Turkish Journal of Computer and Mathematics Education *Vol.10 No.02 (2019), 995-1002*
DOI: https://doi.org/10.17762/turcomat.v10i2.13581

Research Article

Sparse Gradient Regularized Deep Retinex Network for Robust Low-Light Image Enhancement

Resham Taluja
Department of Computer Science & Information Technology, Graphic Era Hill University, Dehradun Uttarakhand India 248002

Abstract
An algorithm for improving images was created in this procedure. It is founded on the linear domain simultaneous estimate of light and reflectance. For single picture low-light enhancement, many image priors have been used. However, the most effective technique is to evenly enhance the illumination directly. By extending the dynamic pixel intensity of a picture, histogram equalisation (HE) can solve the issue of lighting and make dark images visible. Instead than changing the lighting, HE seeks to improve the contrast. As a result, the findings are resilient to noise and improve image quality. The test findings demonstrate the good performance of the suggested approach to provide lighting and reflectance with increased visual outcomes and a promising convergence rate. The suggested technique produces equivalent or superior outcomes in subjective as well as objective evaluations when compared to previous testing methodologies. Image enhancement's main goal is to treat an input image such that the final output is more suitable for a certain application than the original image. It draws attention to or emphasises visual elements like borders, limits, or contrast to make a graphic presentation more useful for study and display. The improvement enhances the dynamic range of the selected characteristics, making it easier to recognise them even while it does not increase the data's intrinsic information richness.

1. Introduction

An image can be improved using a variety of techniques, such as filtering, Histogram Equalisation (HE), and grayscale editing. One of the well-known picture improvement techniques is HE. This method for contrast enhancement immediately became well-liked due to its simplicity and effectiveness. To avoid the development of fictitious artifacts in the final image in the second scenario, the image's input brightness must be maintained. Even if they keep the input brightness on the output picture with a large contrast improvement, these approaches may produce images that seem less realistic than the ones used as input. Re-mapping an image's grey levels is the fundamental concept behind the HE technique. HE often introduces obtrusive artifacts and artificial enhancements.Different brightness-preserving strategies, some of which are addressed in the literature review, are utilised to get around these shortcomings. A comparative examination of several enhancing methods will be conducted. We'll base our comparison on both subjective and objective criteria. Visual quality and calculation time are subjective characteristics whereas Mean Squared Error, Composite Peak Signal-to-Noise Ratio, Normalized Correlation, Error Color, Normalized Absolute Error and Peak Signal to Noise Ratio are objective measures. Sight is the most potent of the five senses that people employ to understand their surroundings: hearing, touch, smell, and taste. A significant portion of human humans' daily mental activity when awake is spent receiving and interpreting visuals. In fact, the processing of visual cortex-derived pictures accounts for more than 99% of all brain activity. A visual picture contains a wealth of data. A photograph is worth a thousand words, according to Confucius. One of most straightforward and visually appealing aspect of all digital image processing methods is picture enhancement. The basic goal of image enhancement is to reveal hidden details in a picture or to boost low contrast images' contrast. Every time a picture is transformed from one form to another, as when it is digitalized, there is some kind of output degradation. Image enhancement is among the easiest and most appealing features of digital image processing. The fundamental idea behind enhancement techniques is to either highlight particular interesting aspects of an image or expose a feature that has been hidden. "It seems better" when we increase an image's contrast and use a filter to remove noise. It's important to keep in mind that enhancement is a very individualised branch of image processing. By applying enhancement techniques, the quality of these deteriorated photos can be improved. This is a development of the conventional Histogram Equalization method. By changing the values in intensity image I, it improves the contrast of the photographs. It works with tiny data sections (tiles), not complete image, unlike HISTEQ. To ensure that the result region's histogram accurately reflects the desired histogram, each tile has its contrast raised. Then, in order to remove artificially produced borders, the adjoining tiles are joined using bilinear interpolation. Limiting the contrast can prevent the image's potential noise from being amplified, especially in homogenous areas. The input picture is divided into 2 similar area sub-images depending on the histogram's grey level probability density function in this innovative histogram equalisation approach. The two sub-images are then each equalised. When processed sub-images are combined into a single picture, we finally receive outcome. In reality, the method may successfully improve the visual information in the image while simultaneously preventing a significant change in the average brightness of the original image. As a result, it may be used directly in video systems. The input histogram is divided into many sub-histograms using a partitioning procedure so that none of them contain a dominant component. After passing through HE, each sub-histogram is then permitted to fill a certain grey level range in the improved resulting picture. DHE achieves a superior contrast enhancement by controlling the dynamic range of grey levels and avoiding the compression of low histogram elements, which might give some areas of the picture a washed-out appearance.

2. Literature Survey

The various picture enhancing methods have been the main emphasis of this article. One of the most crucial uses for vision has been identified to be picture enhancement since it may make images more visible. It makes subpar images more noticeable. Different methods have so far been suggested for raising the quality of digital photographs. Image enhancement can explicitly enhance and limit some data given in the input picture in order to increase picture quality. It is a type of vision system that minimises picture noise, eliminates artefacts, and maintains the educational elements. Its goal is to make specific visual properties available for research, analysis, and future application. This paper's main goal is to identify the limits of the current picture enhancing techniques. The major goals of image enhancement are to enhance the source data for other image processing methods and to increase observation of information in pictures for certain viewers. Image enhancement's main goal is to alter an image's characteristics to better fit for a certain task and viewer. One or more aspects of the image are changed throughout this procedure. The qualities chosen and the modifications made to them are specific to a certain task. Additionally, the choice of picture enhancement techniques will include a significant amount of non-objective due to observer-definite aspects like visual system and the observer's expertise. Digital image may be enhanced using a variety of techniques without distorting it. The picture details diminish after augmentation, which is one issue with earlier techniques. The brightness and contrast augmentation of the input image's V component has therefore been explained in order to solve this issue. Every pixel has the same shape as the nonlinear transfer function for brightness enhancement. However, not all areas of the image have the same level of light; some may be black, while others may be brilliant. Thus, while improving a colour image, the image location must be taken into account. To enhance the brightness of image, the value component picture in the HSV image space was first divided into smaller, overlapping blocks and the nonlinear transfer function for every pixel has now been determined. The amount of enhancement for each pixel in the process of enhancing contrast has been computed based on the values of the central pixel and the pixels around it. To improve the contrast without sacrificing the true histogram properties, built on Histogram Specification approaches, Dynamic Histogram Specification techniques have been presented. The DHS retrieves the differential data contained in input histogram while preserving real histogram properties. On the other hand, it also uses other controls, such as gain control value and frame direct current, to regulate the entire procedure. When processing all of the photos, the procedure is more reliable but pixel substitution causes some of the image's data to become degraded [1].

Due to the extra information and concealed detail offered by outcomes of this technique that would subsequently be utilised for many different helpful reasons, researchers of various computer vision or machine vision have mostly concentrated on the subject of picture improvement. A variety of methods, including Spatial Averaging, Un-sharp Masking, Median Filter, Histogram Equalization, and High Boost Filtering, among others, were designed to improve images. Fuzzy Logic and Artificial Neural Networks are two strategies that we optimised to create a novel hybrid methodology in this study (ANN).A variety of measures, including Peak Signal to Noise Ratio, Root Mean Square Error, Signal to Noise Ratio and Mean Square Error are used to compare the experimental findings. The findings demonstrate that Fuzzy Logic and Artificial Neural Networks are the best techniques for enhancing picture visibility and protecting important image elements, which can then be used for a variety of beneficial reasons. A certain amount of deterioration happens at the output whenever a picture is changed from 1 format to other format, like when digitizing, storing, transmitting, scanning, etc. Therefore, a procedure known as image enhancement must be applied to the resultant image. All methods that comprehend, describe, and treat pictures, their components, and characteristics as fuzzy sets are together referred to as fuzzy image processing. The chosen fuzzy approach and the issue at hand determine the representation and processing. The concept of fuzzy sets is fundamental to human communication and is straightforward and intuitive. Fuzzy logic is simple to use since it is based on the common qualitative description structures found in everyday language. A filtering system must be able to reason with ambiguous and conflicting data. This implies the application of fuzzy logic. However, quantitative measurements can indicate which strategies are most suited whenever image enhancement methods utilised as pre-processing instruments for various image processing methods**.** Gray level mapping onto a vague plane and use membership transformation mechanism is foundation of fuzzy picture enhancement**.** The goal is to create a contrast image that is higher than the original image [2].

In this research, researchers offer a unique adaptive fuzzy contrast enhancement technique for low contrast grayscale photos depending on fuzzy set theory and the fuzzy entropy concept. On several low-quality grayscale photos, they have experimented. The suggested method's results are contrasted with those of the other approaches. The research findings show that suggested algorithm requires less processing time than the other approaches while also being quite successful at enhancing contrast. Many crucial fields, including Biological image analysis, remote sensing, dynamic and traffic scene analysis, machine vision, and autonomous navigation, call for high-contrast pictures with features preserved. However, the majority of digital photos have poor contrast issues because of bad lighting during picture capture, bad weather, or other equipment issues including incorrectly adjusted lens size and shutter speed and nonlinear picture intensity mapping. Therefore, image enhancement has been used for improve image's quality. Image enhancement is key procedure used in picture processing to enhance the image's look and readability. For subsequent image processing tasks, it offers superior input images. Image enhancement is a method that modifies the input image's pixel intensity so that the final image should ostensibly seem better than the original. The fundamental goal of image enhancement is to make the information contained in the image more interpretable or visually appealing to human observers, or to provide other automated image processing a "better" input. A two-dimensional digital image of gray-level intensities is denoted by I to help us comprehend the notion of image enhancement. In software-accessible form, the image I is often represented as an MN matrix with indexed elements I(i, j), where 0 I M - 1, 0 j N - 1. The components I(i, j) indicate samples of the pixels, or image intensities. Researchers believe that they originate from a limited range of integer values in order to keep things simple. Every sector where pictures need to be comprehended and evaluated may apply image enhancement, including machine vision, satellite image analysis, medical image analysis, etc. Simply said, image enhancement is the act of converting a picture X into an image Y with the use of Transformation T in order to make it appear better. The symbols X(i,j) and Y(i,j), stand for the intensity of pixel (i,j) in pictures X and Y. Although the processing time for the enhancement is high, it is ideally suited to increase the information in the image that can be interpreted or visualised by human observers [3].

A resolution technique for improving digital grayscale photographs is presented in this research. High frequency sub bands acquired using SWT and DWT are interpolated to create the suggested enhancement approach. The suggested method divides a picture into several sub-bands using DWT, and then interpolates high frequency sub-band pictures. Utilizing high frequency sub-bands produced using SWT on input picture, interpolated high frequency sub-band coefficients have been rectified. The same interpolation factor is used to interpolate the lower sub band produced by DWT decomposition. After that, IDWT was used to integrate all of these pictures to create a super-resolved image.

With the aid of the fusion, researchers have added further augmentation to the photograph. The goal of picture resolution augmentation is to get around an image acquisition equipment constraint or an awkward acquisition situation. A Super Resolved picture is helpful in a variety of industries. Whether it's a satellite picture or a medical imaging, it has been stated that resolution is a significant component of a picture. High quality satellite photos are crucial since they are used in many different sectors nowadays. The space's absorption, scattering, and other variables all have an impact on these photographs. Increasing the resolution is important to improve perception of these pictures. The extraction of more data from these photos has always been hampered by resolution increases. Numerous image processing applications, including multiple description coding, and picture resolution improvement, facial reconstruction, frequently employ interpolation. Long-term usage of interpolation-based picture resolution augmentation has led to the development of several interpolation algorithms to improve the effectiveness of this job [4].

In order to strengthen image's brightness preservation and contrast improvement capabilities meanwhile lowering its processing complexity, brightness preserving dynamic histogram equalisation approach is reviewed in this study. This article discusses a variety of updated techniques for brightness-preserving dynamic histogram equalisation that leverage digital image statistics to processing and representation. This approach performs better because it can tolerate the imperfection of grey level values better thanks to representation and processing of pictures in the spatial domain. This method efficiently retains brightness while enhancing visual contrast. These methods are used for image enhancement to raise the quality of some photographs because they are not all of high enough resolution to be utilised as is. Although the field of digital image processing is wide and sometimes involves technically challenging processes, the fundamental concept of DIP is actually rather straightforward. Picture processing's goal is to use the image's data to provide the system the ability to comprehend, analyse, and identify the processed information drawn from the image pattern. Numerous branches of research and engineering can benefit from image improvement. The clarity of pictures is also impacted by outside sounds and environmental disturbances such changes in temperature and atmospheric pressure. Histogram equalisation was examined in 2004 and it was suggested that HE is a straightforward yet powerful picture enhancing method. However, it has a propensity to expressively change the brightness of a picture, resulting in annoyance, artificial contrast augmentation, and artefacts. They suggested a brand-new improvement to BBHE called Minimal Mean Brightness Error Bi-Histogram Equalisation. The MMBEBHE feature minimises disparity between the medium of input and output images. The results of simulation demonstrated that MMBEBHE can retain brightness more effectively than other equalisation. This effort also developed a successful, integer-based MMBEBHE implementation. However it has certain limitations. Additionally, an extension of BBHE known as recursive mean-separate histogram equalisation has been developed (RMSHE).Scalable brightness preservation is a property of RMSHE. According to the simulation findings, RMSHE is the most effective equalisation method when compared with other method. It has been shown that MMBEBHE outperforms BBHE and DSIHE in maintaining original brightness when used to bi-histogram equalisation. A brand-new local brightness preserving dynamic histogram equalisation (LBPDHE) technique is presented with the purpose of enhancing contrast. The advantages of histogram splitting before histogram equalisation to prevent too or underly enhanced pictures have been demonstrated in previous contrast enhancement efforts. Additionally, it has been acknowledged that one of the most crucial characteristics for contrast enhancing schemes is brightness preservation. The maintenance of brightness is crucial for lowering energy usage in consumer electronics like televisions and liquid crystal displays (LCD).The primary finding of that study was that, unlike earlier research ideas, brightness preservation could be carried out locally and separately for each division as opposed to globally throughout the whole histogram. Experimental findings from 80 test photographs show that their suggested approach, in comparison to existing methods, not only achieves the best mean brightness preservation but also produces good contrast enhanced images. It adds a straightforward but crucial local mean brightness maintaining mechanism to the DHE method. Experimental findings based on eighty test photos demonstrate that our suggested LBPDHE approach not only achieves the greatest brightness retention but also has high contrast improvement. When used in consumer

Turkish Journal of Computer and Mathematics Education *Vol.10 No.02 (2019), 995-1002*
DOI: https://doi.org/10.17762/turcomat.v10i2.13581

electronic items, their proposed solution has reduced power consumption more than the other contrast enhancement techniques [5].

3. Proposed System

For photographs compressed using the JPEG standard, an image improvement technique is described. The discrete cosine transform (DCT) domain-defined contrast measure serves as the foundation for the method. The approach does not impair the original image's compressibility since it improves the pictures during the decompression step, which is one of the benefits of the psychophysically driven algorithm. The method is distinguished by its lack of computational complexity. Any DCT-based image compression standard, including JPEG, MPEG 2, and H. 261, can use this technique. Although the intricacy of this procedure is lessened, it takes more time. When compared to other works, the procedure' dependability is poor. To overcome all these drawbacks a new system has been proposed. In this study, we construct an end-to-end signal prior-guided layer using the Retinex theory as inspiration.

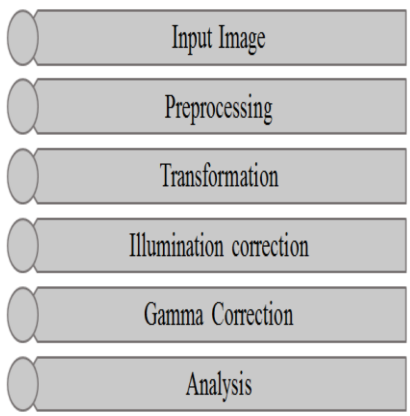

Fig 1: Flow Diagram

In order to eliminate low-amplitude patterns and maintain important relevant features, a Sparse Gradient Minimization sub-Network gets built. This enables extraction of correlated illumination maps from low or normal light pictures. Following the learnt breakdown, Enhance-Net and Restore-Net are used to forecast improved illumination and reflection maps, which aid in extending contrast of illumination map and removing intense noise from the reflection map, respectively. Overall visual quality is improved by the mutually reinforcing impacts of all these specified limitations, including the regularisation and losses of the signal structure.

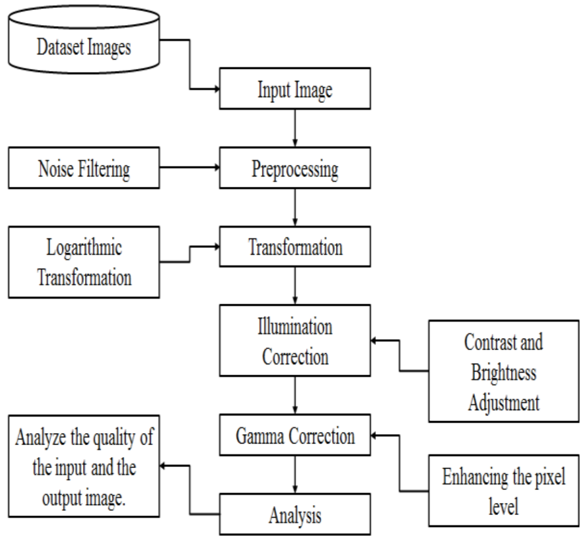

Fig 2: System Architecture

A variety of applications, including contrast enhancement, tone mapping, non-uniform illumination images enhancement, image segmentation, target identification and tracking, as well as remote sensing image rectification, have made use of various techniques that divide a picture into the illumination and the reflectance.

The following list of benefits of the suggested technique is provided:

- High computational speed.
- It is more dependable since if the procedure is repeated numerous times, the image quality will be at its best.
- The improvement is more accurate.
- The picture has also been cleaned of noise.

4. Results

Image enhancement's main objective is to modify a given image such that the finished output is more suitable for a certain purpose than the actual image. It draws attention to or emphasises visual elements like borders, limits, or contrast to make a graphic presentation more useful for study and display. While the augmentation improves the dynamic range of selected characteristics to make them easier to identify, it does not increase the data's fundamental information richness. In this procedure, an algorithm for improving images was created. It is based on the linear domain simultaneous estimate of light and reflectance. Histogram equalisation (HE), which stretches the dynamic pixel intensity of a picture, can solve the lighting issue and make dark images visible.

The experimental findings demonstrate the good performance of the suggested technique for obtaining reflectance and illumination with aesthetically attractive increased outcomes and prominent convergence rate. In comparison to previous testing techniques, suggested techniques also produces results that are equivalent to or superior in terms of subjective and objective evaluations.

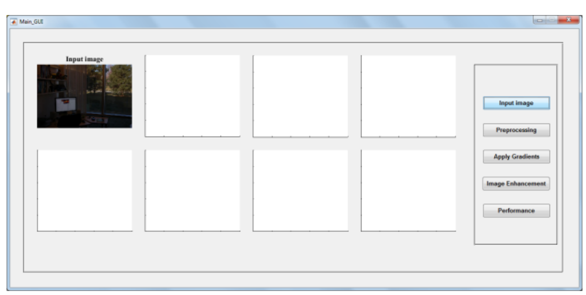

Fig 3: Input Image

DOI: https://doi.org/10.17762/turcomat.v10i2.13581

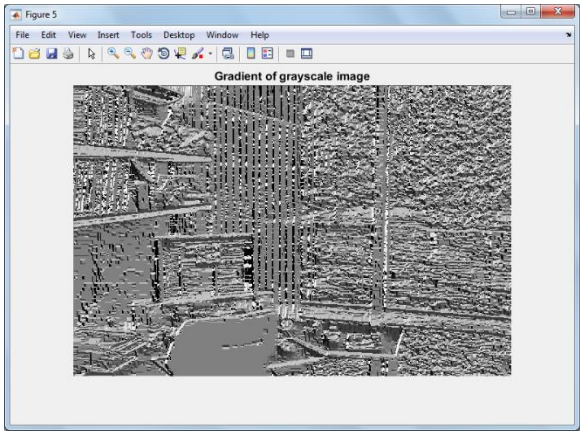

Fig 4: Gradient of Gray-Scale Image

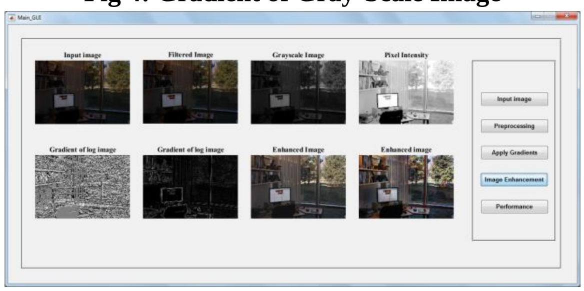

Fig 5: Image Enhancement

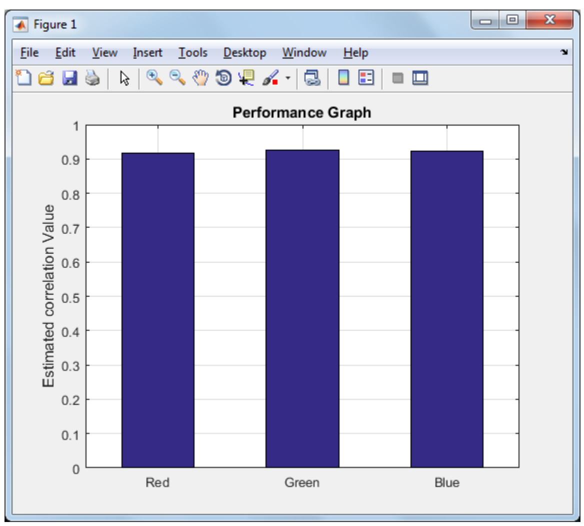

Fig 6: Performance Analysis

5. Conclusion

As we have seen, this method of picture enhancement is quite effective in producing superior results and lossless data from the image. Even so, this method is preferred for any photographs when we wish to improve the image quality.

Reference

[1] Sandeep Singh, Sandeep Sharma," A Survey of Image Enhancement Techniques" 2014
[2] Er. Manu Gupta, Er.Amanpreet Kaur, "An Image Enhancement by Fuzzy Logic and Artificial Neural Network using Hybrid Approach"-2014
[3] DiwakarShrivastava, Dr. Vineet Richhariya, "Adaptive Contrast Image Enhancement Based on Fuzzy Set Theory" -2014
[4] NehaTripathi,"Image Resolution Enhancement by Wavelet Transform Based Interpolation and Image Fusion"-2014
[5] Mahendra PS Kuber1 and Manish Dixit, "A Review on Modified Image Enhancement Applications"-2014
[6] H. Ahn, B. Keum, D. Kim, and H. S. Lee, "Adaptive local tone mapping based on Retinex for high dynamic range images," in Proc. IEEE Int. Conf. Consum. Electron., Jan. 2013, pp. 153–156.
[7] B. Gu, W. Li, M. Zhu, and M. Wang, "Local edge-preserving multiscale decomposition for high dynamic range image tone mapping," IEEE Trans. Image Process., vol. 22, no. 1, pp. 70–79, Jan. 2013.
[8] L. Meylan and S. Susstrunk, "High dynamic range image rendering with a Retinex-based adaptive filter," IEEE Trans. Image Process., vol. 15, no. 9, pp. 2820–2830, Sep. 2006.
[9] S. Pan, X. An, and H. He, "Adapting iterative Retinex computation for high-dynamic-range tone mapping," J. Electron. Imag., vol. 22, no. 2, pp. 023006-1–023006-10, 2013.
[10] B. J. Lee and B. C. Song, "Local tone mapping using sub-band decomposed multi-scale Retinex for high dynamic range images," in Proc. IEEE Int. Conf. Consum. Electron., Jan. 2014, pp. 125–128.
[11] X. Lan, H. Shen, L. Zhang, and Q. Yuan, "A spatially adaptive Retinexvariational model for the uneven intensity correction of remote sensing images," Signal Process., vol. 101, pp. 19–34, Aug. 2014.
[12] C. Li, F. Li, C.-Y. Kao, and C. Xu, "Image segmentation with simultaneous illumination and reflectance estimation: An energy minimization approach," in Proc. IEEE 12th Int. Conf. Comput. Vis., Kyoto, Japan, Sep./Oct. 2009, pp. 702–708.
[13] Y. Liu, R. R. Martin, L. de Dominicis, and B. Li, "Using Retinex for point selection in 3D shape registration," Pattern Recognit., vol. 47, no. 6, pp. 2126–2142, 2014.
[14] C. Jung, T. Sun, and L. Jiao, "Eye detection under varying illumination using the Retinex theory," Neurocomputing, vol. 113, pp. 130–137, Aug. 2013.
[15] E. H. Land, "The Retinex," Amer. Sci., vol. 52, no. 2, pp. 247–253 and 255–264, 1964.