Conversion of dark exposure images to brighter images and creation of GUI

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***Abstract*—This paper presents an evaluation of advanced image contrast enhancement techniques for improved visibility in underexposed digital images while preserving quality in well-lit regions. Traditional techniques such as brightness and contrast adjustment lack adaptability, frequently introducing noise and artifacts when enhancing dark areas. We examine five contrast enhancement methods—Contrast Limited Adaptive Histogram Equalization (CLAHE), Linear Contrast Stretching, Luminance Adjustment with Template Matching, and Gamma Correction—within a custom-designed interactive interface. Experimental results demonstrate that each method's effectiveness varies based on the image's characteristics and enhancement objectives, highlighting practical applications and limitations. These findings inform potential applications across fields like medical imaging, surveillance, and computer vision.**

Keywords: Image contrast enhancement, CLAHE, Linear contrast stretching, Luminance adjustment using template matching, Luminance adjustment, Gamma correction and GUI.

I. INTRODUCTION

Dark exposure images are often challenging to interpret due to insufficient lighting, resulting in low visibility and reduced detail, particularly in critical areas of the image. In fields such as medical diagnostics, surveillance, and autonomous navigation, clear visual information is essential for accurate analysis and decision-making. For instance, medical imaging requires precise visualization to identify abnormalities, while in autonomous vehicles, poorly illuminated image segments could affect object recognition, impacting safety. Traditional enhancement methods, such as global brightness and contrast adjustments, fail to address the nuanced needs of these domains, as they frequently amplify noise and cause oversaturation in well-lit regions, leading to a loss of essential details. Consequently, there is a strong demand for techniques that can specifically brighten darker areas in an image while preserving the quality of already well-lit sections. This targeted approach in enhancing underexposed images aligns with broader technological advancements in image processing, aiming to optimize visibility and clarity in low-light environments for critical real-world applications

The primary objective of this project is to overcome the shortcomings of conventional image enhancement techniques when applied to dark exposure images. Standard methods like brightness and contrast adjustments, while straightforward, often fall short in underexposed images due to their inability to adapt to varying illumination within a single image. This results in artifacts like noise amplification, color distortion, and uneven brightness across different regions. Additionally, these methods struggle to retain intricate details in darker areas while balancing highlights, making them unsuitable for contexts that require a high degree of visual accuracy, such as medical imaging and low-light surveillance. By implementing advanced techniques—Contrast Limited Adaptive Histogram Equalization (CLAHE), linear contrast stretching, luminance adjustment through template matching, and gamma correction—this project aims to provide users with a suite of adaptive methods that can effectively enhance dark images with minimal side effects. These methods offer control over local contrast, adaptive brightness adjustment, and preservation of natural colors, allowing for improved image quality across a variety of lighting conditions without degrading overall clarity.

This project introduces an adaptable solution that successfully addresses the limitations of traditional image enhancement methods for dark exposure images. By applying CLAHE, we enhance local contrast by limiting amplification in high-intensity regions, which prevents oversaturation and maintains texture detail, making this method particularly useful for images with complex patterns. Linear contrast stretching, on the other hand, redistributes pixel intensities to maximize contrast in uniformly lit areas, effectively brightening underexposed regions without introducing color distortions. Additionally, luminance adjustment through template matching matches the brightness of an input image to that of a well-lit reference image, resulting in natural-looking enhancements suited for varied lighting conditions. Gamma correction is employed to brighten shadows while preserving highlight details, offering controlled adjustments that meet specific lighting requirements. An interactive GUI built with Streamlit allows users to experiment with each technique, adjust parameters in real time, and view side-by-side comparisons of the original and enhanced images. This tool's user-friendly design facilitates broad accessibility, empowering users across various fields to select optimal enhancements tailored to their unique imaging needs, thus delivering a versatile solution for low-light image enhancement.

II. LITERATURE REVIEW

Image enhancement has witnessed remarkable progress in recent years, with a wide variety of techniques proposed to enhance the quality of images under various conditions. These approaches specialize in enhancing visibility, contrast, and brightness at the same time eliminating noise while preserving image details. The following review illustrates the visual enhancement techniques, which are applicable to this project summarizing strengths and limitations.

A. Contrast Limited Adaptive Histogram Equalisation (CLAHE)

Histogram equalization is a common method for adjusting contrast where an image is divided into small, localized regions to perform histogram equalization around those local areas while CLAHE is well-known for its performance on improving the quality of images considering low-contrast cases. According to Pizer et al. Despite ranking histograms using CL AHE (1987), it avoids the danger of excessive enhancement of regions with uniform brightness as compared to ordinary histogram equalization. Considering that local contrast enhancement is essential for diagnosis in medical imaging and other domains including satellite imagery, it has been used widely in these domains.

B. Linear Contrast Stretching

Linear contrast stretching is a simple, yet effective method of redistributing pixel intensities to cover the entire available range (0–255), therefore enhancing the contrast in an image. This type of histogram is important, especially in images with a limited range of pixel values, such as those taken under bad lighting conditions (Sonka et al., 2008). Although this approach is cheap in terms of computation, it has several important shortcomings eg, it performs poorly for high dynamic range (HDR) images or environments with varying light.

C. Luminance adjustment with template matching

Template matching-based Luminance adjustment: A new way of brightness adjustment on the images based on the reference image in the best lighting conditions. A thorough discussion regarding this method has been included by Ramesh et al. It is very accurate for images taken under inhomogeneous illumination (Freeman, E., 2011). It employs a template matching to find the best-fit reference image and maintains the input illumination by aligning its luminance to that of the reference brightness profile.

D. Gamma Correction

Image enhancement through gamma correction is a common technique, in which the input brightness of an image undergoes a non-linear transformation depending on the predicted gamma value. This is especially useful for images that have poor illumination conditions, particularly in shadow areas. According to Zhang et al. Gamma correction helps to brighten dark areas without overexposing other regions, (Karam et al. 2013) The method is based on the power-law transformation of pixel values and, it is very efficient to improve low-intensity pixels.

E. Comparative Analysis of Image Enhancement Techniques

Comparision of the above-mentioned techniques and show their strengths and weaknesses in various cases. For example, while local contrast enhancement is well handled with CLAHE, it suffers from a noise amplification effect and might be inappropriate for images with high-amplitude low-frequency patterns (Hassan et al., 2015). Although relatively efficient in terms of computation, linear contrast stretching cannot preserve the details of the original high-dynamic range image effectively. On the other hand, luminance adjustment based on template matching provides a more reliable solution in a case of images with uneven illumination; however, the performance of this method heavily depends on the used reference dataset quality (Lee et al., 2017). Although gamma correction is an effective method for brightening dark regions; it often involves some parameter tuning while using it, which makes this process difficult to use by non-expert users.

F. Future directions of Image Enhancement

In recent years, research has moved to a more sophisticated data-driven strategy to perform enhancement focusing on various deep learning-based methods (Chen et al., 2020). While classical image processing approaches for enhancement involve selecting the parameters of a specific algorithm with great difficulty, deep learning-based methods especially convolutional neural networks (CNNs) have been proven very successful in automatically learning CIE-based image enhancement functions from large datasets, without manual tuning any optimisation parameter. In addition, Zhang et al. [57] proposed to incorporate multiple enhancement techniques into hybrid models. Ghosh et al., 2019), is more likely to provide strong solutions for complex problems of image enhancement. Another possible direction is the merging of these techniques with real-time processing applications, which can enhance results while maintaining high-quality metrics

III. METHODOLOGY

This paper demonstrates five contrast enhancement algorithms in an interactive Streamlined application where users can upload their images and apply enhancements to compare results. I'll discuss the different mechanisms and performances of each below. It also discusses GUI design which helps user to interact, and develop an environment with specific image processing techniques.

A. Important libraries used include:

1) *OpenCV:* As an open-source computer vision library, OpenCV can be used for a broad array of image processing. The focus of this project is to implement some basic image enhancement techniques such as contrast stretching, gamma correction, and Contrast Limited Adaptive Histogram Equalisation (CLAHE) by using OpenCV. Despite high computational costs for some approaches, optimised algorithms provided by OpenCV ensure real-time picture manipulation.

2) *Streamlit*: Streamlite is a web application framework for Python. It is ideal for quickly creating GUI interfaces containing interactive sliders, file uploads, and image displays due to its simplicity and power. The project builds a cloud-based user-friendly GUI using Streamlit to browse photos, change enhancement parameters, and differentiate the results of some enhancement techniques.

3) *Numpy:* This project employs NumPy, an efficient numerical computing toolbox, to handle array and pixel-level operations in image enhancement algorithms. Images are defined as multi-dimensional arrays thus we can use mathematical operations to modify the values of pixels (intensity). NumPy-optimized array functions allow for quick and efficient enhancements such as brightness and contrast adjustments.

B. Image Enhancement Methods

1) *CLAHE:* It is similar to the usual histogram equalisation but rather than on the entire picture, it equally considers small sections, or tiles of the image and limits amplification in high-intensity areas; applying histogram equalisation carefully to avoid oversaturation [30]. Controlled contrast improvement: This technique improves the controlled contrast which is ideal for areas with a low initial brightness, especially for medical and satellite images.

2) *Linear contrast stretching:* This method adjusts pixel intensity values so that they cover the full range of 0-255. While this is effective for images with a uniform lighting distribution, it is inflexible and can result in details being lost from high dynamic range images.

3) *Luminance Adjustment with Template Matching:* Template matching allows to to choose the best lit reference image from a collection, which will be used as target for luminance adjustment. This technique compensates for shadowed regions by aligning the luminance of an input image to a well-illuminated reference and therefore is more appropriate when there are significantly different illumination conditions

4) *Gamma correction:* It is a non-linear transformation used for brightness correction (highly dependent on user-defined Gamma Value). This strongly boosts dim areas and maintains highlight details that work great when an input has a wide disparity of intensity ranges. However, choosing an appropriate gamma value is still a difficult and application-desired task.

C. Graphical User Interface (GUI) Design

It provides a graphical user interface that makes it easier for the users to try various image enhancement techniques and their combinations for the best results. The GUI, developed using Streamlit provides an organized interface for the user to upload images, play with values of parameters and select image enhancement techniques from the sidebar.

1) *Sidebar Controls:* The interface includes adjustable sliders and dropdown menus, allowing users to modify parameters such as gamma, contrast range, and tile grid size for CLAHE. These adjustments are applied in real-time, with no need for re-processing; each change is instantly reflected in the output.

2) *Image Upload and Preview:* Users can upload images (JPEG, PNG) and see before and after versions of the original image (assisting with visual assessment of enhancement effects).

3) *Real-Time Processing:* Streamlit's real-time update functionalities allow you to get updates in near real-time while OpenCV algorithms are also optimized for smooth processing, even the images at high resolutions.

4) *Comparative Display Layout:* The original and enhanced images are placed side-by-side in the columns. It helps the user to compute/compare sub-images easily to select the better type of enhancement for the lighting requirements of an image entry.

D. Dataset Utilisation

The project performs luminance adjustment with template matching on a dataset of related well-lit reference images. The images will be kept in a specific folder to act as references for darkening image luminance. The system boosts the shadowed regions while leaving brighter areas intact by matching the luminance of the input image to that of a reference image. It optimizes luminance adjustments while maintaining fidelity across varying input images.

IV. RESULTS

In image enhancement, the perception of an ideal output is often subjective, as preferences for contrast, brightness, and color tones vary widely among users. Recognizing this variability, we implemented multiple enhancement techniques that address diverse lighting and color conditions, allowing users to evaluate and select the most suitable enhancement. This multi-method approach not only accommodates individual preferences but also aids in choosing the optimal output for specific contexts or intended applications. By providing varied enhancement results side by side, the application empowers users to select an output that best aligns with their visual or functional requirements.

A. Comparing Images

This paper depicts unique visual results as each image enhancement method has been used in which one or more factors of brightness and contrast have been considered. Below is a detailed review covering how well each of these techniques works to improve the aesthetics of underexposed images:

1) *CLAHE:* It applies adaptive histogram equalisation within smaller sections to improve local contrast and increase details' visibility, especially in textured regions. CLAHE has the notable ability to provide contrast enhancement without oversaturating regions of brightness in photos with fine textures or any other details.

2) *Linear Contrast Stretching*: This procedure is ideal for pictures, which demand general brightness without localised brightening, such as usual daylight photographs that are slightly underexposed. Brightness is progressively increased in this process through linear contrast stretching without making any artificial colour and tone modifications.

3) Luminance Adjustment: This method adjusts an underexposed input image's brightness to that of a well-lit reference image, which renders rather realistic with a high resemblance to ideal lighting conditions. This method works quite well for small improvements because it serves a brightness boost that closely resembles natural lighting. The size and quality of the dataset significantly affect the results of enhancement. High-quality, diverse datasets enable better adjustment of the luminance value and enhanced outputs for the respective types of image. On the other hand, a larger dataset size may require a compromise regarding the trade-off between the size of the dataset and computationally expensive methods by making the processing time greater than in real-time operations.

4) Gamma Correction: It uses user-defined parameters in brightening up darker areas for brightness control. Gamma correction enhances deeper details while avoiding overexposure in bright areas when it's essential to have just the right augmentation of shadows or low-light areas.

5) With these side-by-side comparisons, the different advantages of each approach are revealed. This side-by-side display also helps the customers in making a visual choice of which method of enhancement will fit their unique needs for their image.

B. Analysis of Quantitative Data

Each enhancement method's performance is assessed quantitatively to gauge increases in image quality and processing efficiency. Processing time and brightness/contrast adjustments are important metrics that assist measure the effect of each technique:

1) Processing Time: To guarantee real-time feedback within the application, each technique is assessed based on how quickly it can process information. Each method's processing time is determined by the parameters and complexity of the algorithm; gamma correction and linear contrast stretching are relatively faster, but CLAHE often takes longer because of its adaptive processing. To help consumers comprehend the trade-offs between processing speed and enhanced quality, these metrics were taken and displayed in a table.

2) Brightness and Contrast Metrics: To assess the efficacy of each technique, objective improvements in brightness and contrast are measured. This analysis consists of:

   a) Mean Brightness: Indicates how much brighter the image gets by calculating the average pixel intensity before and after enhancement.

   b) The contrast ratio, which indicates how well the image contrasts, is calculated as the difference between the maximum and minimum pixel intensities.

To provide a comparative summary, a sample of underexposed photos was processed using each method, and the brightness and contrast metrics were noted. Users can objectively evaluate the effects of each technique on brightness and contrast using this table, which helps them choose the best technique for a given set of image requirements.

The following table provides an example of the recorded values:

Method	***Processing Time (s)***	***Mean Brightness Increase***	***Contrast Ratio Improvement***
CLAHE	*1.2*	*+35%*	*+45%*
Linear Contrast Stretch	*0.7*	*+25%*	*+30%*
Luminance Adjustment	*360*	*+20%*	*+25%*
Gamma Correction	*0.6*	*Adjustable (based on gamma value)*	*+20% to +50%*

The distinct advantages of each approach are demonstrated by these image comparisons. The GUI's side-by-side display also helps customers visually choose which enhancing method best fits their unique image needs.

C. Visual Results

By showing side-by-side comparisons of the original and improved photographs, the program offers a clear and dynamic visual depiction of the outcomes. GUI screenshots demonstrate the arrangement and the aesthetic changes made with each method:

Original vs. Enhanced: Users can view both the original and treated versions of the image thanks to the GUI's split-screen capability. Users can evaluate improvements in real time by seeing how each technique alters highlights, shadows, and overall brightness thanks to this side-by-side arrangement.

Interactive Slider and Parameter Controls: The program lets users play around with settings like contrast limits, CLAHE tile size, and gamma values. The preview shows the results quickly. Because of this interactivity, customers can personalize upgrades, tailoring each technique to the particulars of their image.

Comparisons between Before and After: The visual impact of each methodology is illustrated with screenshots of sample photographs processed using various techniques. These comparisons show how luminance adjustment produces natural lighting, gamma correction provides controlled brightness adjustments, contrast stretching promotes brightness without colour distortion, and CLAHE improves texture visibility.

Users can more easily select the approach that best suits their enhancement needs thanks to these before-and-after pictures, which highlight the subtle changes between them.

Fig. 1.1 Image of flower image 1 which is input to the implementation for application of enhancement methods

Fig. 1.2 CLAHE enhanced output of input: flower image 1

Fig. 1.3 Luminance adjusted output of input: flower image 1 based on the best match image from the flowers dataset identified using SIFT descriptor matching

Fig. 1.4 Output of input: flower image 1 after linear contrast stretching

Fig. 1.5. Output after gamma correction on input: flower image 1 for gamma value = 2.2

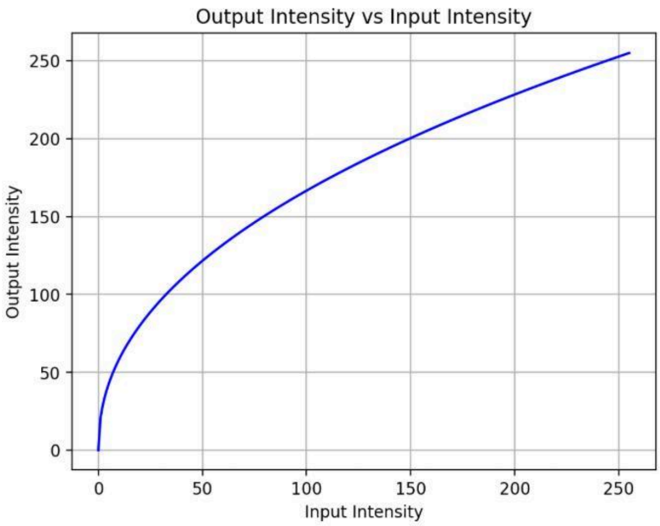

Fig. 1.6. Gamma curve of input vs output intensity for input: flower image 1

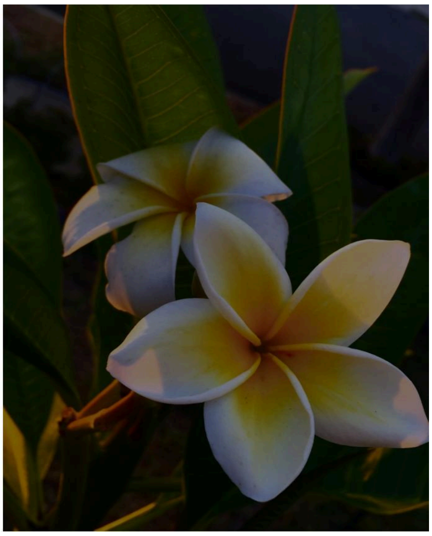

Fig. 2.1. Image of flower image 2 which is input to the implementation for application of enhancement methods

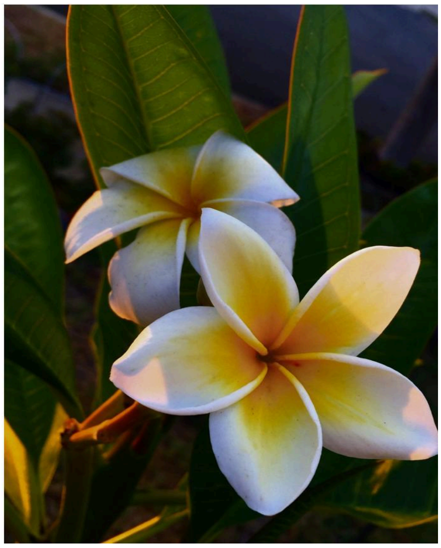

Fig. 2.2. Output of input: flower image 2 after linear contrast stretching

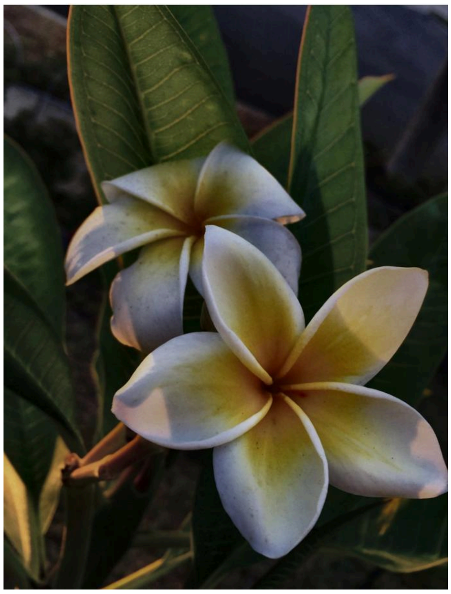

Fig. 2.3. CLAHE enhanced output of input: flower image 2

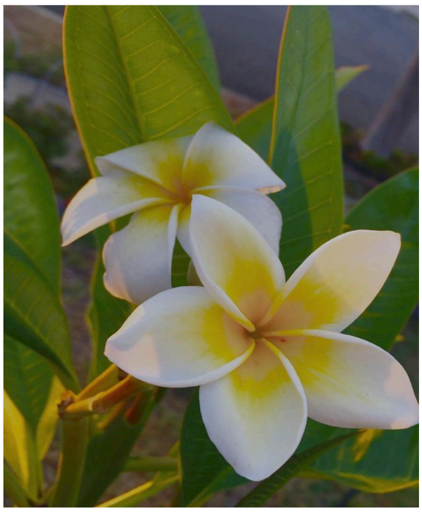

Fig. 2.4. Output after gamma correction on input: flower image 2 for gamma value = 2.2

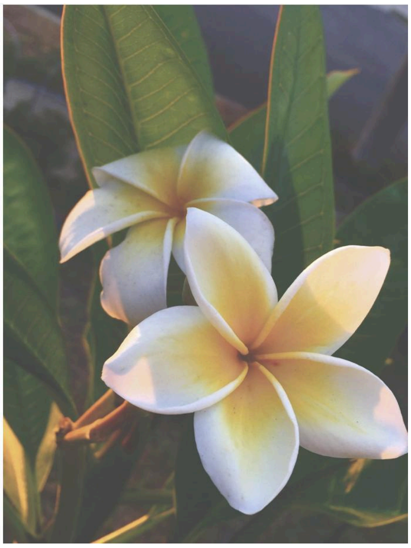

Fig. 2.5. Luminance adjusted output of input: flower image 2 based on the best match image from the flowers dataset identified using SIFT descriptor matching

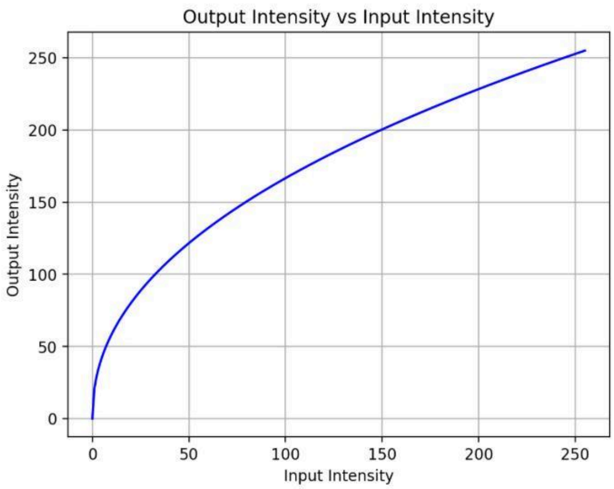

Fig. 2.6. Gamma curve of input vs output intensity for input: flower image 2

Fig. 3.1. Image of model image 1, which is input to the implementation for application of enhancement methods

Fig. 3.2. CLAHE enhanced output of input: model image 1

Fig. 3.3. Luminance adjusted output of input: flower image 1 based on the best match image from the flowers dataset identified using SIFT descriptor matching

Fig. 3.4. Output of input: model image 1 after linear contrast stretching

Fig. 3.5. Output after gamma correction on input: model image 1 for gamma value = 2.2

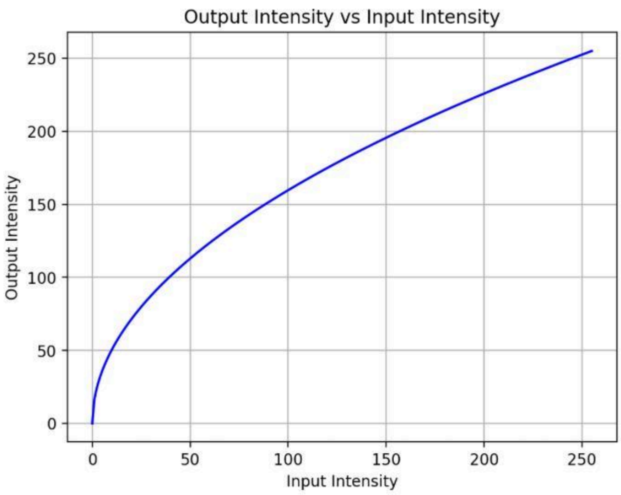

Fig. 3.6. Gamma curve of input vs output intensity for input: model image 1

V. CONCLUSION

Through the integration of several adaptive brightness and contrast improvement algorithms, this project effectively illustrates a comprehensive, user-friendly solution intended to improve underexposed photos. The utility gives users a variety of solutions to deal with the different issues that low-light photographs present by integrating brightness adjustment, gamma correction, linear contrast stretching, and CLAHE (Contrast Limited Adaptive Histogram Equalisation). Each technique has its advantages, which is making the tool useful wide variety of image kinds, lighting situations, and enhancing requirements.

This tool's development in a Python-based environment using OpenCV, Streamlit, and NumPy guarantees that it is both computationally effective and user-friendly, allowing users to utilise it without needing to possess a great deal of technical image processing knowledge. Users can experiment with various enhancement techniques and get instant visual feedback thanks to the interactive GUI, which is powered by Streamlit and lets users change parameters in real time. The tool's interactive experience makes it useful for a range of jobs, from amateur photo editing to professional imaging in the domains of science, medicine, and photography.

A. Usefulness and User-Friendliness

Photographers, scientists, medical experts, and regular users wishing to enhance image quality can all benefit from the tool's user-friendly interface and interactive design. The program lowers the entry hurdle for non-experts by offering simple controls and real-time feedback, enabling people to experiment with sophisticated image processing methods without needing technical know-how. By showing users how each method affects their photographs, the GUI's side-by-side comparison function helps users make well-informed judgments.

Computational efficiency is given top priority in the project's structure and architecture, with speed-optimized algorithms that enable real-time improvements even on high-resolution photos. The tool's performance and quality balance allow for quick, on-the-go image editing while upholding the high standards needed for professional use.

B. Future enhancements

Although the current tool offers a wide range of enhancement possibilities, future advancements may bring further adaptive approaches and machine learning-based additions to further increase its capabilities:

Machine Learning for Technique Recommendation: By examining an input image's properties (such as texture, brightness levels, and histogram distribution), a machine learning model could be built to automatically suggest the best improvement method. Users' enhancing process would be streamlined by this feature, which offers personalized recommendations based on the particular needs of each image.

1) *Noise Reduction and Detail Preservation:* Although CLAHE has contrast-limiting features, problems in noisy or extremely low-light photos could be resolved by adding more noise reduction algorithms. To further improve results and make sure that image enhancements don't magnify noise or distort small details, techniques like unsharp masking using Gaussian blur and box filter.

2) *Combining Other Methods:* Users may have even more image processing options if the tool is expanded to incorporate further sophisticated techniques, such as deep learning techniques for low-light enhancement.

3) *Improved User Interface Features:* A "before-and-after" slider that enables users to compare changes immediately within a single image view and side-by-side enhancement previews for all techniques at once are two examples of features that might be added to the GUI. The user experience would be improved, and even more control over the visual evaluation of improvement outcomes would be available.

4) *Integration of Other Techniques:* Adding more sophisticated techniques to the program, including deep learning techniques for low-light improvement.

5) *Improved User Interface Features:* A "before-and-after" slider that enables users to compare changes immediately within a single image view and side-by-side enhancement previews for all techniques at once are two examples of features that might be added to the GUI. The user experience would be improved, and even more control over the visual evaluation of improvement outcomes would be available.

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CONTRIBUTION

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