A SCENE STATISTICAL APPROACH TO ENHANCE THE LOW-LIGHT IMAGES

A Project report submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

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2021-2022

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CERTIFICATE

This is to certify that the project report entitled **"A SCENE STATISTICAL APPROACH TO ENHANCE LOW- LIGHT IMAGES"** submitted by **Pavan Kumar Yerra (318126512120), Marri Deepthi Chinni Swaroopa (318126512090), Baki Dharma Teja (318126512064), Utkarsh Jaiswal (318126512111)**, in partial fulfilment of the requirements for the award of the degree of **Bachelor of Technology in Electronics & Communication Engineering** of Andhra University, Visakhapatnam is a record of Bonafide work carried out under my guidance and supervision.

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ACKNOWLEDGEMENT

We would like to express our deep gratitude to our project guide **Mrs.K.Yashoda**, Assistant Professor, Department of Electronics and Communication Engineering, ANITS, for her guidance with unsurpassed knowledge and immense encouragement. We are grateful to **Dr. V. Rajyalakshmi**, Head of the Department, Electronics and Communication Engineering, for providing us with the required facilities for the completion of the project work.

We are very much thankful to the **Principal and Management, ANITS, Sangivalasa,** for their encouragement and cooperation to carry out this work.

We express our thanks to all **teaching faculty** of Department of ECE, whose suggestions during reviews helped us in accomplishment of our project. We would like to thank **all non-teaching staff** of the Department of ECE, ANITS for providing great assistance in accomplishment of our project.

We would like to thank our parents, friends, and classmates for their encouragement throughout our project period. At last but not the least, we thank everyone for supporting us directly or indirectly in completing this project successfully.

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ABSTRACT

Obtaining clear, still or moving images under low -illumination conditions has become an urgent problem to solve.Image enhancement is a common problem in various fields, and how to adaptively enhance images with low illumination or uneven illumination requi res further study. To improve the visual quality of an image we have low -light enhancement which is nothing but correcting the contrast , recovering details and to suppress the noise. Low light imaging and low light image enhancement have wild applications in our daily life and different scientific research fields, like night surveillance, automated driving, fluorescence microscopy, high speed imaging and so on. However, there is still a long way to go in dealing with these tasks, considering the great chal lenges in low photon counts, low Signal to Noise Ratio, complicated noise models, etc. In this work, we compared methods that automatically enhances the image using some scene statistical analysis like Fusion-based enhancing method for weakly illuminated images, Adaptive Image Enhancement Method for Correcting Low-Illumination Images, Multi-Exposure Fusion Framework for Low-light Image Enhancement and also we estimate the level of improvement in the enhanced image using some existing Full Reference metrics like Structural Similarity Index Map (SSIM), Multi -Scale Structural Similarity Index Map (MS-SSIM), and some of the state of the art No reference image quality assessment algorithms like Natural Image Quality Evaluator (NIQE), Blind/Referenceless Image Spatial Quality Evaluator (BRISQUE).

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CHAPTER 1
INTRODUCTION

1.1 WHAT IS MEANT BY DIGITAL IMAGE PROCESSING?

Digital image processing deals with manipulation of digital images through a digital computer. It is a subfield of signals and systems but focus particularly on images. DIP focuses on developing a computer system that is used application for processing digital images able to perform processing on an image. The input of that system is a digital image and the system process that image using efficient algorithms, and gives an image as an output. The most common example is Adobe Photoshop.

Image processing basically includes the following three steps:

1) Importing the image via image acquisition tools.

2) Analysing and manipulating the image.

3) Output in which result can be altered image or report that is based on image analysis.

1.2 ORIGIN OF DIGITAL IMAGE PROCESSING:

The first application of digital image was in the newspaper industry when the pictures were first sent by submarine cable between London and New York. The cable picture transmission in 1921 reduced the time required to transport a picture across the Atlantic for more than a week to less than 3 hours. Specialized printing equipment was used to code pictures for transmitting it via cable and then reconstruct the image from the codes at the receiving end.

1.3 FIELDS WHICH USE DIGITAL IMAGE PROCESSING:

1) Gamma-Ray Imaging:

Imaging with gamma rays is creating medical diagnostic images using gamma rays emitted by tiny amounts of radionuclides administered to patients, photons of penetrating electromagnetic radiation emitted from an atomic nucleus. This procedure is an advanced modern medical technique that allows whole body scans (PET), or more organ and tissue specific scans (SPECT).

Imaging with gamma rays is used in nuclear medicine, as well as in court medicine. This technique can be used for both diagnosis and prevention. Imaging with gamma rays has a wide range of functions, such as:

- Tumour imaging
- Infection imaging

- Bones imaging
- Thyroid imaging

2) X-Ray Imaging:

Digital x-ray is also called as digital radiography. Digital x-ray can widely be used in medical technology. Digital radiography (DR) is an advanced form of x-ray inspection which produces a digital radiographic image instantly on a computer. This technique uses x-ray sensitive plates to capture data during object examination, which is immediately transferred to a computer without the use of an intermediate cassette.

3) Imaging in Ultraviolet band:

UV imaging starts with passing the emission of a UV-emitting LED, lamp or diode, or looking at a subject illuminated with UV light that's reflected off the item being inspected. The reflected UV light is then captured by the camera. The wavelength of the UV light is not converted or shifted in this process.

4) Imaging in Radio band:

The production of a visible image of an object by means of radio waves. It is used to study the internal structure of objects that are opaque to waves in the optical region and to observe objects that are located in an optically opaque medium. Since the radio waves usually employ ed in radio imaging are in the millimeter and centimeter bands, rather fine details of an objec structure can be distinguished in the optical image that is produced.

The chief task of radio imaging is to collect the information and present it as a visible image. This is accomplished by special devices called radio introscopes; an example is the radio im age device.

1.4 FUNDAMENTALS OF DIGITAL IMAGE PROCESSING

1. Image Acquisition:

Image acquisition is the first step of the fundamental steps of DIP. In this stage, an image is given in the digital form. Generally, in this stage, pre-processing such as scaling is done.

2. Image Enhancement:

Image enhancement is the simplest and most attractive area of DIP. In this stage details which are not known, or we can say that interesting features of an image is highlighted. Such as brightness, contrast, etc...

3. Image Restoration:

Image restoration is the stage in which the appearance of an image is improved.

4. Colour Image Processing:

Colour image processing is a famous area because it has increased the use of digital images on the internet. This includes colour modelling, processing in a digital domain, etc....

5. Wavelets and Multi-Resolution Processing:

In this stage, an image is represented in various degrees of resolution. Image is divided into smaller regions for data compression and for the pyramidal representation.

6. Compression:

Compression is a technique which is used for reducing the requirement of storing an image. It is a very important stage because it is very necessary to compress data for internet use.

7. Morphological Processing:

This stage deals with tools which are used for extracting the components of the image, which is useful in the representation and description of shape.

8. Segmentation:

In this stage, an image is a partitioned into its objects. Segmentation is the most difficult tasks in DIP. It is a process which takes a lot of time for the successful solution of imaging problems which requires objects to identify individually.

9. Representation and Description:

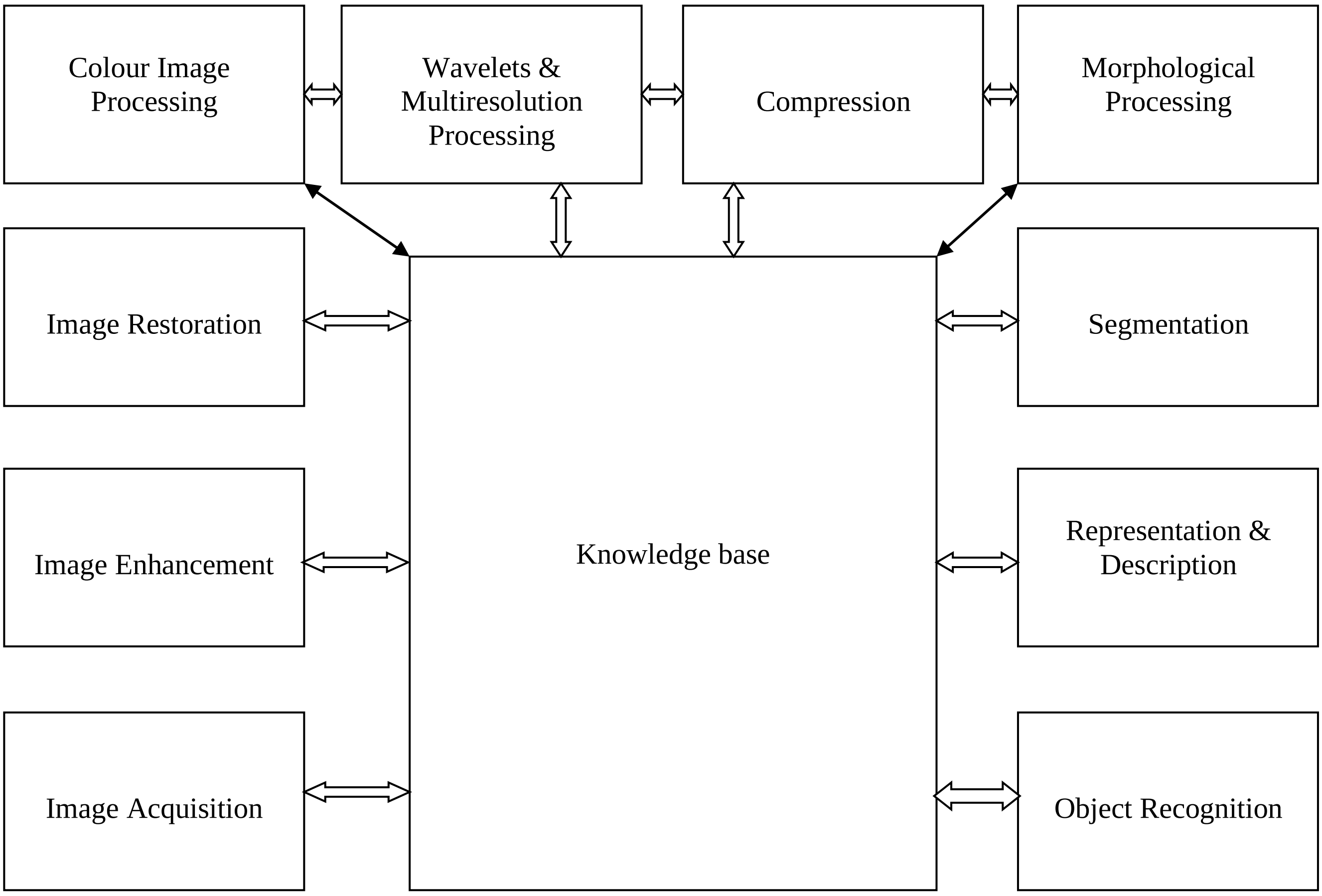
Representation and description follow the output of the segmentation stage. The output is a raw pixel data which has all points of the region itself. To transform the raw data, representation is the only solution. Whereas description is used for extracting information's to differentiate one class of objects from another.

10. Object recognition:

In this stage, the label is assigned to the object, which is based on descriptors.

11. Knowledge Base:

Knowledge is the last stage in DIP. In this stage, important information of the image is located, which limits the searching processes. The knowledge base is very complex when the image database has a high-resolution satellite.



1.5 Image Transformation:

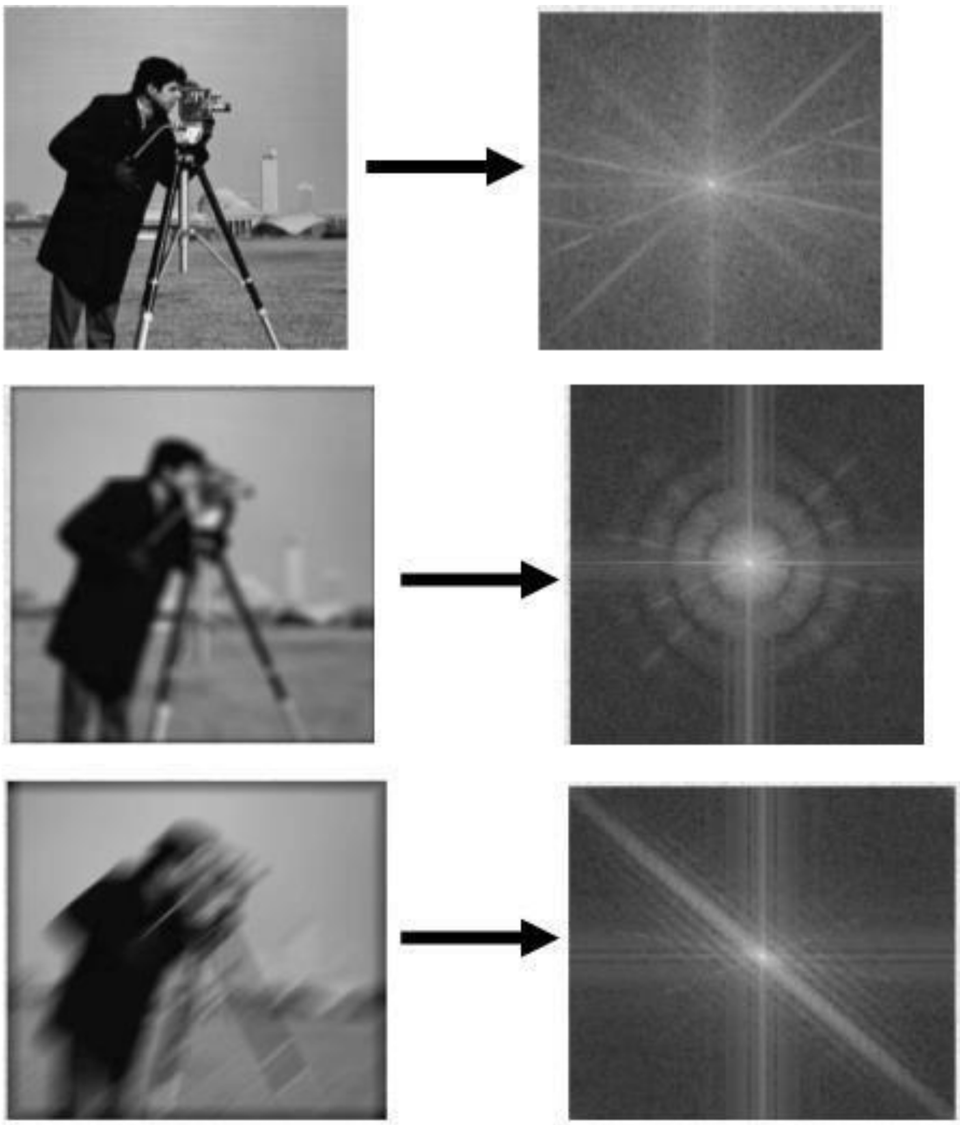
An image is obtained in spatial coordinates (x, y) or (x, y, z). There are many advantages if the spatial domain image is transformed into another domain. In which solution of any problem can be found easily.

Following are two types of transformation:

1. Fourier Transform:

Fourier transform is mainly used for image processing. In the Fourier transform, the intensity of the image is transformed into frequency variation and then to the frequency domain. It is used for slow varying intensity images such as the background of a passport size photo can be represented as low-frequency components and the edges can be represented as high-frequency components. Low-frequency components can be removed using filters of FT domain. When an image is filtered in the FT domain, it contains only the edges of the image. And if we do inverse FT domain to spatial domain then also an image contains only edges. Fourier transform is the simplest technique in which edges of the image can be fined.

Example of Blurred image and its Fourier transformation:



Figures: Blurred image and its Fourier transformation

2. Discrete Cosine Transformation (DCT)

In Discrete Cosine Transformation, coefficients carry information about the pixels of the image. Also, much information is contained using very few coefficients, and the remaining coefficient contains minimal information. These coefficients can be removed without losing information. By doing this, the file size is reduced in the DCT domain. DCT is used for lossy compression.

Example:

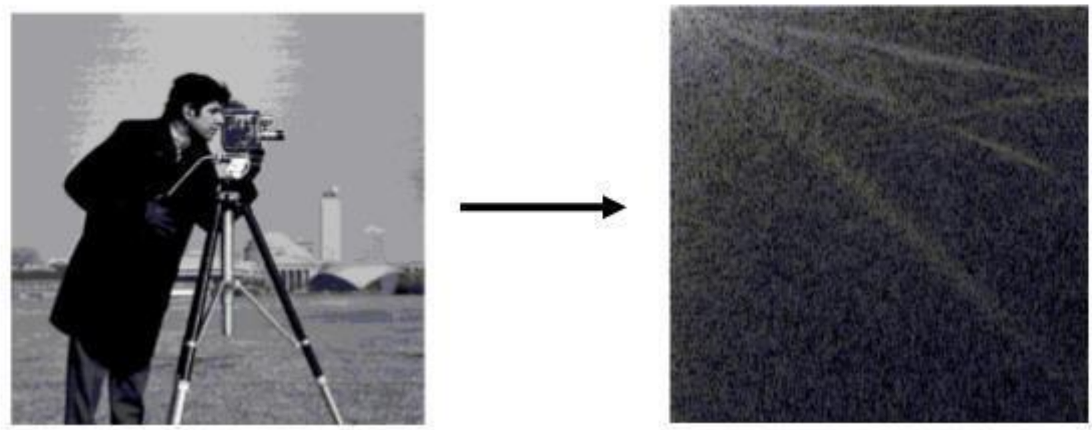


Figure: Input Image and it’s cosine transformation

1.6 COMPONENTS OF DIGITAL IMAGE PROCESSING:

The basic components comprising a typical general-purpose system used for digital image processing are:

Image Sensors:

- It refers to sensing.
- The image sensor captures incoming light, convert it into an electrical signal, measure that signal, and output it to supporting electronics.
- An image sensor is a 2D array of light-sensitive elements that convert photons into electrons.
- CCD (Charged Coupled Device) and CMOS (Complementary MetalOxide Conductor) image sensors are widely used in image-capturing devices like digital cameras.
- Image sensors have two elements that are required to capture digital images.
- The first is a physical device (sensor) that is sensitive to the energy radiated by the object we wish to convert to image.
- The second is a digitizer that is used for converting the output of a physical sensing device into digital form.

Specialized Image Processing Hardware:

- It consists of the digitizer and hardware that performs primitive operations, such as an Arithmetic Logic Unit (ALU), which performs arithmetic and logical operations in parallel on entire images.

Computer:

- The computer in an image processing system is a general-purpose computer and can range from a PC to a supercomputer.

Image Processing Software:

- Software for image processing consists of specialized modules that perform specific tasks.
- A well-designed package also includes the capability for the user to write code.

Mass Storage:

- Mass storage refers to the storage of a large amount of data in persisting and machine-readable fashion.
- The mass storage capability is a must in image processing applications.

Image Displays:

- Image display is the final link in the digital image processing chain.
- Image displays are mainly colored TV monitors.

Hardcopy Devices:

- Various devices for recording images are Laser printers, film cameras, heat-sensitive devices, and digital units, such as optical and CD-ROM disks.

Networking:

- It is a required component to transmit image information over a networked computer.
- Because of the large amount of data inherent in image processing applications, the key consideration in image transmission is bandwidth.

1 .7 HISTOGRAM PROCESSING:

An image histogram is a type of histogram that acts as a graphical representation of the tonal distribution in a digital image.[1] It plots the number of pixels for each tonal value. By looking at the histogram for a specific image a viewer will be able to judge the entire tonal distribution at a glance.

Image histograms are present on many modern digital cameras. Photographers can use them as an aid to show the distribution of tones captured, and whether image detail has been lost to blown-out highlights or blacked-out shadows. This is less useful when using a raw image format, as the dynamic range of the displayed image may only be an approximation to that in the raw file.

The horizontal axis of the graph represents the tonal variations, while the vertical axis represents the total number of pixels in that particular tone. The left side of the horizontal axis represents the dark areas, the middle represents mid-tone values and the right hand side represents light areas. The vertical axis represents the size of the area (total number of pixels) that is captured in each one of these zones.

1.8 HISTOGRAM EQUALIZATION:

Histogram Equalization is a computer image processing technique used to improve contrast in images. It accomplishes this by effectively spreading out the most frequent intensity values, i.e. stretching out the intensity range of the image. This method usually increases the global contrast of images when its usable data is represented by close contrast values. This allows for areas of lower local contrast to gain a higher contrast.

A color histogram of an image represents the number of pixels in each type of color component. Histogram equalization cannot be applied separately to the Red, Green and

Blue components of the image as it leads to dramatic changes in the image's color balance. However, if the image is first converted to another color space, like HSL/HSV color space, then the algorithm can be applied to the luminance or value channel without resulting in changes to the hue and saturation of the image.

1.9 LOCAL ENHANCEMENT:

Local enhancement technique can enhance overall contrast more effectively. In local enhancement, a small window slides through every pixel of the input image sequentially and only those block of pixels are enhanced that fall in this window. And then gray level mapping is done only for the center pixel of that window.

Local Enhancement essentially takes into consideration the local properties of the image by moving a window/mask throughout. The image from pixel to pixel. The histogram of the points in the window is calculated and then a histogram

Local contrast enhancement attempts to increase the appearance of large-scale light-dark transitions, similar to how sharpening with an "unsharp mask" increases the appearance of small-scale edges.

CHAPTER 2
Image Enhancement And Image Quality Assessment

2.1 INTRODUCTION:

With the rapid development of computer vision technology, digital image processing systems have been widely used in many fields, such as industrial production, video monitoring, intelligent transportation, and remote sensing monitoring, and thus play important roles in industrial production, daily life, military applications, etc. However, some uncontrollable factors often exist during the process of image acquisition, resulting in various image defects. In particular, under poor illumination conditions, such as indoors, nighttime, or cloudy days, the light reflected from the object surface may be weak; consequently, the image quality of such a low-light image may be seriously degraded due to color distortions and noise. After image conversion, storage, transmission and other operations, the quality of this kind of low-light image is seriously further reduced. The main purpose of low-light image enhancement is to improve the overall and local contrast of the image, improve its visual effect, and transform the image into a form more suitable for human observation or computer processing, while avoiding noise amplification and achieving good real-time performance. To this end, it is essential to enhance the validity and availability of data captured under low illumination to obtain clear images or videos. Such enhancement can not only render images more consistent with the subjective visual perception of individuals and improve the reliability and robustness of outdoor visual systems but also allow such images to be more conveniently analyzed and processed by computer vision equipment, which is of great importance for promoting the development of image information mining.

In the real world, color images are most commonly used, so most of the algorithms are either designed for color image enhancement or derived from gray image enhancement methods. The major methods are listed below.

(i) Enhancement based on the RGB (red, green, blue) color space. The specific steps are as follows. The three color components (R, G and B) are extracted from the original RGB color image. Then, these three components are each individually enhanced using a grayscale image enhancement method. Finally, the three components are merged, and the enhanced results are output. This method is simple but can result in serious color deviations in the enhanced images because it neglects the correlations between the components.

(ii) Enhancement based on the HSI (hue, saturation, intensity) color space (or the YCbCr, $L*$ $a*b$, YUV color space). The brightness component I in the HSI color space is separate from and unrelated to the chrominance component H, i.e., the color information of an image. When the chrominance does not change, the brightness and saturation will determine all of the image information. Hence, to enhance a color image, the I and S components are usually enhanced separately while maintaining the same chromaticity H.

2.2 CLASSIFICATION OF LOW-LIGHT IMAGE ENHANCEMENT ALGORITHMS

Many image enhancement algorithms for images captured under low-illumination conditions are proposed to improve low-light videos and images from different perspectives. In accordance with the algorithms used for brightness enhancement, these processing methods into seven classes: gray transformation methods, histogram equalization (HE) methods, Retinex methods, frequency-domain methods, image fusion methods, defogging model methods and machine learning methods. These methods can be further divided into different subclasses in accordance with the differences in their principles.

2.3 HISTOGRAM EQUALIZATION (HE) METHODS:

In the HE method, the CDF is used as the transformation curve for the image gray values. Let I and L denote an image and its gray levels, respectively. I(i, j) represents the gray value at the position with coordinates (i, j), N represents the total number of pixels in the image, and nk represents the number of pixels of gray level k. Then, the gray-level probability density function of image I is defined as

$$p(k) = nk / N , (k = 0, 1, 2, . . . , L - 1)$$

If the pixel values of an image are evenly distributed across all possible gray levels, then the image shows high contrast and a large dynamic range. On the basis of this characteristic, the HE algorithm uses the cumulative distribution function (CDF) to adjust the output gray levels to have a probability density function that corresponds to a uniform distribution; in this way, hidden details in dark areas can be made to reappear, and the visual effect of the input image can be effectively enhanced.

BASIC MODELS OF HE METHODS:

Depending on the regions considered in the calculation, HE methods can be divided into global histogram equalization (GHE) and local histogram equalization (LHE). The general concept of a GHE algorithm is illustrated by the model shown in Fig. 8, where X represents the original image, Y represents the enhanced image generated by the HE algorithm, Y = f (X) represents the traditional HE process or an improved version, and X1, X2, X3, · · · , Xn represent n subimages composed of pixels in the original image that satisfy certain conditions according to a given property, which is defined as Q(x). The parameter x represents the magnitude of the image gray value, Y1, Y2, Y3, · · , Yn denote the equalized images corresponding to the n subimages, and the image Y after equalization is obtained by merging the subimages in accordance with the pixel positions.

The GHE model has several advantages, such as relatively few calculations and high efficiency, and it is especially suitable for the enhancement of overall darker or brighter images. However, it is difficult for a global algorithm, which conducts statistical operations based on the gray values of the whole image, to obtain the optimal recovered values for each local region. Such an algorithm is unable to adapt to the local brightness characteristics of the input image, and consequently, the sense of depth in the image will be decreased after processing.

To solve this problem, many scholars have proposed that an LHE algorithm should be used instead, and such algorithms have hence been put into wide practice. The basic idea of LHE is to apply the HE operation separately to various local areas of an image. The original image is spatially divided into multiple subblocks, and equalization is conducted separately on each subblock to adaptively enhance the local information of the image to achieve the desired enhancement effect. LHE methods can be further divided into three approaches, namely, LHE with nonoverlapping subblocks, LHE with overlapping subblocks and LHE with partially overlapping subblocks.

Many algorithms have been developed based on the classic HE approach like brightness-preserving bi-histogram equalization (BBHE), dualistic subimage histogram equalization (DSIHE) algorithm, minimum mean brightness error bi-histogram equalization (MMBEBHE) model, iterative brightness bi-histogram equalization (IBBHE) algorithm, contrastlimited adaptive histogram equalization (CLAHE) algorithm and many more.

2.4 RETINEX METHODS:

The Retinex theory, namely, the theory of the retinal cortex, established by Land and McCann, is based on the perception of color by the human eye and the modeling of color invariance. The essence of this theory is to determine the reflective nature of an object by removing the effects of the illuminating light from the image. According to Retinex theory, the human visual system processes information in a specific way during the transmission of visual information, thus removing a series of uncertain factors such as the intensity of the light source and unevenness of light. Consequently, only information that reflects essential characteristics of the object, such as the reflection coefficient, is retained. Based on the illumination-reflection model, an image can be expressed as the product of a reflection component and an illumination component : $I(x, y) = R(x, y)L(x, y)$

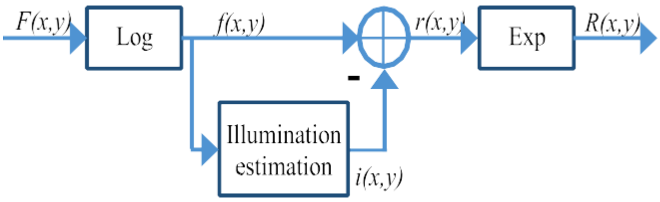


Figure: General Process of the Retinex algorithm

where R(x, y) is the reflection component, which represents the reflective characteristics of the object surface; L(x, y) is the illumination component, which depends on the environmental light characteristics; and I(x, y) is the received image. L(x, y) determines the dynamic range of the image, whereas R(x, y) determines the inherent nature of the image. According to Retinex theory, if L(x, y) can be estimated from I(x, y), then the reflection component can be separated from the total amount of light, and the influence of the illumination component on the image can be reduced to enhance the image. The Retinex algorithm features a sharpening capability, color constancy, large dynamic range compression and high color fidelity. In the general process of the Retinex algorithm , where Log denotes the logarithmic operation and Exp denotes the exponential operation.

2.5 METHODS BASED ON IMAGE FUSION:

In these methods, many images of the same scene are obtained with different sensors, or additional images are obtained with the same sensor using various imaging methods or at different times.

Finally, as much useful information as possible is extracted from every image to synthesize a high-quality image, thus improving the utilization rate of the image information. The synthesized image can reflect multilevel information from the original images to comprehensively describe the scene, thus allowing the available image information to better meet the requirements of both human observers and computer vision systems.

1) MULTISPECTRAL IMAGE FUSION:

Multispectral image fusion is an improved method of obtaining the details of a low-light imaged scene by fusing a visible image with an infrared image. Near-infrared (NIR) light has a longer wavelength and stronger penetration ability than does visible light, allowing redundant information to be removed from a filtered infrared image. Additionally, a low-light visible image can provide rich background information; consequently, better images can be obtained through image fusion. Zhu et al. proposed a fusion framework for night vision applications called night vision context enhancement (FNCE), in which the fused result is obtained by combining decomposed images using three different rules. Furthermore, many scholars have studied the use of night vision technology for single- and double-channel low-light color fusion based on bispectral and trispectral features. Vision technology has been developed based on low-light and infrared thermal image fusion, low-light and longwave infrared image fusion, ultraviolet and low-light image fusion, and even trispectral color fusion based on low-light, medium wave and longwave infrared images. However, the visible and infrared images need to be acquired simultaneously, which constrains such algorithms in terms of the hardware conditions necessary to support them. Moreover, the intelligence and adaptability of these algorithms are poor, and their parameters need to be artificially set. Therefore, these algorithms have still not been widely adopted.

2) IMAGE FUSION BASED ON BACKGROUND HIGHLIGHTING:

enerally, image fusion methods based on background highlighting rely on the integration of low-light images with daytime images to enhance the image details, thus improving the visual effect of the low-light images. The general process is described as follows. First, an image is obtained in the daytime under reasonably sufficient lighting conditions for use as the source of the background for the fused image. Then, another image is obtained in the same position under low illumination, and the background of this image is removed. The remainder of the latter image is taken as the foreground of the fused image. Finally, the background and foreground are integrated into a single image using a suitable algorithm. Rao et al. proposed a low-light enhancement method based on video frame fusion. The foreground area of each low-light video frame was fused with the background area from a daytime video frame of the same scene to improve the brightness of the low-light video and compensate for detail loss. In daytime images from the same site at various times were fused, and the final fused image was obtained using a moving object extraction technique and weighting processing based on brightness estimation theory. This process is shown in Fig. below.

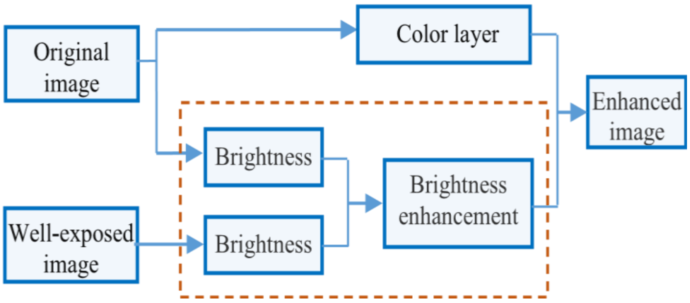


Figure: Fusion based on background highlighting

3) FUSION BASED ON MULTIPLE EXPOSURES:

Image fusion is the process of combining multiple images of the same scene into a single high-quality image that contains more information than any single input image. Petschnigg et al. proposed a method of obtaining various images with both flash and nonflash technologies and then realizing low-light image enhancement through image fusion. In this method, a flash image is captured to record detailed information of the scene, and a nonflash image is captured to record the brightness information of the background. Then, the image detail information is integrated with the background brightness information. The resulting image contains not only the details from the flash image but also the brightness information from the nonflash image. Similarly, high-dynamic-range (HDR) imaging using multiexposure fusion (MEF) techniques has become very popular in recent years. MEF methods use multiple images of the same scene with different exposures. The final HDR image is obtained by synthesizing the best details from the images corresponding to each exposure time. A gradient domain HDR compression algorithm was proposed. In this algorithm, different gradients are proportionally compressed in the gradient domain of the images, and Poisson's equation is solved in the modified gradient domain to obtain output images with a low dynamic range. This algorithm can also reveal detailed information in areas of various brightness in HDR night images. Li et al. proposed an image enhancement algorithm based on multiple image fusion. In this algorithm, multiple images of the same scene are first acquired with different exposure times, and then, various details are extracted from each image. Finally, these details are integrated to generate an enhanced HDR image. Merianos and Mitianoudis combined two image fusion methods, one for the fusion of the luminance channel and one for the fusion of the color channels. The fusion output thus derived outperforms both individual methods.

The fusion of multiple images acquired from the same scene can be applied to effectively enhance low-light images. Because good-quality image information from the same scene is needed, methods of this kind have stringent requirements in terms of image acquisition; in particular, the camera equipment needs to be stable. Since a long shooting time is required, this method cannot be applied for real-time imaging or video enhancement. Moreover, the enhancement effect for images of globally low brightness is poor.

4) FUSION BASED ON A SINGLE IMAGE:

Many scholars have studied the synthesis of the entire dynamic range of a scene, including details extracted in a variety of ways from a single image, to break the dependence on image sequences, as shown in Fig. below

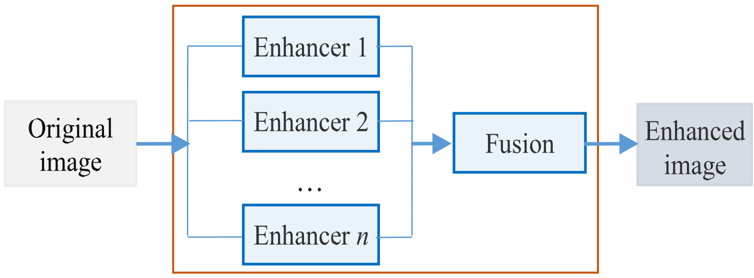


Figure: fusion based on single image

Le and Li improved the contrast of an image by fusing the original image with the image obtained after a logarithmic transformation. Yamakawa and Sugita presented an image fusion technique that used a source image and the Retinex processed image to achieve high visibility in both bright and dark areas.Wang et al. adaptively generated two new images based on nonlinear functional transformations in accordance with the illumination-reflection model and multiscale theory and used a principal component analysis (PCA)-based fusion method to enhance a low-light image. In an adaptive histogram separation method was used to construct underexposed and overexposed images from an original image sequence; these images were then separately processed, and finally, HDR images were generated via multiexposure image fusion. In addition, Fu et al. proposed an image enhancement algorithm based on the fusion of the results of multiple enhancement techniques. This algorithm integrates multiple image enhancement techniques by means of a linear weighted fusion strategy to improve the enhancement effect. However, this strategy is too complex to satisfy real-time requirements. The algorithm proposed in, integrates the color contrast, saturation and exposure brightness of an original or preprocessed image by incorporating MSRCR into a pyramid algorithm using the gold tower technique and specifying different weight parameters depending on the image information to achieve the effective color enhancement of a traditional low-light image.

In short, the main idea of methods based on image fusion is that useful information on the same target collected from multiple sources can be further utilized, without requiring a physical model, to obtain a final high-quality image through image processing and computer technology. These fusion-based methods are simple and can achieve good results. However, they require two or more different images of the same scene; therefore, it is difficult to realize image enhancement within a short time, as is needed for realtime monitoring situations, and these methods are difficult to apply and popularize in practice.

2.6 METHODS BASED ON MACHINE LEARNING:

Most existing low-light image enhancement techniques are model-based techniques rather than data-driven techniques. Only in recent years have methods based on machine learning for image enhancement begun to emerge in significant numbers. An image enhancement method based on a color estimation model (CEM) was proposed by Fu et al., in which the dynamic range of color images in the RGB color space was controlled by adjusting the CEM parameters to effectively inhibit oversaturation of the enhanced images. Fotiadou et al. proposed a low-light image enhancement algorithm based on a sparse image representation in which both a low-light condition dictionary and a daylight condition dictionary were established. The sparse constraint was used as prior knowledge to update the dictionaries, and low-light image blocks were used to approximately estimate the corresponding daylight images. An image enhancement algorithm based on fuzzy rule reasoning was proposed in which three traditional enhancement methods were combined by applying fuzzy theory and machine learning to establish a set of fuzzy rules, and the best enhancement algorithm was adaptively selected for different images to achieve image enhancement. This method can also be used to objectively and accurately evaluate the image enhancement effect.

Several deep-learning-based methods for image enhancement have also emerged. For example, Yan et al. proposed the first deep-learning-based method for photo adjustment. Lore et al. adopted a stacked sparse denoising autoencoder in a framework for training an LLNet for low-light image enhancement. In this framework, a sparsity regularized reconstruction loss was taken as the loss function, and deep learning based on the self-encoder approach was used to learn the features of image signals acquired under various low-illumination conditions to realize adaptive brightness adjustment and denoising. Park et al. proposed a dual autoencoder network model based on Retinex theory; in this model, a stacked autoencoder was combined with a convolutional autoencoder to realize low-light enhancement and noise reduction. The stacked autoencoder, with a small number of hidden units, was used to estimate the smooth illumination component in the space, and the convolutional autoencoder was used to process two-dimensional image information to reduce the amplification of noise during the process of brightness enhancement.

CNNs have been used as the basis of deep learning frameworks in many research works. Tao et al. proposed a low-light CNN (LLCNN) in which a multistage characteristic map was used to generate an enhanced image by learning from low-light images with different nuclei. A global illumination-aware and detail-preserving network (GLADNet) was designed. In this network, the input image is first scaled to a certain size and then passed to encoder and decoder networks to generate global prior knowledge of the illumination. Based on this prior information and the original images, a convolutional network is then used to reconstruct the image details. Ignatov et al. took a different approach of learning a mapping between images acquired by a mobile phone camera and a digital single-lens reflex (DSLR) camera. They built a dataset consisting of images of the same scene taken by the different cameras and presented an end-to-end deep learning approach for translating ordinary photos into DSLR-quality images. Lv et al. proposed a new network (MBLLEN) consisting of a feature extraction module (FEM), an enhancement module (EM) and a fusion module (FM), which produces output images via feature fusion. Gabriel et al. designed a deep convolutional neural network (DCNN) based on a large dataset of HDR images, and Liu et al. trained the DCNN using only synthetic data to recover the details lost due to quantization. Undoubtedly, deep-learning-based methods can achieve excellent performance in low-light image enhancement, and they also represent a major trend of current development in image processing research. However, such methods must be supported by large datasets, and an increase in the complexity of a model will lead to a sharp increase in the time complexity of the corresponding algorithm. With the steady growth of research on low-light image enhancement, not only are some low-light data available from widely used public benchmark datasets such as PASCAL VOC, ImageNet , and Microsoft COCO, but researchers are also building public datasets specifically designed for low-light image processing, such as SID and EDD (Exclusively Dark Dataset) .

2.7 Image Quality Assessment:

Image quality degrades in seconds from capturing to displaying to observer. Different distortions during the stages that it might pass through such as storing, processing, compressing, and transmitting etc. So there is need to maintain image quality so that it can be shown clearly to observer and hence there is need to access this quality .There are two methods for assessing image quality, the subjective and the objective method. The subjective methods are considered costly, expensive, and time consuming but the results given by these methods are best correlated with human vision. In subjective method since we have to select a number of observers, show then a number of images and ask them to score images quality depending on their own opinion. The objective evaluation uses automatic algorithms to assess the quality of the image depending on the existence of the original image.

2.8 CLASSIFICATION OF IQA METHODS:

The evaluation of image quality may be classified into two classes, subjective and objective methods

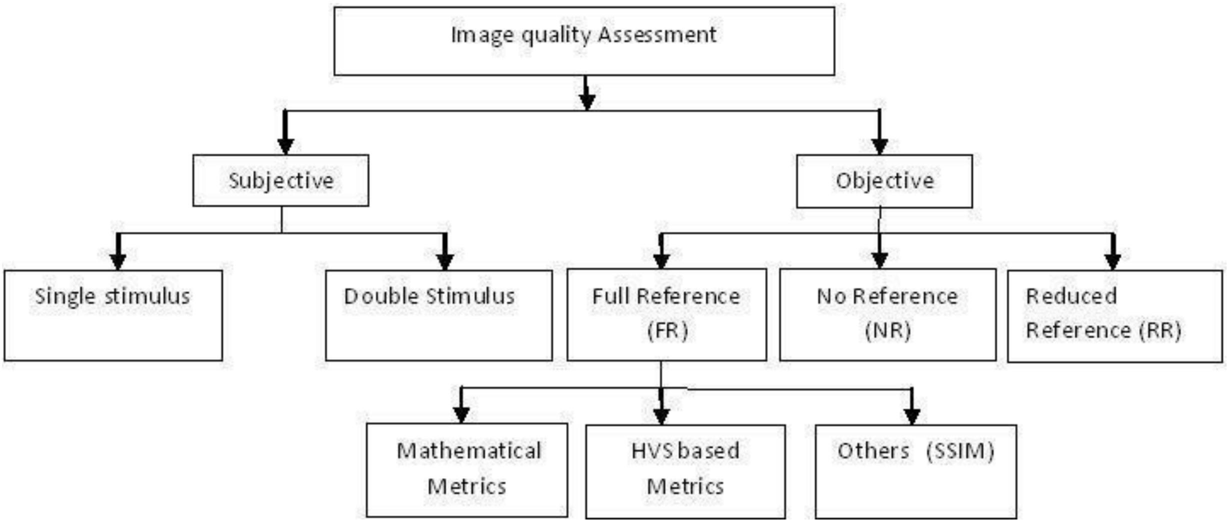


Figure: Flow graph of IQA

2.8.1 Subjective Methods:

In subjective quality assessment, images are provided to a number of observers and are asked to compare original images with distorted images in order to evaluate the quality of the distorted images. Based on their evaluation, mean opinion score (MOS) is calculated which is taken as the image quality index. Each image is shown to the observer which is asked to score the image on a scale from 1 to 5.Mean Opinion Score (MOS) scores are given in Table

1. There are three different factor used:luminance, viewing distance from observer to display and display properties are taken into account while conducting the subjective quality test.

A. Double stimulus impairment scale (DSIS):

In this method videos are shown consequently in pairs: first one is the reference, and expert is informed about it, second one is impaired. After their playback, Observers are then asked to vote on the second, keeping first in mind using a scale containing 5 scores: Imperceptible, Perceptible but not annoying, slightly annoying, Annoying, and Very annoying.

B. Double-Stimulus Continuous Quality-Scale (DSCQS):

This subjective method was developed to measure the quality of service on longer viewing sequences. The method is cyclic which means that the assessor is asked to view a pair of pictures. One is the original video or image without any transmission errors and the other is the same but after alteration by transmission errors. In other words, both images are from the same source, but one passed through radio channel and the other one came directly from the source. The observers assess the quality of both images by direct comparison.

C. Single Stimulus Continuous Quality Scale (SSCQS):

In this technique image sequences without a reference are presented to the observer only once Observers continuously weigh the image sequence along the time on a linear scale by an electronic recording handset associated to a computer and provide a result as “best” or “worst”.

D. Simultaneous Double Stimulus for Continuous Evaluation (SDSCE):

In this technique image sequences are offered in pairs such that original and impaired sequences are presented side by side at same time. Then, the observers are enquired to check the alterations amid the two sequences and to evaluate the fidelity of the image information along the time on a linear scale by an electronic recording handset attached to a computer. The observers are conscious of the original and distorted sequences throughout calculation session. After the calculation session, data is collected from the tests and processed to achieve a level of impairment.

2.8.2 Objective Methods:

Objective method is a quantitative approach where we are using two images in which intensity of two images, reference and distorted type are used to calculate a number which indicate the image quality. Objective method is classified into three types’ full- reference, reduced-reference and no-reference on basis of availability of reference image.The goal of these models is to automatically estimate the perceptual quality of images, in a way correlated with the human appreciation.

1) Full Reference (FR) model:

   In this objective reference IQA methods, in general the human visual system require of a reference sample to determine the quality level of an image.

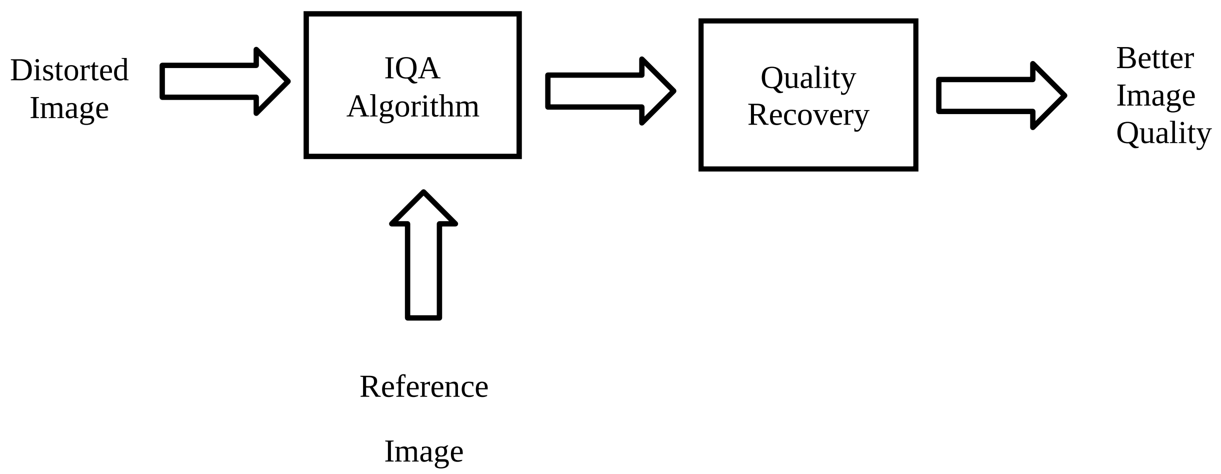
2) No Reference (NR) models:

In this objective reference IQA method, in general the human visual system does not require of a reference sample to determine the quality level of an image. This method also called “blind models” methods.

3) Reduced Reference (RR) models:

In this method original reference image from sender side is not completely available at receiver side IQA system. However, some set of features are extracted from the original reference image and they are being utilized by the quality assessment system, which helps assessment system to evaluate the quality of the distorted image and quantify it.

2.9 Full Reference Image Quality Assessment:



2.9.1 MSE (Mean Square Error):

The MSE represents the cumulative squared error between the compressed and the original image.The lower the value of MSE, the lower the error.MSE is the most common estimator of image quality measurement metric. It is a full reference metric. It is the second moment of the error. The variance of the estimator and its bias are both incorporated with mean squared error. The MSE is the variance of the estimator in case of unbiased estimator. It has the same units of measurement as the square of the quantity being calculated like as variance. The MSE introduces the Root-Mean- Square Error (RMSE) or Root-Mean-Square Deviation (RMSD) and often referred to as standard deviation of the variance.

The MSE can also be said the Mean Squared Deviation (MSD) of an estimator. Estimator is referred as the procedure for measuring an unobserved quantity of image. The MSE or MSD measures the average of the square of the errors. The error is the difference between the estimator and estimated outcome. It is a function of risk, considering the expected value of the squared error loss or quadratic loss.

Calculation of MSE:

MSE = sum(sum(squaredErrorImage)) / (rows * columns)

Root Mean Square Error**:**

Root Mean square Error is another type of error measuring technique used very commonly to measure the differences between the predicted value by an estimator and the actual value. It evaluates the error magnitude. It is a perfect measure of accuracy which is used to perform the differences of forecasting errors from the different estimators for a definite variable.

Let us suppose that θˆθ^ be an estimator with respect to a given estimated parameter θ, the Root Mean Square Error is actually the square root of the Mean Square Error as

RMES=(MSE)^1/2

2.9.2 PSNR (Peak Signal to Noise Ratio):

PSNR is used to calculate the ratio between the maximum possible signal power and the power of the distorting noise which affects the quality of its representation. This ratio between two images is computed in decibel form. The PSNR is usually calculated as the logarithm term of decibel scale because of the signals having a very wide dynamic range. This dynamic range varies between the largest and the smallest possible values which are changeable by their quality.

The Peak signal-to-noise ratio is the most commonly used quality assessment technique to measure the quality of reconstruction of lossy image compression codecs. The signal is considered as the original data and the noise is the error yielded by the compression or distortion. The PSNR is the approximate estimation to human perception of reconstruction quality compared to the compression codecs. there is no perceptual basis for the PSNR, it does fit reasonably well with subjective assessments, especially in cases where algorithms are compared that produce similar types of artifact. It remains the most commonly used objective distortion metric, because of its mathematical tractability and because of the lack of any widely accepted alternative. It is worth noting, however, that the PSNR can be deceptive, for example when:

1. There is a phase shift in the reconstructed signal. Even tiny phase shifts that the human observer would not notice will produce significant changes.
2. There is visual masking in the coding process that provides perceptually high quality by hiding distortions in regions where they are less noticeable.
3. Errors persist over time. A single small error in a single frame may not be noticeable, yet it could be annoying if it persists over many frames.

2.9.3 Structural Similarity Measures:

Although being very convenient and widely used, the aforementioned image quality metrics based on error sensitivity present several problems which are evidenced by their mismatch with subjective human-based quality scoring systems.Among Structural Similarity Index Measure (SSIM), has the simplest formulation and has gained widespread popularity in a broad range of practical applications.In this method measuring the similarity between two images, here we measure image quality based on an initial uncompressed or distortion-free image as reference.

It compares two images using information about luminous, contrast and structure. SSIM metric is designed to improve on traditional methods like PSNR and MSE and this is calculated on various windows of an image. The measure between two windows x and y of common size N×N is given as follows:

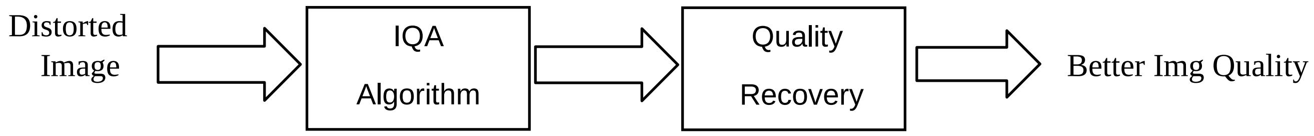
$$SSIM(x, y) = \{(2\mu_x \mu_y + C_1)(2\sigma_{xy} + C_2)\} / \{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)\}$$

Where μ_x is average of x, μ_y is average of y, σ_x, σ_y are standard deviation between the original and processed images pixels, respectively.C1, C2 are positive constant chosen empirically to avoid the instability of measure. SSIM is a decimal value between (-1, 1).

The Structural Similarity Index (SSIM) metric extracts 3 key *features* from an image:

- **Luminance:** Luminance is measured by *averaging* over all the pixel values. Its denoted by μ .
- **Contrast:** It is measured by taking the *standard deviation (square root of variance)* of all the pixel values. It is denoted by σ (sigma).
- **Structure:**The structural comparison is done by using a consolidated formula (more on that later) but in essence, we divide the input signal with its standard deviation so that the result has unit standard deviation which allows for a more robust comparison.

2.10 NO-REFERENCE IMAGE QUALITY ASSESSMENT (NR-IQA):



2.10.1 Distortion-specific approaches:

The final quality measure is computed according to a model trained on clean images and on images affected by this particular distortion. Two of these measures have been included in the biometric protection method.

The JPEG Quality Index (JQI):

This method evaluates the quality in images affected by the usual block artifacts found in many compression algorithms running at lowbit rates such as the JPEG.

The High-Low Frequency Index (HLFI):

This method is inspired by previous work which considered local gradients as a blind metric to detect blur and noise. Similarly, the HLFI feature is sensitive to the sharpness of the image by computing the difference between the power in the lower and upper frequencies of the Fourier Spectrum.

2.10.2 Training-based approaches:

In this approach features are extracted from the image and algorithm is trained to distinguish distorted and undistorted image as used in BLIINDS

The BRISQUE score is usually in the range [0, 100]. Lower values of score reflect better perceptual quality of image A with respect to the input model. It is a Non reference image quality assessment .

Blind Image Quality Index (BIQI) follows a two-stage framework in which the individual measures of different distortion-specific experts are combined to generate one global quality score.

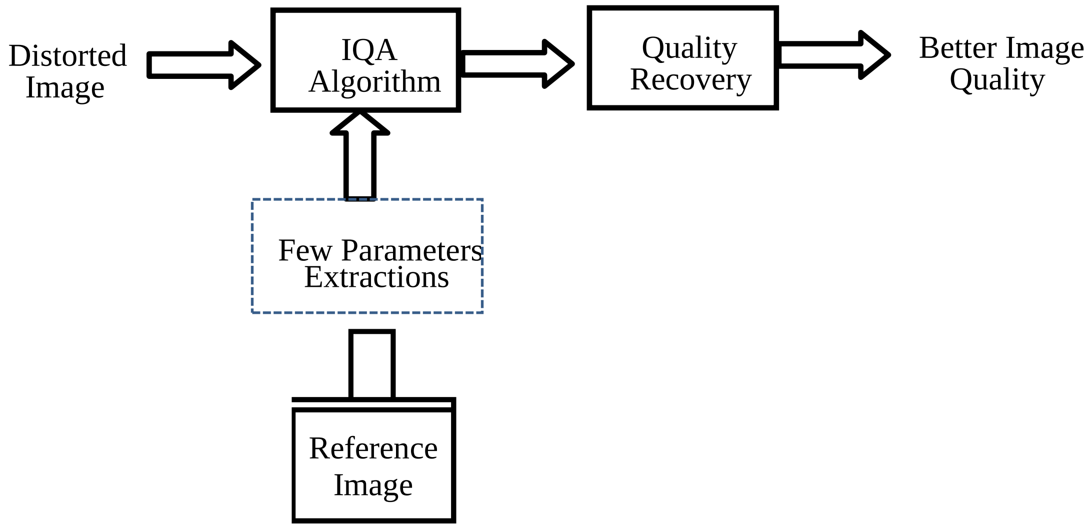
2.10.3 Natural Scene Statistic approaches:

This approach relies on how the statistics of images change as distortions are introduced to them. It assumes that natural or undistorted images occupy a subspace of the entire space of possible images, and then seeks to find a distance from the distorted image (which supposedly lies outside of that subspace) to the subspace of natural images

This approach is followed by the Natural Image Quality Evaluator (NIQE):

Completely blind image quality analyzer based on the construction of a quality aware collection of statistical features (derived from a corpus of natural undistorted images) related to a multivariate Gaussian natural scene statistical model.

2.11 REDUCED-REFERENCESIMAGE QUALITY ASSESSMENT (RR-IQA):



A RR image quality assessment method based on Roberts cross derivative or wavelet domain model of statistic of natural image is possible. The Roberts cross derivative can be used to extract geometric features of an image, which are applied in HVS perception.

Another method is based on wavelet domain RRIQA using natural image statistics model. This method of RRIQA implements the Kullback-Leibler distance between the marginal PDFs of wavelet coefficients of the original reference and distorted images as an image distortion measure.

Technique	Algorithms	Performance
Full Reference Image Quality Assessment	MSE PSNR	Widely utilized but has poor correlativeness
	NQM UQI SSIM MS - SSIM IFC VIF VSNR	It is good as that of FR-IQA. But required whole knowledge of the image. Quite complex in the computational point of view
Reduced - Reference Image Quality Assessment	Application orient	It is required prior and sufficient knowledge about distortions of the image. It compensate in between FR and NR approaches in terms of quality prediction accuracy
Non - Reference image quality Assessment	BIQI BLIND BLIND II BRISQUE DIVINE	Meets desired expectation with least available knowledge. It gives better correlative data score as compared to previous techniques

Table: Performances of IQA algorithms

In this chapter we discussed about the various approaches used to evaluate the quality of an image. The experimental results demonstrate that the MSE and PSNR methods are simple and are easy to implement but it does not correlate highly with human awareness. Quality assessment algorithms are desirable to monitor the quality for real time applications. Subjective methods are difficult to implement in real time schemes, so objective approaches are more involved in current years. But correct and effective IQA measures help to improve their applicability in real time applications.

CHAPTER 3
METHODOLOGY

In this work particularly 3 methods were used .They are Fusion-based enhancing method for weakly illuminated images, Adaptive Image Enhancement Method for Correcting Low-Illumination Images,Multi Exposure Fusion Framework for Low-light Image Enhancement.The estimation of the level of improvement in the enhanced image using some existing Full Reference metrics like Structural Similarity Index Map, Multi Scale Structural Similarity Index Map, and No reference metrics like Blind/reference less Image Spatial Quality Evaluator, Naturalness Image Quality Evaluator is performed.

3.1 Fusion-based enhancing method for weakly illuminated images:

A fusion-based method for enhancing weakly illumination images that uses several mature image processing techniques. First, we employ an illumination estimating algorithm based on morphological closing to decompose an observed image into a reflectance image and an illumination image. We then derive two inputs that represent luminance-improved and contrast-enhanced versions of the first decomposed illumination using the sigmoid function and adaptive histogram equalization. Designing two weights based on these inputs, we produce an adjusted illumination by fusing the derived inputs with the corresponding weights in a multi-scale fusion. Through a proper weighting and fusion strategy, we blend the advantages of different techniques to produce the adjusted illumination. The final enhanced image is obtained by compensating the adjusted illumination back to the reflectance. Through this synthesis, the enhanced image represents a trade-off among detail enhancement, local contrast improvement and preserving the natural feel of the image. In the proposed fusion-based framework, images under different weak illumination conditions such as backlighting, non-uniform illumination and nighttime can be enhanced.

Step 1: Weakly ilumination image is taken.
Step 2: Decompose an observed image into a reflectance image and an illumination image.
Step 3: Inputs derivation is done on the illumination image.
Step 4: Designing two weights based on these inputs.
Step 5: Multi-scale fusion is done by fusing the derived inputs with the corresponding weights.

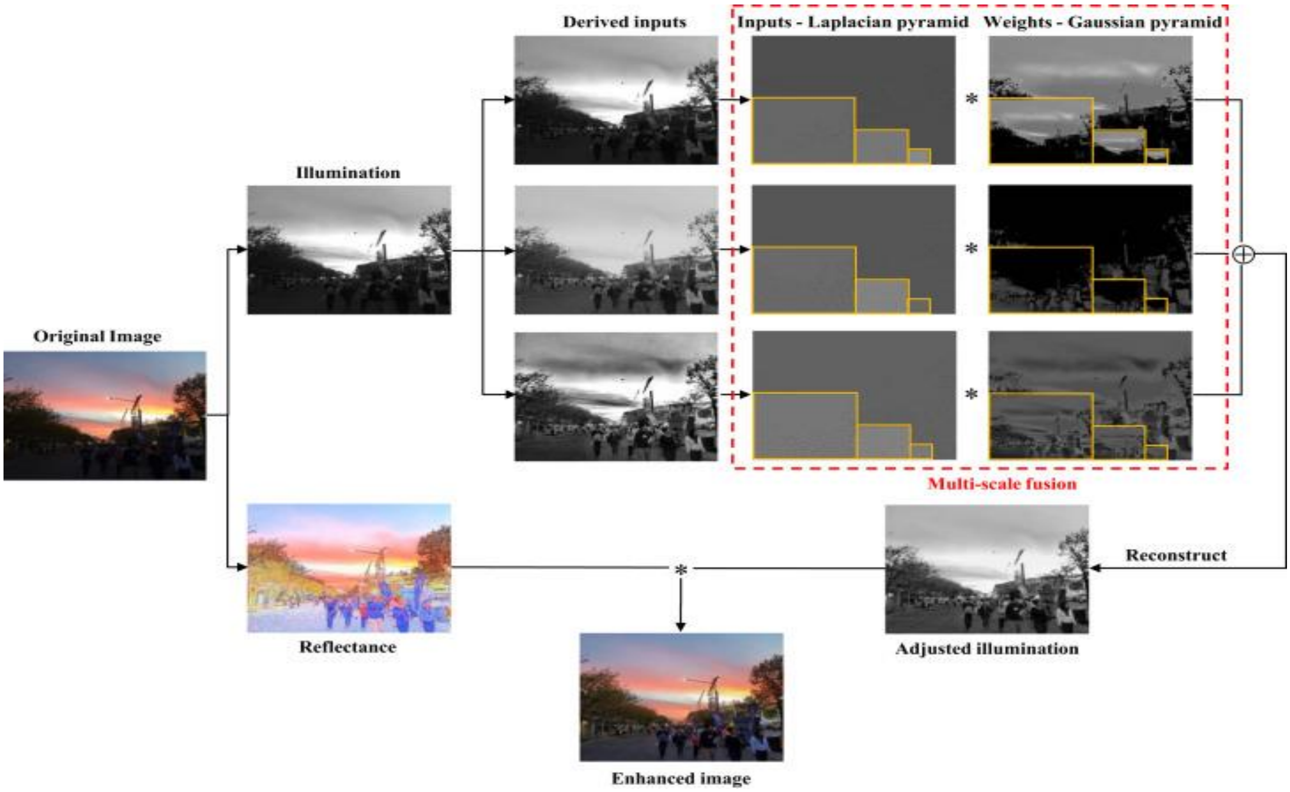


Figure: Flow chart for fusion-based Enhancing method

3.2 Adaptive Image Enhancement Method for Correcting Low-Illumination Images:

The adaptive method addresses two problems of low-illumination image enhancement: local overenhancement due to uneven illumination and the lack of adaptability in the parameter settings of image enhancement algorithms. A color image correction method based on nonlinear function transformation was proposed based on the light reflection model and multiscale theory. First, the original RGB color image was converted to HSV color space, and the V component was used to extract the illumination component of the scene via the multiscale Gaussian function. Then, a correction function was constructed based on the Weber-Fechner law, and two images were obtained through an adaptive adjustment of the parameters of the image enhancement function based on the distribution profiles of the illumination components. Finally, an image fusion strategy was used to extract the details of the two images.
Obtaining clear still or moving images under low-illumination conditions has become an urgent problem to solve. Image enhancement techniques offer one possible solution, as image enhancement not only satisfies the need for a better visual experience but also improves the reliability and robustness of outdoor vision systems, which makes it easier for image processing systems to analyze and process images.

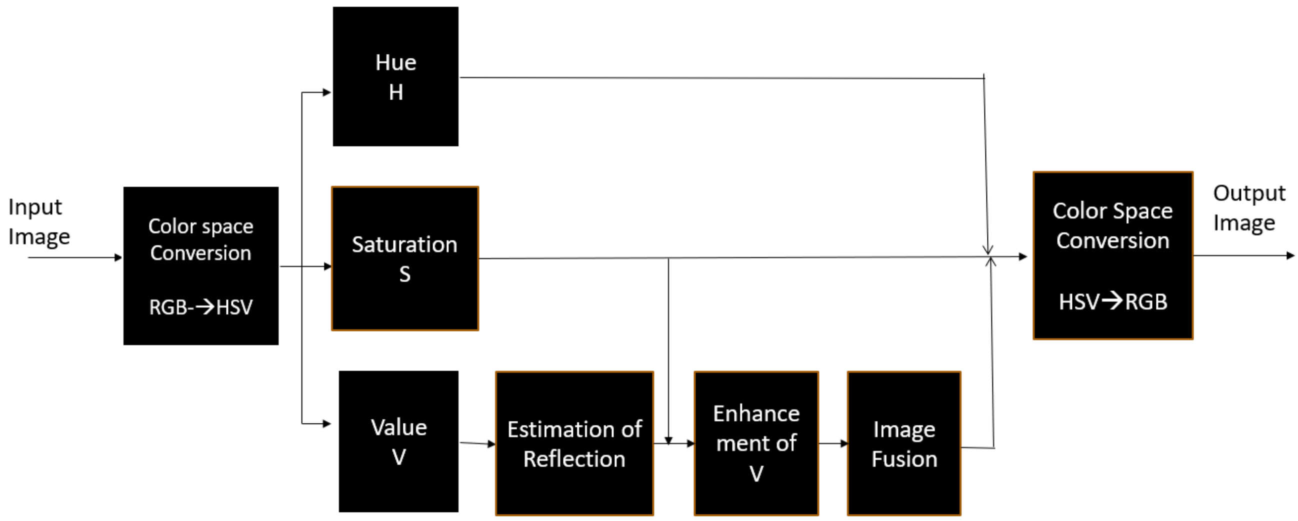


Figure: Flow of Adaptive Image Enhancement

Step 1: Enter a low-illumination image I.
Step 2: Convert the image from RGB space to HSV space using Formula to obtain the brightness map Iv, saturation map Is , and tone map Ih.
Step 3: Extract the illumination component from Iv using Formulato obtain image Iv_g.
Step 4: Let α1 = 0.1 and α2 = 1 and obtain the enhanced images Iv1 and Iv2 using Formulas and, respectively.
Step 5: Calculate the covariance values of Iv1 and Iv2 using Formula.
Step 6: Calculate the eigenvalue and feature vector of covariance matrix C.
Step 7: Calculate the weight coefficient using Formula.
Step 8: Obtain the fused image using Formula.
Step 9: Use Image F as the lamination component to merge with Is and Ih and convert the image into image J in RGB space.
Step 10: Output the enhanced color image J.

3.3 Multi Exposure Fusion Framework for Low-light Image Enhancement:

This method is a multi-exposure fusion framework inspired by the HVS. There are two stages in our framework: Eye Exposure Adjustment and Eye Exposure Adjustment. The first stage simulates the human eye to adjust the exposure, generating an multi-exposure image set. The second stage simulates the human brain to fuse the generated images into the final enhanced result. Based on our framework, we propose a dual-exposure fusion method. Specifically, we first employ the illumination estimation techniques to build the weight matrix for image fusion. Then we derives our camera response model based on observation. Next, we find the optimal exposure for our camera response model to generate the synthetic image that is well-exposed in the regions where the original image is under-exposed.

Finally, we obtain the enhanced results by fusing the input image with the synthetic image using the weight matrix.

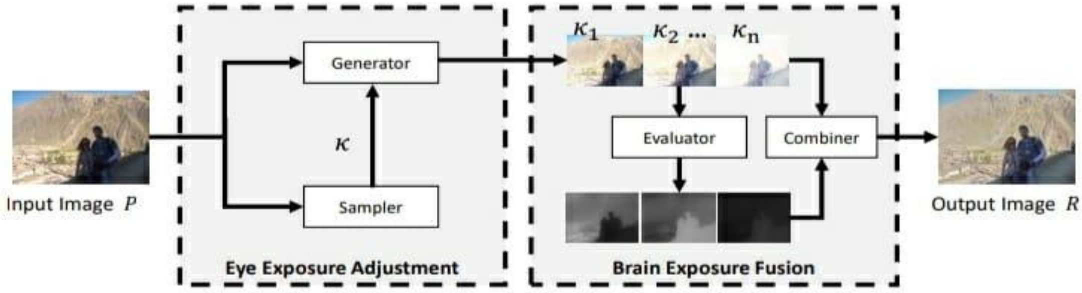


Figure : Multi Exposure Fusion Framework flow

Step 1: Multi-Exposure Sampler, determines how many images are required and the exposure ratio of each image to be fused.

Step 2: Multi-Exposure Generator, use a camera response model and the specified exposure ratio to synthetic multi-exposure images.

Step 3: Multi-Exposure Evaluator, determines the weight map of each image when fusing.

Step 4: Multi-Exposure Combiner, is to fuse the generated images to the final enhanced result based on the weight maps.

In this chaper, we will be using Fusion-based enhancing method for weakly illuminated images, Adaptive Image Enhancement Method for correcting low-illumination images, Multi Exposure fusion framework for low-light image Enhancement methods for enhancing the low-light images and the generated enhanced images are evaluated using the various images assessment methods to obtain the best method in which level of enhancement is good.

CHAPTER 4
SOFTWARE DESCRIPTION

4.1 Introduction:

In this project ,we implemented using MATLAB. **MATLAB** (an abbreviation of "matrix laboratory") is a proprietary multi-paradigm programming language and numeric computing environment developed by Math Works. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages.

Although MATLAB is intended primarily for numeric computing, an optional toolbox uses the Mu PAD symbolic engine allowing access to symbolic computing abilities. An additional package, Simulink , adds graphical multi- domain simulation and model-based design for dynamic and embedded systems.

As of 2020, MATLAB has more than 4 million users worldwide. MATLAB users come from various backgrounds of engineering ,science, and economics.

Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or Fortran.

The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects, which together represent the state-of-the-art in software for matrix computation. MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

MATLAB features a family of application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to *learn* and *apply* specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

4.2 Matlab System :

The MATLAB systems consists of 5parts

The MATLAB language:

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs.

The Matlab Working Environment:

This is the set of tools and facilities that you work with as the MATLAB user or programmer. It includes facilities for managing the variables in your workspace and importing and exporting data. It also includes tools for developing, managing, debugging, and profiling M-files, MATLAB's applications.

Handle Graphics:

This is the MATLAB graphics system. It includes high-level commands for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level commands that allow you to fully customize the appearance of graphics as well as to build complete Graphical User Interfaces on your MATLAB applications.

The MATLAB mathematical function library:

This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigen values, Bessel functions, and fast Fourier transforms.

The MATLAB Application Program Interface (API):

This is a library that allows you to write C and Fortran programs that interact with MATLAB. It include facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

4.3 MATLAB's Power of Computational Mathematics

MATLAB is used in every facet of computational mathematics. Following are some commonly used mathematical calculations where it is used most commonly −

- Dealing with Matrices and Arrays
- 2-D and 3-D Plotting and graphics
- Linear Algebra
- Algebraic Equations
- Non-linear Functions
- Statistics
- Data Analysis
- Calculus and Differential Equations
- Numerical Calculations
- Integration
- Transforms
- Curve Fitting
- Various other special functions

4.4 Features of MATLAB:

Following are the basic features of MATLAB −

- It is a high-level language for numerical computation, visualization and application development.
- It also provides an interactive environment for iterative exploration, design and problem solving.
- It provides vast library of mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, numerical integration and solving ordinary differential equations.
- It provides built-in graphics for visualizing data and tools for creating custom plots.
- MATLAB's programming interface gives development tools for improving

code quality maintainability and maximizing performance.

It provides functions for integrating MATLAB based algorithms with external applications and languages such as C, Java, .NET and Microsoft Excel.

Uses Of MATLAB:

MATLAB is widely used as a computational tool in science and engineering encompassing the fields of physics, chemistry, math and all engineering streams. It is used in a range of applications including −

- Signal Processing and Communications
- Image and Video Processing
- Control Systems
- Test and Measurement
- Computational Finance
- Computational Biology

MATLAB environment behaves like a super-complex calculator. You can enter commands at the command prompt.

MATLAB is an interpreted environment. In other words, you give a command and MATLAB executes it right away.

CHAPTER-5
SIMULTATION RESULTS

5.1 FUSION-BASED ENHANCEMENT METHOD RESULTS:

Fig:5.1.1 Original image

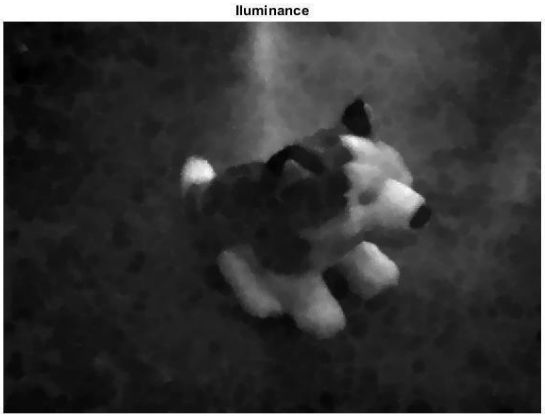


Fig: 5.1.2 Iluminance image

Fig:5.1.3 Reflectance image:

Fig: 5.1.4 Image lightness

Fig:5.1.5 Adjusted Illuminance with pyramid **Fig:5.1.6 Morphologically closing operation**

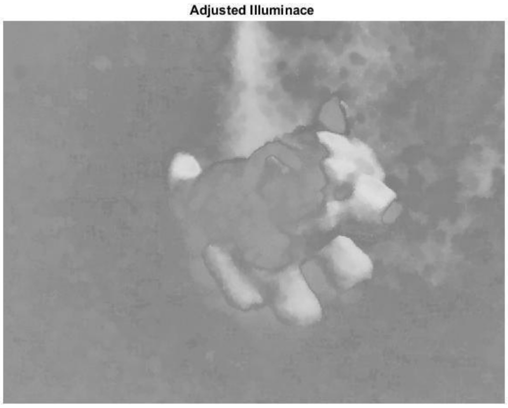
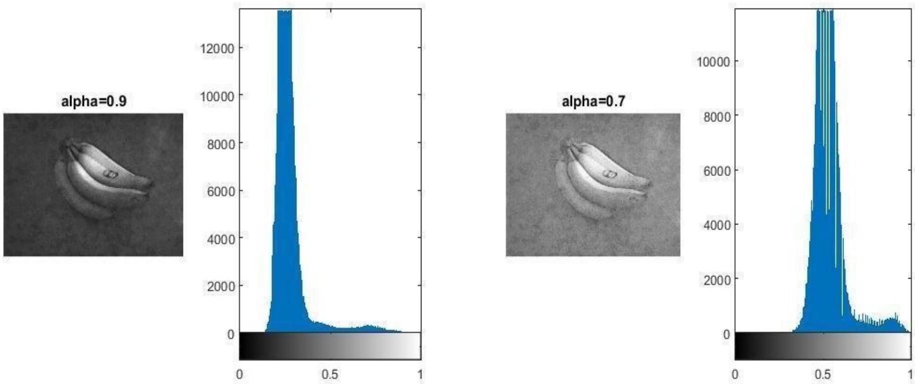


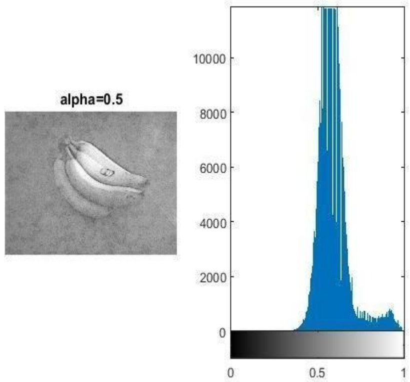
Fig:5.1.7 Adjusted illuminance:

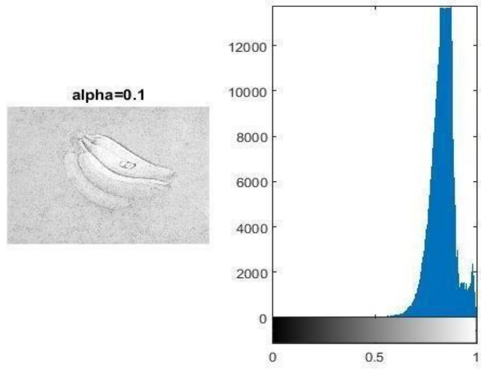
Fig:5.1.8 Enhanced image

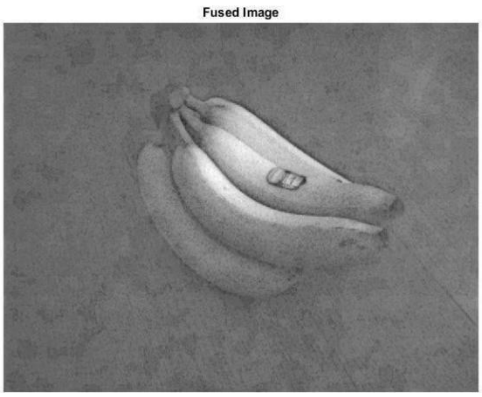
5.2 ADAPTIVE IMAGE ENHANCEMENT METHOD RESULTS:

FIG: ORIGINAL IMAGE









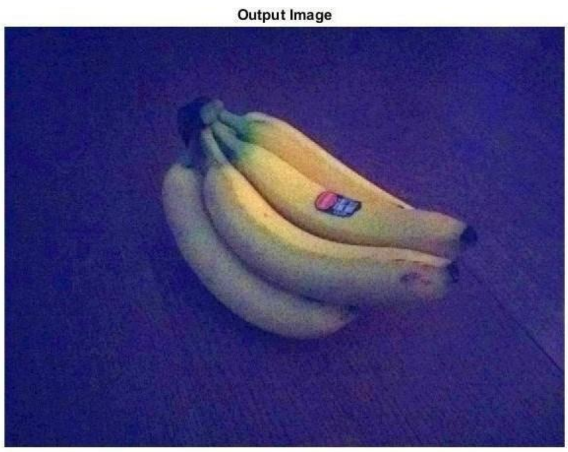
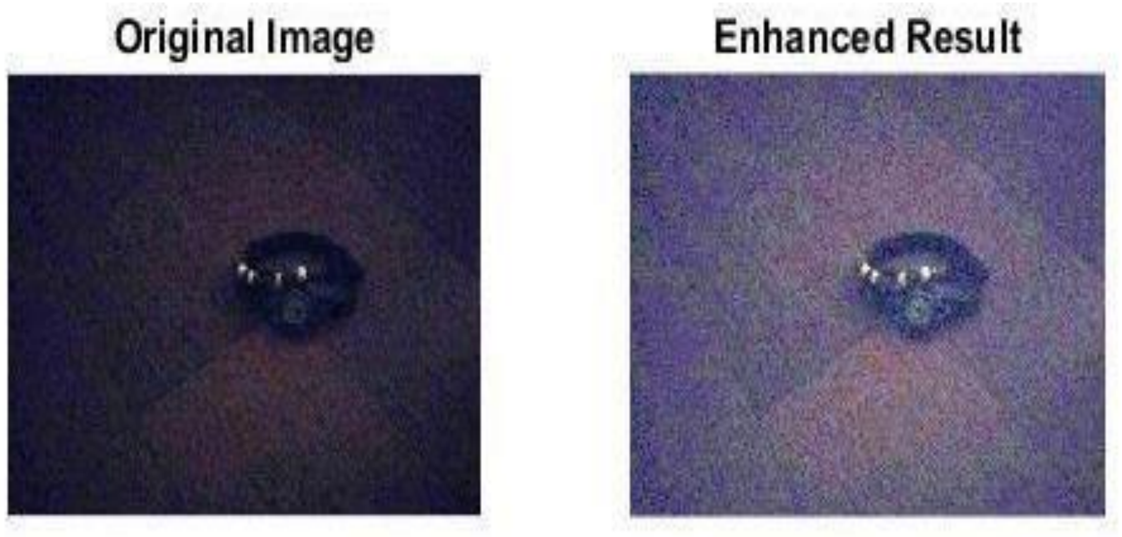


Fig:Output image

5.3 MULTI EXPOSURE FUSION FRAMEWORK RESULTS

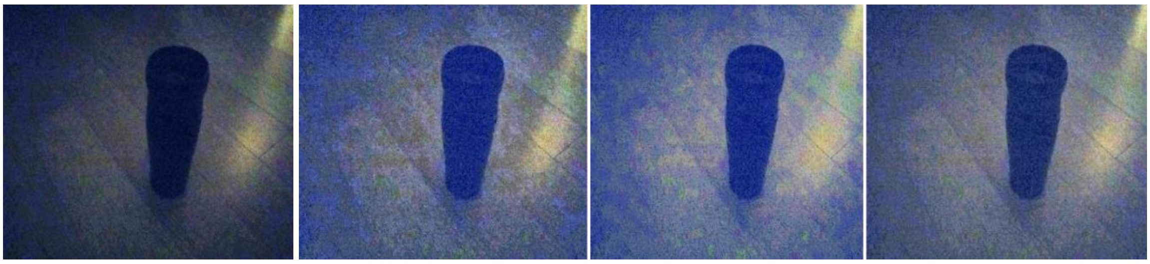


5.4 RESULTS OF DIFFERENT IMAGE ENHANCEMENT METHODS:

1.

a b c d

2.

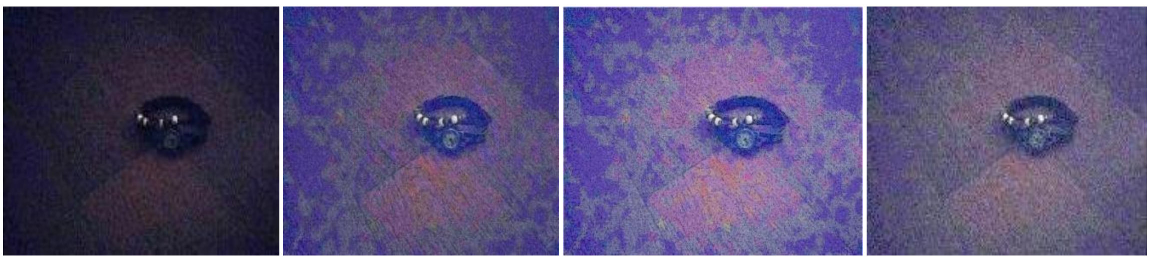


a b c d

3.

a b c d

4.

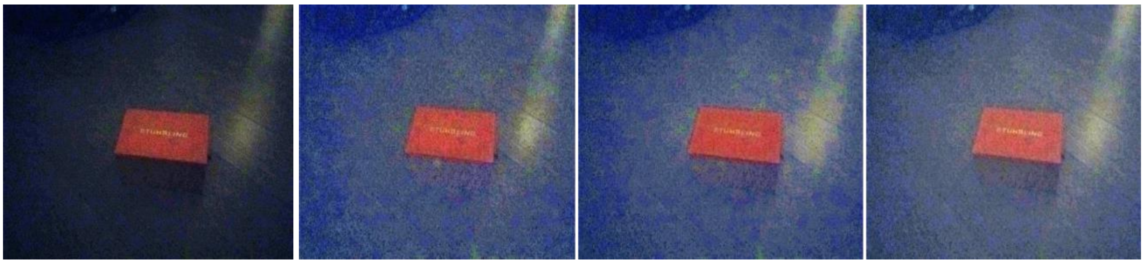


a b c d

5.

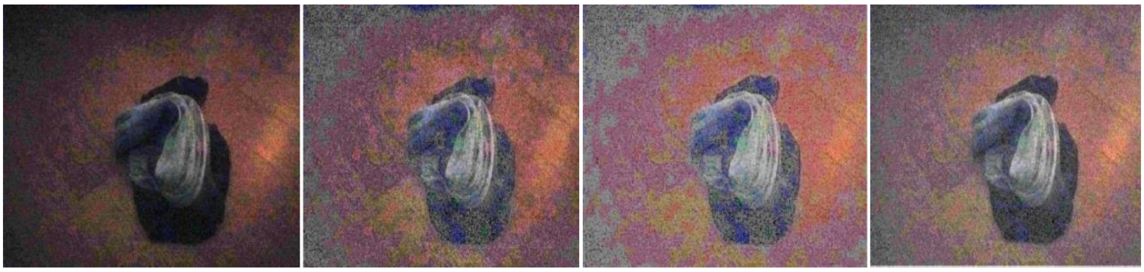
a b c d

6.



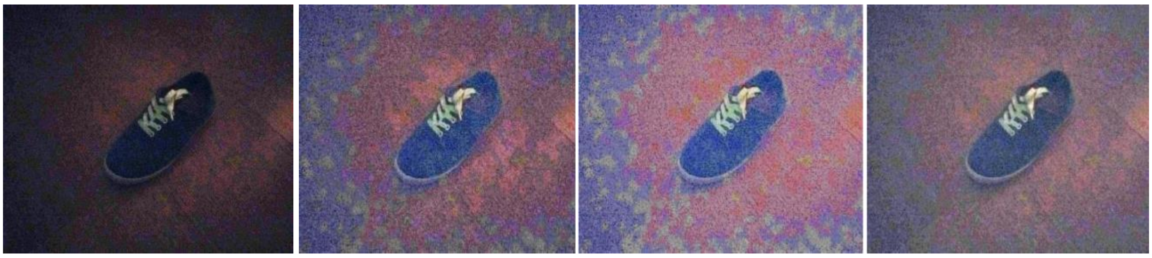
a b c d

7.



a b c d

8.



a b c d

Fig: (a) Original Image (b) Fusion (c) Adaptive (d) Bio-Fusion

Image Quality Assessment Of Fusion Based Enhancement Method:

	SSIM	MS-SSIM	BRISQUE	NIQE
IMAGE 1	0.3707	0.3929	44.4078	3.5841
IMAGE 2	0.3088	0.4073	46.5033	5.8810
IMAGE 3	0.2557	0.3562	46.7944	4.5670
IMAGE 4	0.2712	0.3832	46.2684	6.0005
IMAGE 5	0.3003	0.4150	47.4422	5.4288
IMAGE 6	0.2908	0.4079	46.5703	5.5450
IMAGE 7	0.2614	0.3594	46.5425	5.4353
IMAGE 8	0.2525	0.3652	46.4659	5.9964
AVG	0.288925	0.3858875	46.37441	5.3047625

Table 1: Quantitative performance comparison on 8 images with SSIM, MS-SSIM,BRISQUE and NIQE .

Image Quality Assessment Of Adaptive Image Enhancement Method:

	SSIM	MS-SSIM	BRISQUE	NIQE
IMAGE 1	0.4202	0.3979	42.9895	3.1397
IMAGE 2	0.3083	0.4150	46.2885	5.5954
IMAGE 3	0.2911	0.3657	47.0688	4.3016
IMAGE 4	0.2192	0.3560	45.3804	5.7750
IMAGE 5	0.2923	0.4004	47.0974	5.3155
IMAGE 6	0.3041	0.4017	46.6465	5.3521
IMAGE 7	0.2478	0.3821	46.1331	5.7877
IMAGE 8	0.2178	0.3675	45.8413	6.1149
AVG	0.287825	0.3857875	**45.9306875**	5.1727375

Table 2**:** Quantitative performance comparison on 8 images with SSIM, MS-SSIM, BRISQUE and NIQE .

Image Quality Assessment Of Multi-Exposure Fusion Framework Method:

	SSIM	**MS-SSIM**	**BRISQUE**	**NIQE**
IMAGE 1	0.3524	0.3998	43.1984	3.3304
IMAGE 2	0.3300	0.4272	46.9382	5.6557
IMAGE 3	0.3118	0.3722	45.8696	4.0835
IMAGE 4	0.2841	0.4081	46.4099	5.1754
IMAGE 5	0.3059	0.4303	47.7178	4.8266
IMAGE 6	0.2904	0.4196	46.4801	5.3150
IMAGE 7	0.2709	0.3815	47.0635	5.0990
IMAGE 8	0.2759	0.3956	47.3815	5.3002
AVG	**0.302675**	**0.4042875**	46.38375	**4.848225**

Table 3: Quantitative performance comparison on 8 images with SSIM, MS-SSIM,BRISQUE and NIQE .

From the above results, when SSIM is used to compare the above three approaches, the average scores for fusion method, adaptive method, and bio-fusion method are 0.288925, 0.287825, and 0.302675, respectively. The enhanced result is obtained in bio-fusion as SSIM delivers a better enhanced image when the score is closer to 1. When MS-SSIM is used compare the above three approaches, the average scores for fusion method, adaptive method, and bio-fusion method are 0.3858875, 0.3857875 and 0.4042875, respectively. The enhanced result is obtained in bio-fusion as MS-SSIM delivers a better enhanced image when the score is closer to 1. When BRISQUE is used to compare the above three approaches, the average scores for fusion method, adaptive method, and bio-fusion method are 46.37441, 45.9306875 and 46.38375 respectively. The enhanced result is approximately obtained in bio-fusion as BRISQUE delivers a better enhanced image when the score is closer to 0. And similarly for NIQE , the value should be lower which is better in bio fusion method. So, on the comparison of 3 methods the better enhanced result is obtained in Bio-Fusion method.

CONCLUSION

The quality of images is really important when related to any digital image processing that is involved in medical equipment or also in our daily life. Therefore, by using the enhancement methods like Adaptive image enhancement method, Fusion based enhanced method, Bio-Inspired multi-exposure fusion framework the quality of low illuminated images has been improved.The estimation of the level of improvement in the enhanced image using some existing Full Reference metrics like Structural Similarity Index Map, Multi Scale Structural Similarity Index Map, and No reference metrics like Blind/reference less Image Spatial Quality Evaluator, Naturalness Image Quality Evaluator has been done. This study may lend new ideas to future studies on the correction of images with uneven illumination. The algorithms used here are computationally efficient and straight-forward to implement and can be used as post-processing for other applications. On the comparison of 3 methods the better enhanced result is obtained in Bio-Fusion method.

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