited light conditions suffer from low contrast, less brightness and poor visibility. Low quality images result in reduction in the performance of many computer and multimedia vision algorithms designed mainly for input data of very high quality. A simple method of improving the image in low light conditions (LIME). [Guo, X. 2016] [1] The illumination for every pixel is initially estimated individually by calculating the maximum value in channels R, G and B. Then, make the initial illumination map by imposing a previous structure on it, like the final lighting map. Enhancement approach that focuses on a single backlit image based on a multi-scale fusion [Q, Wang. 2016] [5]. The fusion technique depends on inputs and weight maps, the features for the backlight are designed to find appropriate inputs and weights. First, three inputs are derived which are obtained by improving the luminance in the original value of the HSV space. Secondly, a weight map is designed to calculate the exposure function from the derived inputs. Finally, to effectively combine all the different types of useful information into one, all these inputs and the weight maps are merged to obtain the improved image. [Guo et al. 2017] [4] He offered a technique to improve the quality of colors in images and the contrast of dark areas highlighted based on the features of human vision and the transformation of logarithms. Furthermore, the gamma transform was used to improve the contrast in image. Resulting in, an algorithm that has achieved better results in color restoration. Hao et al. [7] Method for estimating lighting and used a guided filter for dividing the texture patterns into a refined lighting map. This technique used for the estimation of the lighting map in low light conditions, but the lighting estimate was slightly different in both strategies and one of the great limitations of this technique was that it was still necessary to maintain the constancy of the true color in finished images and they are improved. A wavelet-based algorithm to improve color. The Euler-Lagrange formula worked together with wavelets to calculate detail coefficients. This method eliminated the color tone of overexposed and underexposed images. This distortion of light is frequently found in images where the luminous environment have very complex conditions. After estimating weak lighting, the improved end results were achieved by combining multiple results with the help of a multi-scale pyramid [6]. This algorithm worked to perform multiple tasks, such as night, backlight and uneven lighting.

III. LOW ILLUMINATION BASED ENHANCEMENT TECHNIQUES

Image enhancement is still an area of research by many experts. Low Illumination conditions, Low Light Images, Night Time images are not clear and have many distortions like noise, poor lightning conditions, limited range visibility, low contrast, color variations, color distortion, quality of the image is reduced in images. Image enhancement is one of the most important and difficult component of security surveillance system, road safety and waterway transport, object tracking, scientific research, detecting system, counting system, navigation system.

Therefore, some of the techniques have been introduced to overcome this problem are explained below:

A. Robust Retinex Model [2018]

The methods of image enhancement in low light conditions constructed on the Retinex model try to manipulate the estimated illumination and assign it to the corresponding reflectance. However, this method does not consider noise, which unavoidably exists in those images which are captured in low illumination conditions. Here, a robust Retinex model, that also considers a map based on noise is being compared to the Retinex model, for improving the performance for image enhancement in low light conditions accompanied with intense noise. And optimization technique that comprises new regularization for lighting and reflection. In particular, the softness of the lighting of the parts adopts a term of fidelity for reflectance gradients to reveal the details of the structure in the images in low light conditions and to estimate a noise map of the robust Retinex model. For efficiently solving the optimization problem, they offer an alternative address minimization algorithm based on the increased Lagrange multiplier without logarithmic transformation [1].

B. JED Method [2018] Joint Enhancement and Denoising

Many methods of improvement in low light conditions ignore the intense noise found in the original images. Resulting, in the improvement of severe noise simultaneously. Furthermore, the extra noise removal techniques adopted in most of the methods can ruin all the important details in images. Here, a strategy of improving and eliminating noise in low light conditions, aimed at obtaining excellent images improved in low light conditions and at the same time eliminating the problem of intrinsic noise. The method performs decomposition based on the Retinex model in a subsequent sequence, that consecutively estimates attenuated illumination and reflectance with noise suppression. After obtaining the illumination and reflectance map, also regulate the lighting level and generate an improvement result. In this process of sequential decomposition with noise suppression, the spatial smoothness of each component and the use of weight matrices to suppress noise and improve contrast and suppress noise[3].

C. SRIE Method [2016] Simultaneous Reflectance and Illumination Estimation

A method to improve the image based on a simultaneous estimation of illumination and reflectance in the linear domain is presented. The linear domain model can represent a better preliminary information for a better estimation of the reflectance and the illumination with respect to the logarithmic domain. A maximum a posteriori formulation (MAP) is used with a history of illumination and reflection. To effectively estimate illumination and reflectance, an alternative management method of multipliers is used to solve the MAP problem.

D. LECARM Method [2016] low light Camera Response Model

Image enhancement algorithms in low light conditions can improve the visual quality of images in low light conditions and support the extraction of valuable information for some artificial vision techniques. However, existing techniques inevitably introduce color distortions and brightness when improving images. To reduce distortions, we propose a new improvement framework that uses the response characteristics of the cameras. First, let's discuss how to determine a reasonable camera response pattern and its parameters. So we use lighting estimation techniques to estimate the exposure ratio for each pixel. Finally, the selected camera response pattern is used to adapt each pixel to the desired exposure based on the estimated exposure ratio map.

E. LIME Method [2016] Low Light Image Enhancement

When images are captured in low light conditions, images often suffer from poor visibility. A method of improving the low-light image (LIME), the illumination of each pixel is initially estimated individually by finding the maximum value in the R, G and B channels. In addition, we perfect the initial illumination map by imposing a previous structure on it like the final illumination map. Once the lighting map is created, an improvement can be achieved accordingly.

F. Fusion Based Enhancing Method [2016]

Fusion based method to improve low-light images using various mature image processing techniques. First of all, we use a lighting estimation algorithm based on morphological closure to break down an image observed in a reflectance image and a lighting image. Then you get two inputs that represent improved luminance and contrast versions of the first decomposed illumination using the sigmoid function and the adaptive equalization of the histogram. By designing two weights based on these inputs, we produce adequate lighting by combining the derived inputs with the corresponding weights on a multiple scale. Through an appropriate weighting and fusion strategy, we combine the advantages of different techniques to produce regulated lighting. The improved final image is obtained by compensating the lighting adapted to the reflection. You can enhance images in different low light conditions, such as backlight, uneven lighting and night.

G. BIMEF Method [2015] bio Inspired Multi-Exposure Fusion

Images in low light conditions are not useful for artificial vision algorithms due to their poor visibility. Although many image enhancement techniques solve this problem, existing methods inevitably introduce an excessive or insufficient improvement of the contrast. Inspired by the human visual system, a multiple exposure fusion frame to improve the image in low light conditions. Based on the frame, an algorithm with double exposure to provide a precise improvement in contrast and brightness. In particular, first of all design the weight matrix for image fusion using lighting estimation techniques. Then we present our response model of the camera for multiple exposure images of synthetic dimensions. Next, find the best exposure ratio so that the synthetic image is well exposed in the regions where the original image is underexposed.

H. LDR Method [2013]

Here a contrast improvement algorithm based on the representation of the difference in the 2D histogram layers, to improve image contrast by amplifying the gray level differences between adjacent pixels.

The 2D histogram of an input image, which counts pairs of adjacent pixels with levels of gray and represents the gray level differences in a layered tree-like structure. Thus, a limited optimization problem based on the observation that gray level differences occur more frequently in the input image. Solve the optimization problem to derive the transformation function in each level. Then combine the transformation functions at all levels in the unified transformation function, which is used to assign the input gray levels to the output gray levels.

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I. NPEA Method [2013]

Among the various enhancement algorithms, Retinex-based algorithms can efficiently improve details and have been widely adopted. Since Retinex-based algorithms consider that lighting elimination is a predetermined preference and does not limit the field of reflection, the naturalness of non-uniform lighting images cannot be effectively preserved. However, naturalness is essential for improving the image to obtain a pleasant perceptive quality. To preserve the naturalness by improving the details, an improvement algorithm for non-uniform lighting images. In general, it provides the following three main contributions. First, a measure of error in the order of lightness to objectively access natural conservation. Secondly, a luminous step filter is proposed to decompose an image into reflectance and illumination, which, respectively, determine the details and the naturalness of the image. Thirdly, a bi-log transformation, which is used to map the lighting to find a balance between details and naturalness.

J. Generalized Unsharp Masking Algorithm [2011]

A generalized approach masking algorithm that uses the exploratory data model as a unified framework. The proposed algorithm is designed to address three problems: first, to improve contrast and sharpness simultaneously by treating the model component and the residue individually. This reducing the halo effect with a filter to protect the edges and finally solving the problem out of the interval through log-ratio operations and tangent operations. Logarithmic relation operations reveal a new connection between Bregman's divergence and generalized linear systems.

K. CVC Method

An algorithm that improves the contrast of an input image using contextual information between pixels. The algorithm uses a 2D histogram of the input image constructed using a reciprocal relationship between each pixel and the adjacent pixels. A smooth two-dimensional objective histogram is obtained by minimizing the sum of the Fro-benius norms of the differences with the input histogram and the uniformly distributed histogram. The improvement is obtained by assigning the diagonal elements of the input histogram to the diagonal elements of the target histogram.

IV. RESULTS

				
Input Image	Robust Retinex[3]	JED Method [5]	SRIE Method [6]	LECARM [2]
				
LIME Method [7]	Fusion [10]	BIMEF [15]	ICASSP [13]	Global SIP [14]
				
LDR Method [16]	NPEA Method [17]	HE Method [19]	CVC Method [18]	WAHE [23]
				
Unsharp Masing [21]	Tone Mapping [20]			

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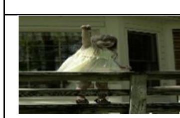				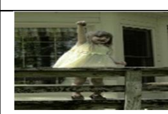
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V. CONCLUSION

In this paper the problem related to Low Illumination Image Enhancement for finding the visibility of long-distance objects in hazy low light images is a great challenge for us, and the presence of no light due to scattering and low contrast, little brightness phenomenon in low illumination pictures that results in the poor visibility create difficulties, we have examined a few of the enhancement algorithms which have been specifically developed for the hazy low illumination pictures, and we will find results from the output image. we have compared the previously developed methods and we have evaluated the performance of all the techniques in relations to various calculations, these methods work on all the low light images, the elimination of image low contrast develops a simpler and more effective technique, so we aim to use these results as the base for developing furthermore advanced low light image enhancement techniques in future.

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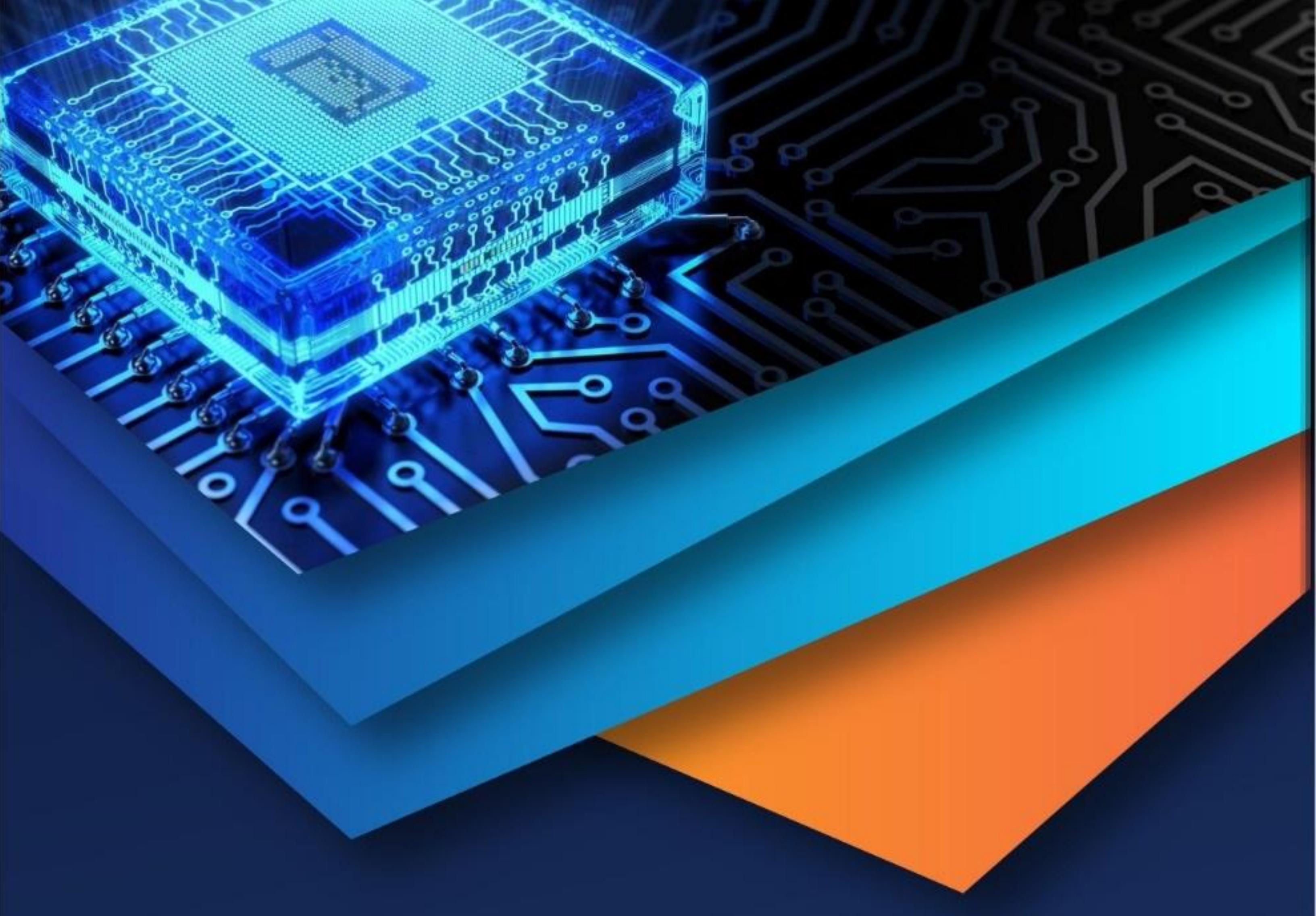

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