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Image Contrast Enhancement Using General Histogram Equalization and Homomorphic Filtering

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Abstract

The realm of image processing is characterized by the judicious application of mathematical operations to facilitate image transformation and refinement. By synergizing signal processing techniques, image processing can culminate in an enhanced image or the extraction of salient parameters. This research concentrates on ameliorating the contrast of images beset by low contrast, concomitantly extracting relevant image parameters. Images with subpar contrast can engender flawed outcomes in myriad disciplines, highlighting the necessity of contrast enhancement. This study introduces an innovative image processing system, conducting a comparative analysis of General Histogram Equalization and Homomorphic Filtering. The results unequivocally demonstrate the superiority of Homomorphic Filtering. The system's output manifests pronounced efficiency in elevating image contrast, heralding far-reaching implications.

Keywords: Image Contrast Enhancement, General Histogram Equalization, Homomorphic Filtering, Image Processing, Computer Vision

INTRODUCTION

Image processing is a specialized form of signal processing that utilizes images as input, yielding an enhanced image or a set of relevant characteristics as output. This dynamic field encompasses a range of techniques, including image alteration, enhancement, and compression. By converting images into digital form, image processing enables the extraction of valuable information and the creation of refined images, driving innovation across various industries and disciplines (Ravinder et al., 2016).

The image processing pipeline comprises several key stages. Initially, images are imported using optical scanners or digital photography. Subsequent stages involve image analysis and manipulation, encompassing techniques such as data compression and image enhancement. Furthermore, image processing enables the detection of patterns imperceptible to the human eye, as seen in satellite photography. Ultimately, the output stage yields an altered image or a report based on image analysis. Image processing can also be viewed as the application of mathematical operations to images, leveraging various signal processing techniques. In this context, the input is an image, such as a photograph or video frame, and the output may be an enhanced image or a set of extracted characteristics (Ravinder et al., 2016). Image enhancement techniques play a vital role in various image processing applications where image quality is crucial for human interpretation. Contrast is a critical factor in evaluating image quality, as it enables objects to be distinguishable from their surroundings. Contrast is created by the difference in luminance between adjacent surfaces, making objects perceptible through variations in color, brightness, and visual properties. Notably, the human visual system is more sensitive to contrast than absolute luminance, allowing us to perceive the world consistently despite changes in illumination. Various algorithms have been developed to enhance contrast in image processing (Muhammad et al., 2018). The field of digital image processing is experiencing rapid growth, driven by its applications in various areas of our daily lives. Digital image processing involves the analysis, manipulation, storage, and display of graphical images from various sources. Noise reduction and image enhancement are fundamental aspects of digital image processing, and are essential requirements for various applications, including digital photography, biomedical tests, and microscopic image enhancement. As a result, digital image processing plays a vital role in numerous fields, including medicine, space exploration, authentication, and automated industry inspection (Fari, 2012). Image enhancement is a technique designed to enhance the interpretability and perception of image information for human viewers. It also provides improved input for automated image processing techniques. The primary objective of image enhancement is to modify specific image attributes to make them more suitable for a particular task. This process involves altering one or more image attributes, with the choice of attributes and modification methods being task-dependent. Additionally, observer-specific factors, such as the human visual system and observer experience, introduce subjectivity into the selection of image enhancement methods. Image enhancement is applied in various contexts, including noise removal, dark image enhancement, and edge highlighting. The ultimate goal of image enhancement is to improve image quality, ensuring that the processed image surpasses the original image for specific applications or objectives (Fari, 2012). In this research, we will utilize General Histogram Equalization and Homomorphic filtering to enhance image contrast. Image quality is often compromised by noise introduced during the capturing, transmission, and acquisition processes. This degradation can result from various factors, including transmission errors, distortion during acquisition or storage, device quality issues, and interference from external sources. In medical environments, poor-quality images with inadequate contrast enhancement can lead to incorrect diagnoses by medical personnel, highlighting the need for contrast enhancement.

The inherent characteristics of physiological systems under investigation, combined with the imaging procedures employed, can further diminish contrast and detail visibility.

This research aims to develop a system that leverages a fusion of General Histogram Equalization and Homomorphic Filtering to enhance image contrast. The primary objectives of this study are:

1. To improve image quality, enabling meaningful extraction of contained information.
2. To design and implement a system that integrates the specified algorithms and techniques, facilitating a comparative analysis.
3. To evaluate the efficiency of these techniques using key performance indicators, including Peak Signal-to-Noise Ratio (PSNR), Entropy, Structural Similarity Index Measure (SSIM), and Absolute Mean Brightness Error (AMBE).

Image enhancement, a crucial preprocessing technique, is employed to mitigate noise and distortions while preserving the integrity of edges and detailed information within an image. This enables maximum utilization of the image. A significant advantage of contrast enhancement is its ability to eliminate ambiguity between different regions within an image.

The anticipated outcome of this research is to address the challenges posed by poor image quality. For instance, in medical laboratories and hospitals, images play a critical role, and distortions can lead to fatal diagnostic errors. The results of this research are expected to reduce diagnostic errors and prove valuable in businesses and organizations that rely heavily on image analysis.

The primary objective of this research is to design a system that leverages a fusion of General Histogram Equalization and Homomorphic filtering algorithms to enhance the contrast of images. This system will provide users with images that have been optimized for improved visual clarity and detail.

Definition of Terms

Image: An image is a visual representation of an object or scene, typically captured through photography or other two-dimensional mediums. It is a depiction of visual perception that resembles a physical subject.

Contrast: Contrast refers to the difference in luminance or color that distinguishes an object from its surroundings. In visual perception, contrast is determined by the variation in color and brightness between objects within the same field of view.

Enhancement: Enhancement involves improving or increasing the quality, value, or extent of something.

Homomorphic Filtering: Homomorphic filtering is a signal and image processing technique that employs nonlinear mapping to transform data into a different domain. Linear filter techniques are then applied, followed by mapping back to the original domain.

Histogram: A histogram is a graphical representation of numerical data, displayed as upright bars. The area of each bar corresponds to the frequency of the data.

Equalization: Equalization refers to the act of making something equal or uniform. In the context of image processing, equalization involves adjusting the intensity distribution of an image to achieve a more uniform representation.

Literature Review

In the real world, an image is a function of two real variables, represented as a(x,y), where 'a' denotes the amplitude or brightness of the image at coordinates (x,y). Images can be divided into sub-images or regions-of-interest (ROIs), which reflect the presence of multiple objects within an image. Sophisticated image processing systems can apply specific operations to selected regions, enabling targeted enhancements such as motion blur suppression or color rendition improvement (Ian, et al., 2004). Images can exist in two-dimensional (e.g., photographs) or three-dimensional (e.g., statues) forms. They can be captured using optical devices like cameras, mirrors, and lenses, or occur naturally through human vision or environmental phenomena. The term "image" also encompasses two-dimensional figures like maps, graphs, and paintings, which can be created manually or automatically through various techniques.

Binary Images

Binary images utilize a single bit to represent each pixel, resulting in a binary state of either on or off. This limitation confines binary images to two colors, usually black and white. The inability to represent intermediate shades of gray hinders their effectiveness in capturing photographic images (Jonathan S., 1999).

Black and white

Black and white images are comprised of pixels, each containing a single number that corresponds to the gray level at a specific location. These gray levels graduate smoothly from black to white, encompassing 256 discrete shades. Characteristically, gray-scale images possess 8-bit pixel data, facilitating the representation of 256 distinct gray levels (Jonathan S., 1999).

Color Images

Color images can be represented as a combination of three monochrome images, each corresponding to a different color band. The digital image data stores gray-level information for each spectral band, which is then combined to produce the final color image. Typically, color images are represented using the RGB model, which requires 24 bits per pixel, with 8 bits allocated to each of the three color bands (red, green, and blue) (Jonathan S., 1999).

Image Enhancement

According to Raman et al. (2010), image enhancement involves improving image interpretability and perception for human viewers, as well as providing optimized input for automated image processing techniques. The primary goal of image enhancement is to modify image attributes to suit a specific task and observer. This process involves altering one or more image attributes, with the choice of attributes and modification methods depending on the task. Observer-specific factors, such as the human visual system and experience, also influence the selection of image enhancement methods.

Image enhancement techniques can be broadly classified into two categories:

1. Spatial domain techniques, which operate directly on pixels.
2. Frequency domain techniques, which operate on the Fourier transform of an image.

Spatial domain enhancement methods:

Spatial domain techniques directly manipulate image pixels to achieve desired enhancements. Techniques such as logarithmic transforms, power law transforms, and histogram equalization modify pixel values to produce the desired outcome. Spatial domain techniques are effective for adjusting gray level values and image contrast. However, they often apply uniform enhancements to the entire image, which can lead to undesirable results. Moreover, selectively enhancing edges or specific information can be challenging with these techniques (Snehal, et al., 2012).

Poonam et al. (2014) define the spatial domain as the aggregate of pixels that compose an image. Spatial domain techniques operate directly on these pixels, applying mathematical functions to produce new images.

$g(x, y) = T[f(x, y)]$ as follows:

$$\boldsymbol{g}(\boldsymbol{x},\boldsymbol{y}) = \boldsymbol{T}[\boldsymbol{f}(\boldsymbol{x},\boldsymbol{y})] \qquad \textbf{(1)}$$

Contrast stretching: Contrast stretching is a technique employed to enhance images with low contrast. In low-contrast images, details are often obscured due to the similarity in intensity values among pixels. Contrast stretching addresses this issue by boosting the intensity of lighter pixels and diminishing the intensity of darker pixels. This technique effectively stretches the image's histogram to occupy the full dynamic range, resulting in enhanced contrast and improved image quality (Rakhi, et al., 2011).

Histogram Equalization: Histogram equalization is a technique that enhances the dynamic range of an image's histogram, resulting in improved contrast. This method redistributes the intensity values of pixels in the input image to achieve a uniform distribution of intensities in the output image. The primary objective of histogram equalization is to obtain a uniform histogram, which can be applied to the entire image or a specific region (Rakhi, et al., 2011).

Frequency domain enhancement methods

The new image $g(x, y)$ is formed by the convolution of an image $f(x, y)$ and a linear position invariant operator $h(x, y)$, i.e.:

$$\boldsymbol{g(x, y) = h(x, y) * f(x, y)} \qquad \textbf{(2)}$$

We compute the Fourier transform of the image to be enhanced, multiply the result by a filter (rather than convolve in the spatial domain), and take the inverse transform to produce the enhanced image (Poonam *et al.,*2014).

Smoothing Domain Filters: The presence of edges, noise, and sharp transitions in gray levels significantly contributes to the high-frequency components in an image. Smoothing or blurring can be achieved by attenuating a specified range of high-frequency components in the image's transform using a low-pass filter. By reducing high frequencies and preserving low frequencies, low-pass filters produce a smoothing effect in the spatial domain. This report examines three types of low-pass filters: Ideal, Gaussian, and Butterworth (Sinha, 2009).

Sharpening Domain Filters: Sharpening filters are designed to accentuate the edges in an image by emphasizing the differences between adjacent light and dark pixels. High-pass filters are particularly effective in achieving edge enhancement or detection in the spatial domain, as edges are characterized by high-frequency components. Conversely, areas with relatively constant gray levels, which are predominantly composed of low-frequency components, are suppressed. A high-pass filter can be obtained by inverting the corresponding low-pass filter. An ideal high-pass filter blocks frequencies below a certain threshold (r0) while leaving higher frequencies unchanged.

$$\boldsymbol{H_{hp}(u, v) = 1 - H_{lp}(u, v)} \qquad \textbf{(3)}$$

where $H_{hp}(u, v)$ and $H_{lp}(u, v)$ are the transfer function of highpass and lowpass filter respectively (Sinha, 2009).

Homomorphic Filtering: An image can be expressed as the product of illumination and reflectance components:

$$\boldsymbol{f}(\boldsymbol{x},\boldsymbol{y}) = \boldsymbol{i}(\boldsymbol{x},\boldsymbol{y})\boldsymbol{r}(\boldsymbol{x},\boldsymbol{y}) \qquad \textbf{(4)}$$

where $i(x,y)$ and $r(x,y)$ are illumination and reflectance components respectively (Sinha, 2009).

Image contrast enhancement algorithms

There are different types of image contrast enhancement algorithms.

Median filter

The median filter is a nonlinear signal processing technology based on statistics. The noisy value of the digital image or the sequence is replaced by the median value of the neighborhood (mask). The pixels of the mask are ranked in the order of their gray levels, and the median value of the group is stored to replace the noisy value. The median filtering output is:

$$\boldsymbol{g}(\boldsymbol{x},\boldsymbol{y}) = \boldsymbol{med}\{\boldsymbol{f}(\boldsymbol{x}-\mathbf{1},\boldsymbol{y}-\boldsymbol{j}),\boldsymbol{i},\boldsymbol{j} \in \boldsymbol{W}\} \qquad \textbf{(5)}$$

where $f(x,y)$, $g(x,y)$ are the original image and the output image respectively, W is the two-dimensional mask: the mask size is $n \times n$ (where n is commonly odd) such as 3×3, 5×5, and etc.; the mask shape may be linear, square, circular, cross, and etc **(**Youlian et al, 2012).

Wiener filter

The primary objective of the Wiener filter is to eliminate noise that has compromised a signal, utilizing a statistical approach. Unlike traditional filters, which are designed to achieve a specific frequency response, the Wiener filter employs a distinct methodology. It assumes prior knowledge of the spectral properties of both the original signal and the noise, and seeks to optimize the filter to produce an output that closely approximates the original signal (Suresh et al, 2010).

Homomorphic Filtering

Homomorphic filtering is a technique specifically designed to remove multiplicative noise with certain characteristics. One of its primary applications is correcting non-uniform illumination in images. According to the illumination-reflectance model of image formation, pixel intensity is the product of scene illumination and object reflectance. By exploiting this model, homomorphic filtering can effectively separate and correct for non-uniform illumination, resulting in enhanced image quality.

$$\boldsymbol{I(x,y) = L(x,y)\,R(x,y)} \qquad \textbf{(6)}$$

The image formation process can be represented as the product of three components: the image (I), scene illumination (L), and scene reflectance (R). Reflectance (R) is determined by the inherent properties of the scene objects, while illumination (L) is influenced by the lighting conditions at the time of image capture. To compensate for non-uniform illumination, it is essential to separate the illumination component (L) from the reflectance component (R). This can be achieved by exploiting the difference in their spatial variations, as illumination typically changes gradually across the image, whereas reflectance can change abruptly at object edges.

$$\boldsymbol{F(x,y) \;=\; I(x,y) \;*\; R(x,y)} \qquad \textbf{(7)}$$

Equation (7) cannot be used directly to operate separately on the frequency components of illumination and reflectance because the Fourier transform of the product of two functions is not separable. Instead the function can be represented as a logarithmic function wherein the product of the Fourier transform can be represented as the sum of the illumination and reflectance components as shown below:

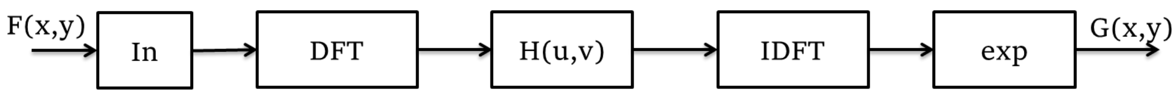
$$\boldsymbol{ln(x,y) \;=\; ln(I(x,y)) \;+\; ln(R(x,y))} \qquad \textbf{(8)}$$

The Fourier transform of equation (8) is:

$$\boldsymbol{Z(u,v) \;=\; Fi(u,v) \;+\; Fr(u,v)} \qquad \textbf{(9)}$$

(Nithya S., n,d).

According to Sanjib *et al.,* (2015) the fourier transformed signal is processed by means of a filter function H(u,v) and the resulting function is inverse fourier transformed. Finally, inverse exponential operation yields an enhanced image. This enhancement approach is termed as homomorphic filtering. The whole operation is expressed as a block diagram:



(Nithya S., n,d).

Figure 1: Block diagram of Holomorphic filtering

Histogram Equalization

A histogram is a graphical representation of an image's pixel intensity values, providing a visual interpretation of the image's frequency distribution. It serves as a data structure that stores the frequencies of all pixel intensity levels in the image. Histograms are a fundamental concept in image processing, forming the basis for numerous spatial domain processing techniques. By manipulating histograms, images can be enhanced, and contrast can be improved. Contrast is essential in image processing, as it refers to the difference in intensity between two objects in an image. Histogram equalization is a widely used technique for enhancing contrast due to its efficiency and simplicity (Great Learning Team, 2020).

Global histogram equalization (GHE):

Global Histogram Equalization (GHE) is a basic yet efficient technique for image enhancement. Although its contrast enhancement power is limited, it remains a useful tool. The method involves using the histogram of the entire input image to compute the histogram transformation function. This transformation flattens and stretches the dynamic range of the image histogram, resulting in improved overall contrast (Great Learning Team, 2020).

Local histogram equalization (LHE): While Global Histogram Equalization (GHE) has its limitations, Local Histogram Equalization (LHE) can enhance overall contrast more effectively. Nevertheless, histogram equalization techniques can significantly alter the mean brightness of an image, which may not be desirable in certain applications. To mitigate this issue, Bi-Histogram Equalization was introduced, offering a more nuanced approach to histogram equalization (Great Learning Team, 2020).

Related literature review:

Image processing encompasses various contrast enhancement algorithms, each designed to address specific challenges. Researchers have proposed numerous methods for image enhancement and restoration, with a primary focus on uniformly enhancing structures while suppressing noise and artifacts. To achieve optimal image contrast enhancement, several algorithms have been applied. The increasing demand for high-quality digital images has driven research in image processing, leading to the development of image enhancement techniques. Kumara et al. (2012) explored the application of image filtering processes to remove noise and improve image quality. Their research highlighted the importance of addressing salt and pepper noise, blurring, and other image degradation issues.

Recent studies have investigated image quality parameters, including a 2016 research paper that analyzed the necessity of developing adequate models for predicting image usability. Bora (2017) examined the importance of image enhancement techniques in color image segmentation, while Shalika et al. (2018) conducted a comparative study of image enhancement techniques using histogram equalization. Syed et al. (2019) introduced a novel technique combining homomorphic filtering and fuzzy transform to enhance image clarity. This research proposes a new method that cascades General Histogram Equalization and Homomorphic filtering for image contrast enhancement, aiming to achieve better results than previous studies.

METHODS

System Analysis

This research work employs the Waterfall model as its software development life cycle (SDLC) framework. The Waterfall model is a linear approach that divides the software development process into distinct, sequential phases. Each phase builds upon the previous one, with the output of one phase serving as the input for the next.

Fact finding

System analysis necessitates a comprehensive gathering of facts through data and information collection to inform the design of an improved system. The fact-finding process involves a variety of techniques, including sampling existing documents, research, observation, questionnaires, interviews, prototyping, and joint requirements planning. For this research, we employed two primary techniques for gathering required facts:

1. sampling existing documentation and
2. observation.

Additionally, the data used for testing the system were sourced from the internet, comprising images that facilitated the evaluation of the system's performance.

Sampling of existing documentation:

This technique involves collecting facts from existing documentation, rather than relying on human sources. In this research, the technique was employed to gather information about the existing system by reviewing relevant literature, including related works, internet resources, journals, and textbooks.

Observation:

Observation is a technique employed in this research, where the researcher conducts surveillance to gather information. The researcher studies the environment and observes how image contrast enhancement is carried out and reported, gaining valuable insights into the processes and methods used.

Analysis of the Existing System

Historically, image enhancement has been performed using manual methods, yielding limited results. The development of algorithms for contrast enhancement has significantly improved image quality. However, existing algorithms, such as General Histogram Equalization and Holomorphic Filtering, have limitations when used individually. This research aims to address these limitations by proposing a novel approach that combines these two algorithms to produce enhanced images with improved quality.

Problems of the existing system

The proposed system seeks to overcome several challenges associated with existing systems. These challenges are:

a. Histogram Equalization's lack of discernment, which can lead to increased background noise and decreased signal quality.
b. The inefficiency of output from independent systems.

The non-existence of a system that employs the proposed method for image enhancement.

Advantages of the proposed system

The proposed system boasts several key advantages over existing systems, including:

a. Streamlined workflow: By integrating two independent systems, the proposed system saves time and reduces stress.
b. Enhanced output: The proposed system generates more efficient output than existing systems.
c. Platform compatibility: The proposed system is designed to be compatible with Windows operating systems.

Output management: The proposed system enables users to save and manage outputs or results generated from the system.

Modeling of the Proposed System

The Unified Modeling Language (UML) is a graphical language used to visualize, specify, construct, and document software-intensive systems. It provides a standard way to visualize system design and serves as a blueprint for the system's architecture (Anderson, 2005). In this project, we utilized three standard UML tools: use case diagrams, activity diagrams, and dataflow diagrams to model the system.

Use Case

A use case represents the interaction between users and a system, capturing the users' goals and the system's responsibilities. The use case model outlines the system's uses and illustrates the possible courses of events that can occur. This model is primarily focused on the users, or "actors," of the system, as shown in the accompanying figure.

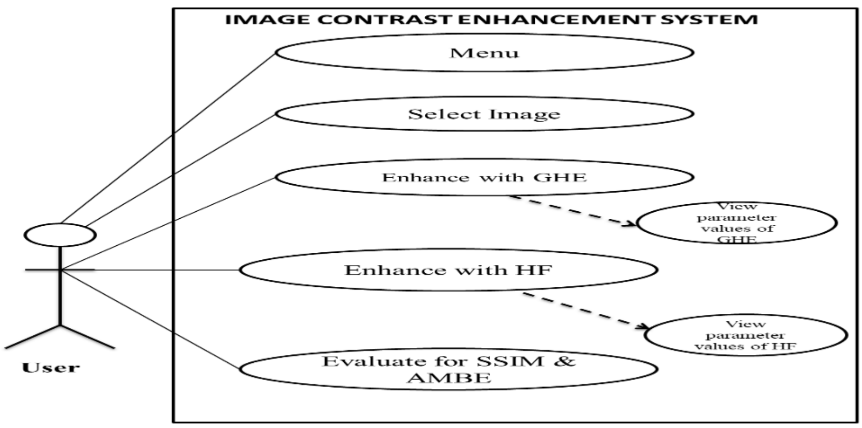


Figure 2: Use Case Diagram for the Proposed Image Enhancement system

Activity Diagram

An activity diagram is a visual representation of a series of actions or the flow of control within a system. Similar to flowcharts or data flow diagrams, activity diagrams illustrate the progression from one activity to another. They provide a graphical representation of workflows, highlighting step-by-step activities, actions, and decision points, as well as supporting choice, iteration, and concurrency.

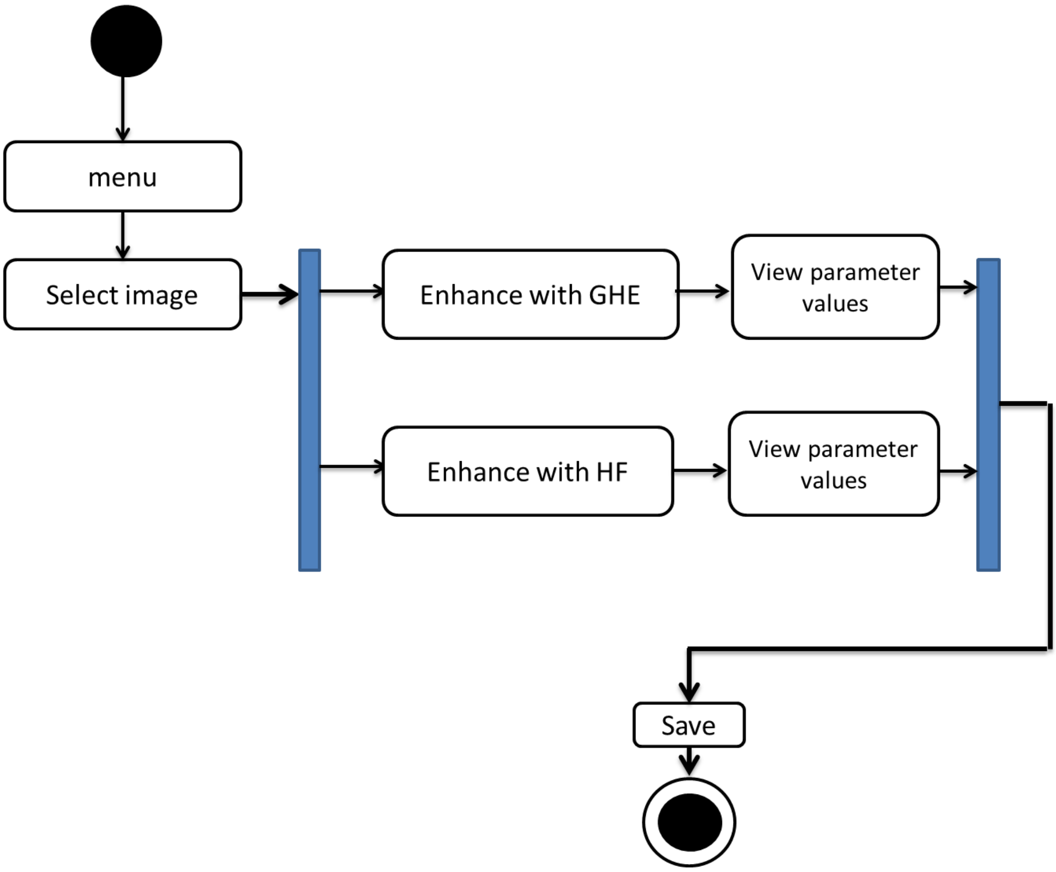


Figure 3: Activity Diagram for the Proposed Image Enhancement system

Data flow diagram (DFD)

This describes the data and the manual and machine processing performed on the data and its moves and changes from one state to the next .it also include the location were the data are placed in the system storage.

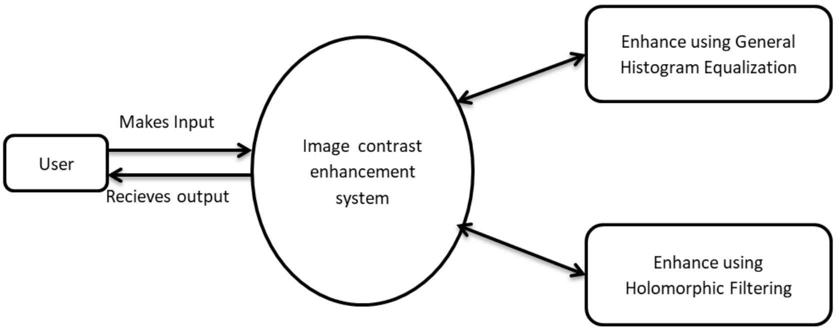


Figure 4: Dataflow Diagram for the Proposed Image enhancement system

The proposed system functions by passing the input image through two algorithms independently, generating results for each parameter. The system then enhances the image using a cascade of General Histogram Equalization and Holomorphic filtering, producing improved results. The system's components include an input menu, enhancement system, user interface, and storage system.

The input menu allows users to import images, while the enhancement system performs image enhancement using two independent systems and a combined system. The user interface facilitates human-computer interaction, displaying results and allowing users to interrogate the system.

The steps below depicts General Histogram Equalization;

It can be implemented in four stages.

Step-1: Compute probability density function (pdf) of the input image.

$$pdf(i) = \frac{number\ of\ pixels\ with\ intensity\ i}{total\ number\ of\ pixels\ in\ image\ x}\ 0< I < L \quad \textbf{(10)}$$

where L is highest intensity value.

Step-2: Calculate cumulative distribution function (cdf) considering pdf(i) for each pixel.

$$cdf(i) = \sum_{k=0}^{L-1} pdf(i) \quad \textbf{(11)}$$

Step-3: Get the value of the pixels by multiplying cdf(i) by L-1 and then round it to the nearest integer.

$$\boldsymbol{s_{k=}\ \sum_{k=0}^{L-1}(L-1) * pdf(i)} \quad \textbf{(12)}$$

Step-4: Add new image to the input image to get the enhanced output image.

$$E = s_k + x \quad \textbf{(13)}$$

E = enhanced output image

x = input image

These steps depicts Homomorphic filtering;

It implemented using five stages, as stated as follows:

STAGE 1: Take a natural logarithm of both sides to decouple $i(x,y)$ and $r(x,y)$ components

$$z(x, y) = \ln i(x, y) + \ln r(x, y) \quad (14)$$

STAGE 2: Use the Fourier transform to transform the image into frequency domain:

$$\Im\{z(x, y)\} = \Im\{\ln i(x, y)\} + \Im\{\ln r(x, y)\} \quad (15)$$

or

$$Z(u, v) = F_i(u, v) + F_r(u, v) \quad (16)$$

where $F_i(u,v)$ and $F_r\,(u,v)$ are the Fourier transforms of $\ln i(x,y)$ and $\ln r(x,y)$ respectively.

STAGE 3: High pass the $Z(u,v)$ by means of a filter function $H(u,v)$ in frequency domain, and get a filtered version $S(u,v)$ as the following:

$$S(u, v) = H(u, v)Z(u, v) = H(u, v)F_i(u, v) + H(u, v)F_r(u, v) \quad (17)$$

STAGE 4: Take an inverse Fourier transform to get the filtered image in the spatial domain:

$$s(x, y) = \Im^{-1}\{S(u, v)\} = \Im^{-1}\{H(u, v)F_i(u, v) + H(u, v)F_r(u, v)\} \quad (18)$$

STAGE 5: The filtered enhanced image $g(x,y)$ can be obtained by using the following equations:

$$g(x, y) = \exp\{s(x, y)\} \quad (19)$$

The flow of the system is divided into three sections, the General Histogram Equalization system, the Homomorphic filtering system and the cascade of General Histogram Equalization and Homomorphic filtering respectively.

System Design

This phase involves the creation of a detailed technical blueprint and specification, which serves as a guide for implementing the final solution. This blueprint outlines the system's requirements, including inputs, outputs, and processes, providing a comprehensive framework for implementation.

Input Design

Input design is a critical phase that involves selecting the most effective strategy for capturing and entering data into the computer system accurately and at the right time. A well-designed input process ensures that all necessary data is captured. In this system, the input data required is image files. The system provides a user-friendly interface that enables users to select and upload image files.

Table 1: Input design of the system

S/N	File name	Datatype	Description
1	Image name	Blob	System receives image

Output design

Output design refers to the reports generated by the system, providing users with essential information. As the primary source of information, output design plays a crucial role in system design. During system testing, output design communicates important milestones and any issues that arise. For this proposed system, two output designs have been developed: Personal Details Output Design and Result Output Design.

Table 2: Output design of the system

S/N	Filename	Datatype	Description
1	Image name	Blob	Display enhanced image

Functional Decomposition Diagram (FDD)

Functional decomposition is a systematic analysis method that breaks down complex processes into their individual components. This approach enables a deeper understanding and more effective management of large and intricate processes. As illustrated in Figure 4, functional decomposition has been applied to the proposed system, providing a clear and detailed representation of its constituent elements.

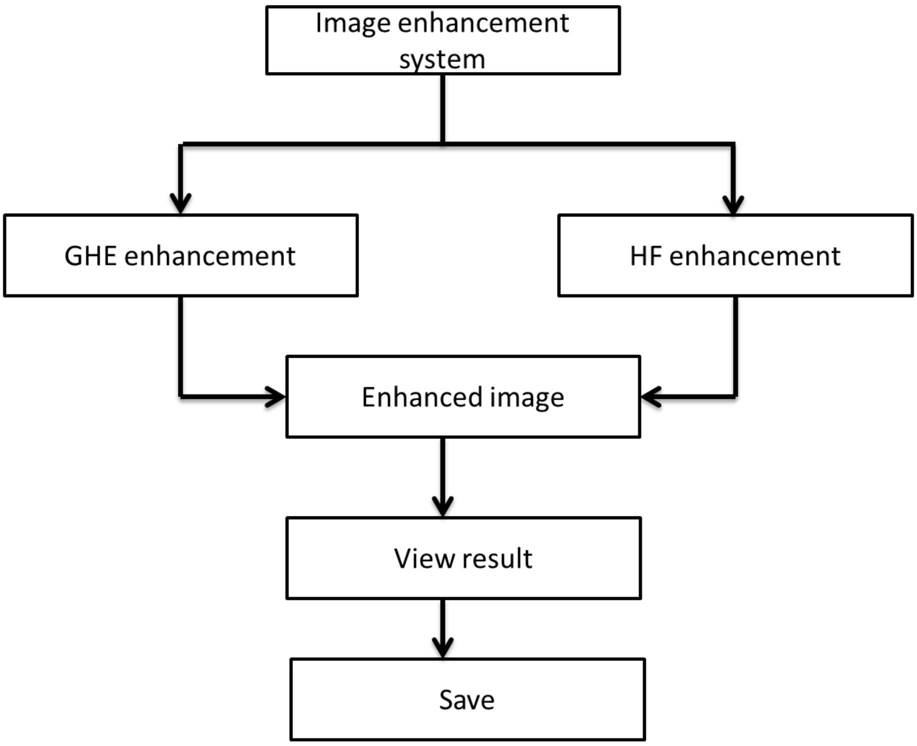


Figure 5: Functional Decomposition Diagram (FDD)

Program Design

Program design is the process of transforming a specification of requirements into a detailed description of the program itself. This phase is a critical component of the software life cycle, where design decisions are made to ensure the program meets the specified requirements. The output of this phase is a comprehensive program description that serves as the foundation for implementation.

Program Architecture (Flowchart)

A flowchart is a visual representation of a workflow or process, illustrating the sequence of steps required to accomplish a task. It is a diagrammatic depiction of an algorithm, showcasing a step-by-step approach to solving a problem. The flowchart utilizes boxes of various types to represent individual steps, which are then connected by arrows to illustrate their order. Figure 6 presents a flowchart of the proposed system, providing a clear and concise visual representation of its workflow.

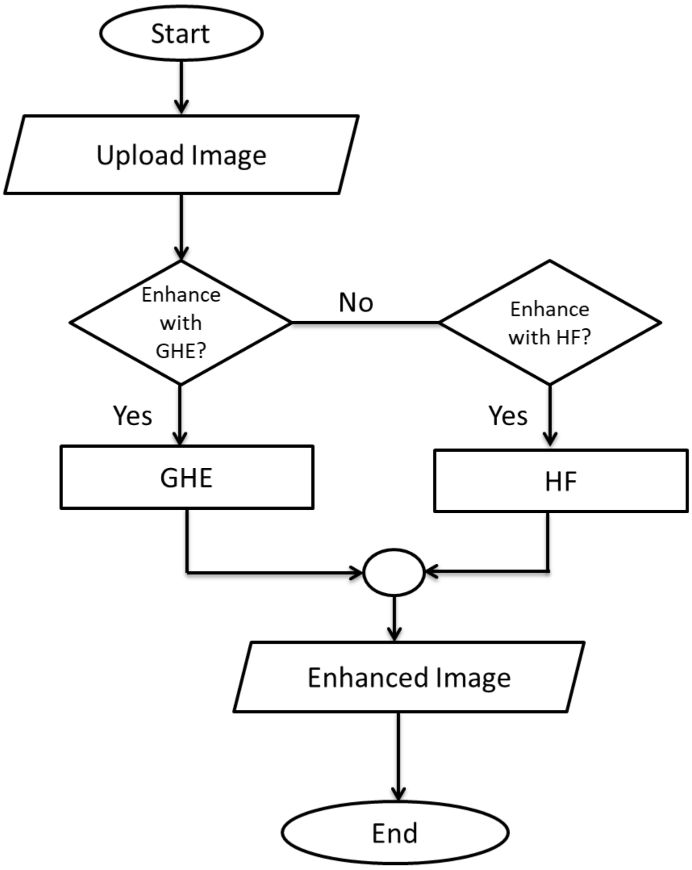


Figure 6: Program flow chart for the proposed Image enhancement system

Programming tools/Choice of programming

Python is the main programming language used for this study. It is a great option for many reasons. Here are some reasons why the language is deemed right for this project:

a. **Easy to Read, Learn and Write:** Python is a high-level programming language that has English-like syntax. This makes it easier to read and understand the code.

b. **Improved Productivity:** Python is a very productive language. Due to the simplicity of Python, developers can focus on solving the problem. They don't need to spend too much time in understanding the syntax or behavior of the programming language.

c. **Interpreted language:** Python is an interpreted language which means that Python directly **executes the code** line by line.

d. **Free and Open-source:** You can download the source code, modify it and even distribute your version of Python.

e. **Vast Libraries support:** The standard library of Python is huge; you can find almost all the functions needed for your task. So, you don't have to depend on external libraries.

Metrics for evaluating the developed system

a. Peak Signal-to-Noise Ratio (PSNR)
b. Entropy
c. Structural Similarity Index Measure (SSIM)
d. Absolute Mean Brightness Error (AMBE)

Peak Signal-to-Noise Ratio (PSNR)

According to Umme et al. (2019), the Peak Signal-to-Noise Ratio (PSNR) is a metric used to evaluate the quality of an image or video by calculating the ratio of the maximum possible signal power to the power of the distorting noise. This ratio is typically expressed in decibels (dB) and is calculated using the logarithmic term of the decibel scale, due to the wide dynamic range of signals. The PSNR is a widely used technique for assessing the quality of image and video compression codecs.Given a reference image *f* and a test image *g*, both of size M×N, the PSNR between *f* and *g* is defined by:

$$PSNR(f,g) = 10\log_{10}\left(\frac{225^2}{MSE(f,g)}\right) \quad (20)$$

Where

$$MSE(f,g) = \frac{1}{M}\sum_{i=1}^{M}\sum_{j=1}^{N}(f_y - g_y)^2 \quad (21)$$

Entropy:

Entropy is used to measure the richness of details in the output images. It is defined as:

$$Entropy[p] = -\sum_{k=0}^{L-1} p(X_k)\log_{10} p(X_k) \quad (22)$$

Higher entropy value indicates richness of details.

Structural Similarity Index Measure (SSIM)

According to Umme *et al.,* (2019), it is a method for predicting the perceived quality of digital television and cinematic pictures, as well as other kinds of digital images and videos. SSIM is used for measuring the similarity between two images. The SSIM index is a full reference metric; in other words, the measurement or prediction of image quality is based on an initial uncompressed or distortion-free image as reference.

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad (23)$$

Absolute Mean Brightness Error (AMBE)

Absolute Mean Brightness Error is defined as absolute difference between the mean input and output image. It is defined as:

$$AMBE = E_x - E_y. \quad (24)$$

where x and y are input and output image. E_x represents mean of input image and E_y represents the mean of output image. Small AMBE value indicates that brightness is preserved.

Implementation

Program Implementation

The implementation stage of software development is where the system specification is transformed into a functional reality. This stage involves bringing the new system to life, making it operational and usable. For the proposed system, Python was chosen as the implementation language due to its extensive libraries and support for artificial intelligence-based solutions, which streamline development and save time. The implementation process utilized Visual Studio Code as the text editor, along with the Python application interface.

Program Testing

Program testing is a systematic evaluation process aimed at determining whether a system or its components meet the specified requirements. In essence, testing involves executing a system to identify gaps, errors, or missing requirements that deviate from the actual requirements. The primary objective of testing is to detect software failures, enabling the discovery and correction of defects. Additionally, testing validates and verifies that a computer program meets business and user requirements, functions as expected, and produces the desired end result.

Table 3: Test Cases

S/N	Test Case Id	Test Objectives	Expected Outcome
1	IET1	Test if system can enhance image using GHE.	System output should be able to display enhanced image using GHE.
2	IET2	Test if system can enhance image using Homomorphic Filtering.	System output should be able to display enhanced image using HF.
3	IET4	Test if system can calculate PSNR, Entropy, AMBE & SSIM of the image.	System should be able to output values for PSNR, Entropy, AMBE & SSIM of the image.

RESULTS

During the system testing, the software was executed using a set of test cases as specified in Table 3 and the output of programs for the test cases was evaluated to determine if the program is performing as specified. The results of the test carried out are shown in Table 4.

Table 4: Test Result

S/N	Test Case Id	Test Objectives	Results	References
1	IET1	Test if system can enhance image using GHE	During the system testing, the system was able to enhance image using GHE	See Figure 6
2	IET2	Test if system can enhance image using Homomorphic Filtering	During the system testing, the system was able to enhance image using Homomorphic Filtering	See Figure 7
3	IET4	Test if system can calculate PSNR, Entropy, AMBE & SSIM of the image.	During the system testing, the system was able to generate values for PSNR, Entropy, AMBE & SSIM of the image.	See Table 5, Table 6, Table 7, Table 8.

Table 5: Entropy

Image name	GHE	HF
Austine	6.3982	0.0044
EmmySax	0.0222	0.0601
LOBO	0.0056	0.0355
FrBon	0.0589	0.1151
OmaNeibo	0.0675	0.1229
Average	1.3105	0.0676

Table 6: Peak Signal to Noise Ratio (PSNR)

Image name	GHE	HF
Austine	3.3978	8.6629
EmmySax	3.7325	9.4468
LOBO	4.2380	10.3260
FrBon	2.0949	5.5656
OmaNeibo	2.3721	6.6541
Average	3.1671	8.1311

Table 7: Structural Similarity Index Measure (SSIM)

Image name	GHE	HF
Austine	0.5400	1.0000
EmmySax	0.5100	0.7800
LOBO	0.4200	0.8800
FrBon	0.5500	0.9700
OmaNeibo	0.4900	0.9100
Average	0.5020	0.9080

Table 8: Absolute Mean Brightness Error (AMBE)

Image name	GHE	HF
Austine	8991.20	17.64
EmmySax	11348.91	2718.38
LOBO	9264.30	765.14
FrBon	18283.76	78.12
OmaNeibo	12476.07	1051.85
Average	12072.85	926.23

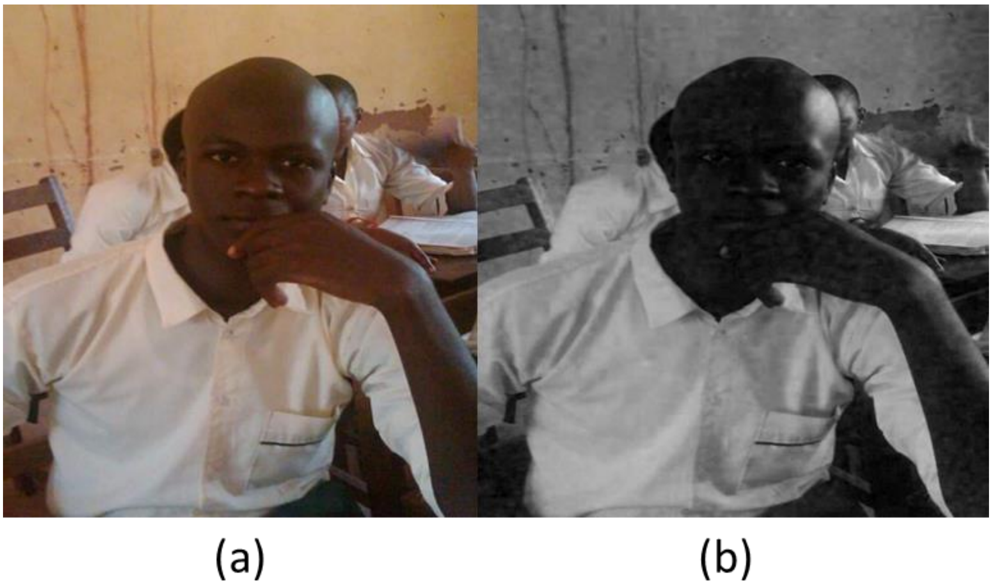


Figure 7: (a) Original Image (b) Enhanced Image using General Histogram Equalization

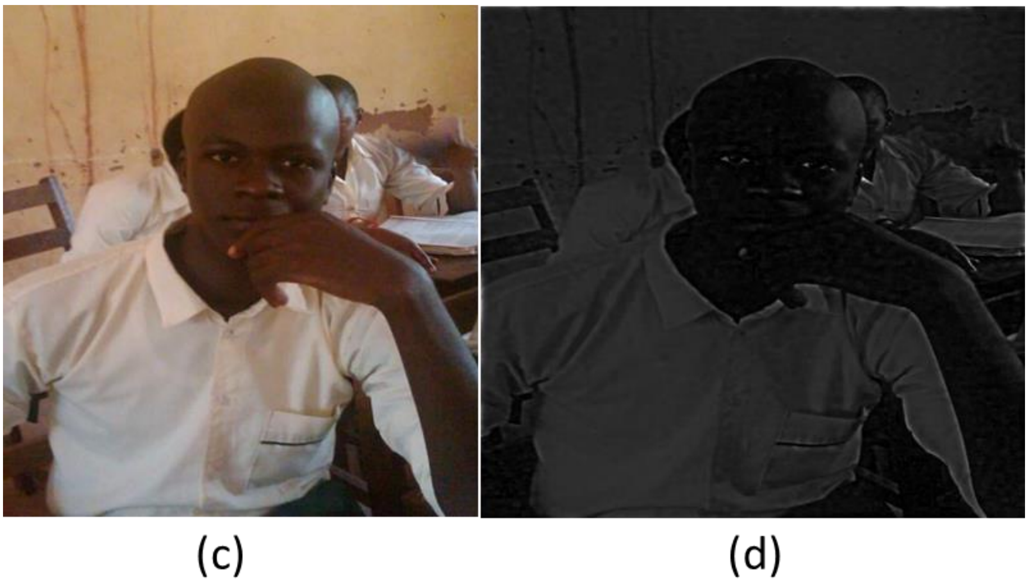


Figure 8: (c) Original Image (d) Enhanced Image using Homomorphic Filtering

Program Interfaces/ Test Case Results

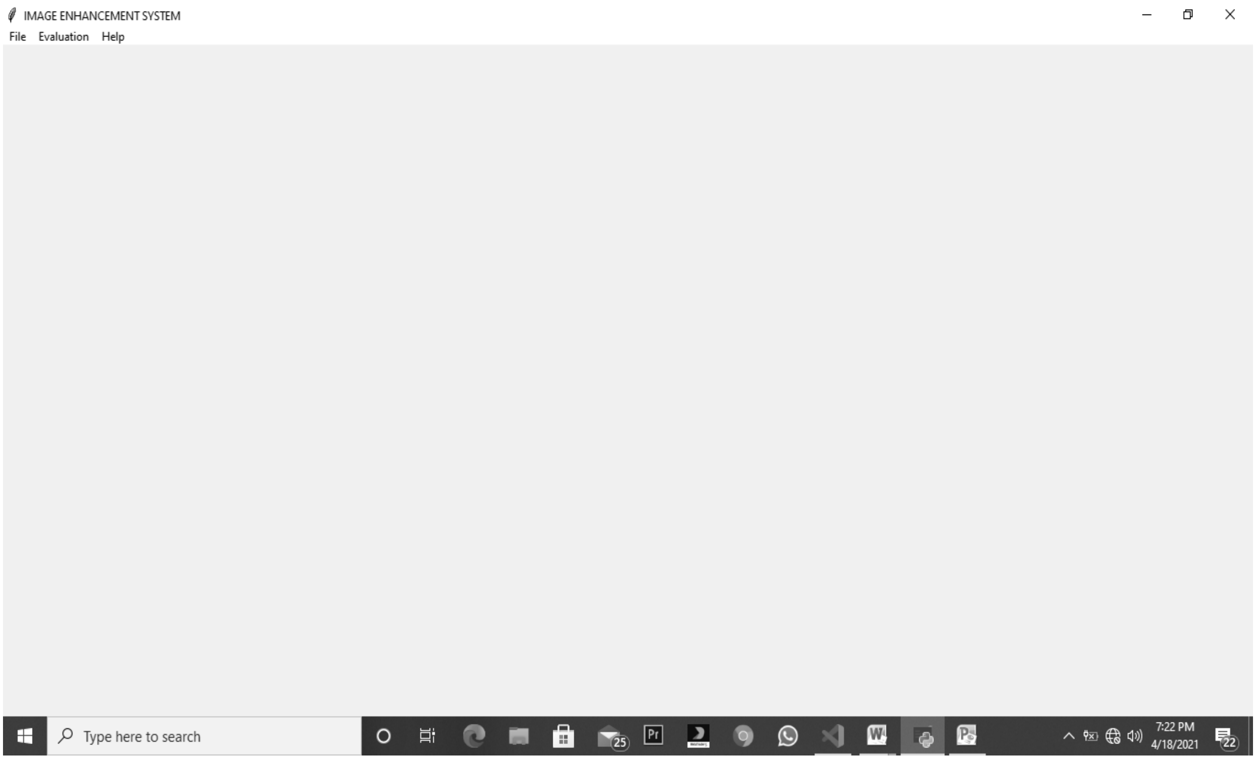


Figure 9: Home Screen.

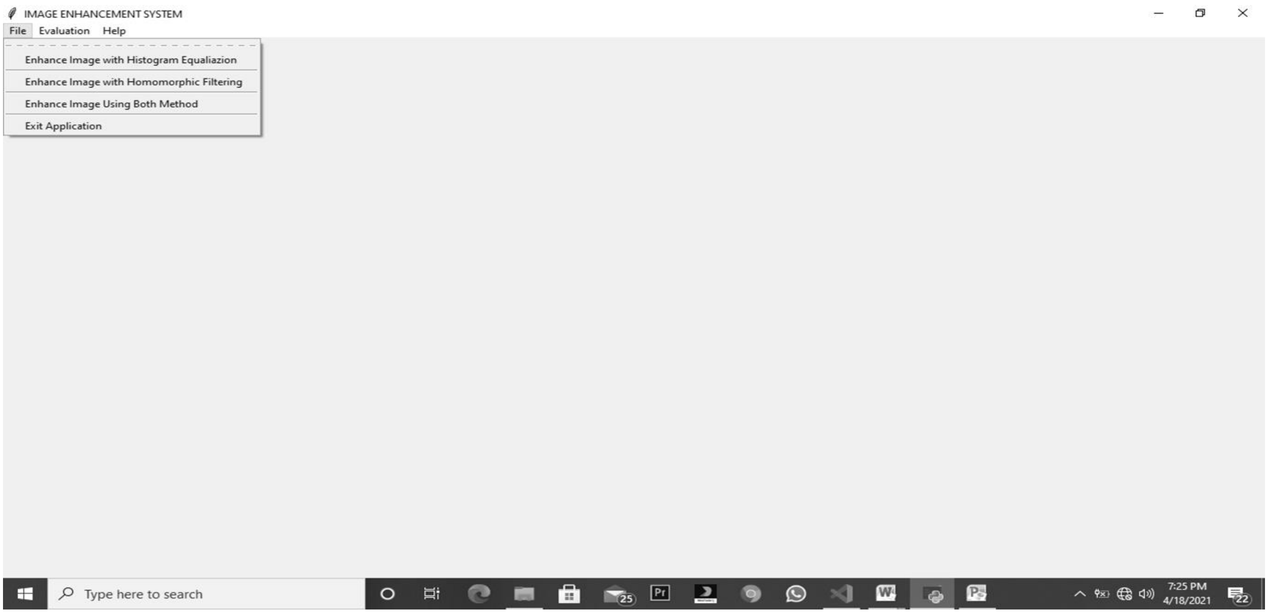


Figure 10: Menu.

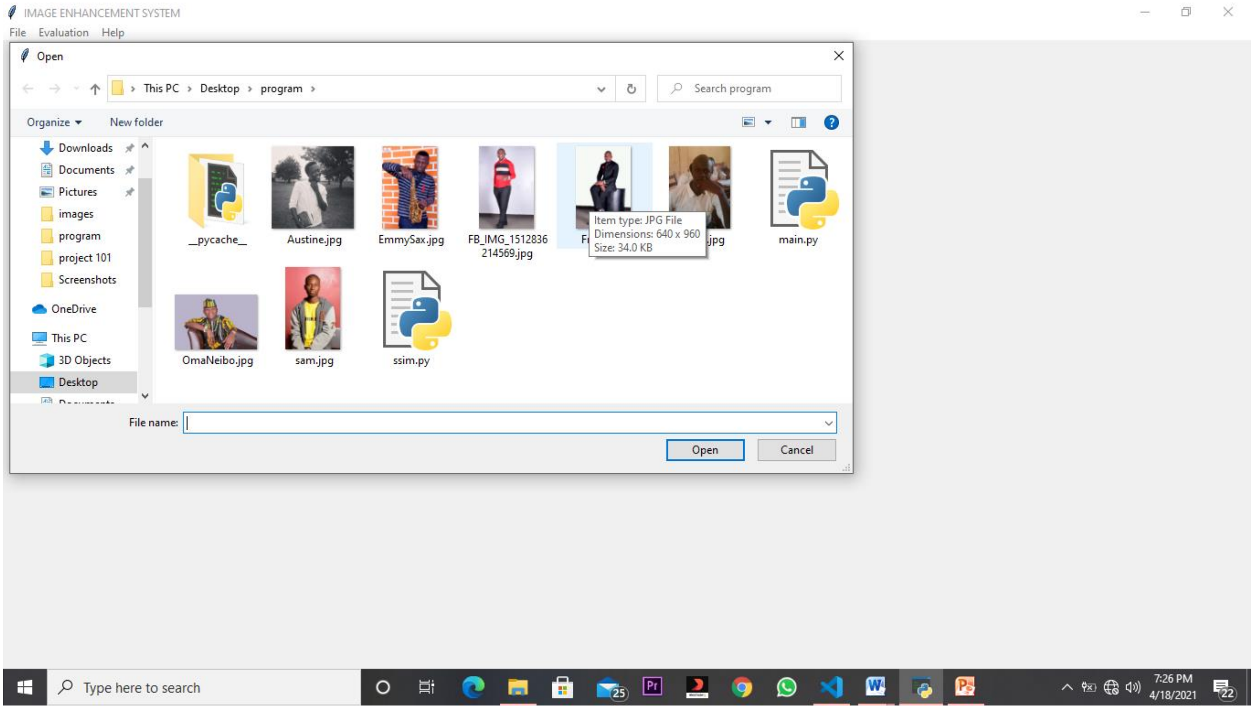


Figure 11: Selection of image file.

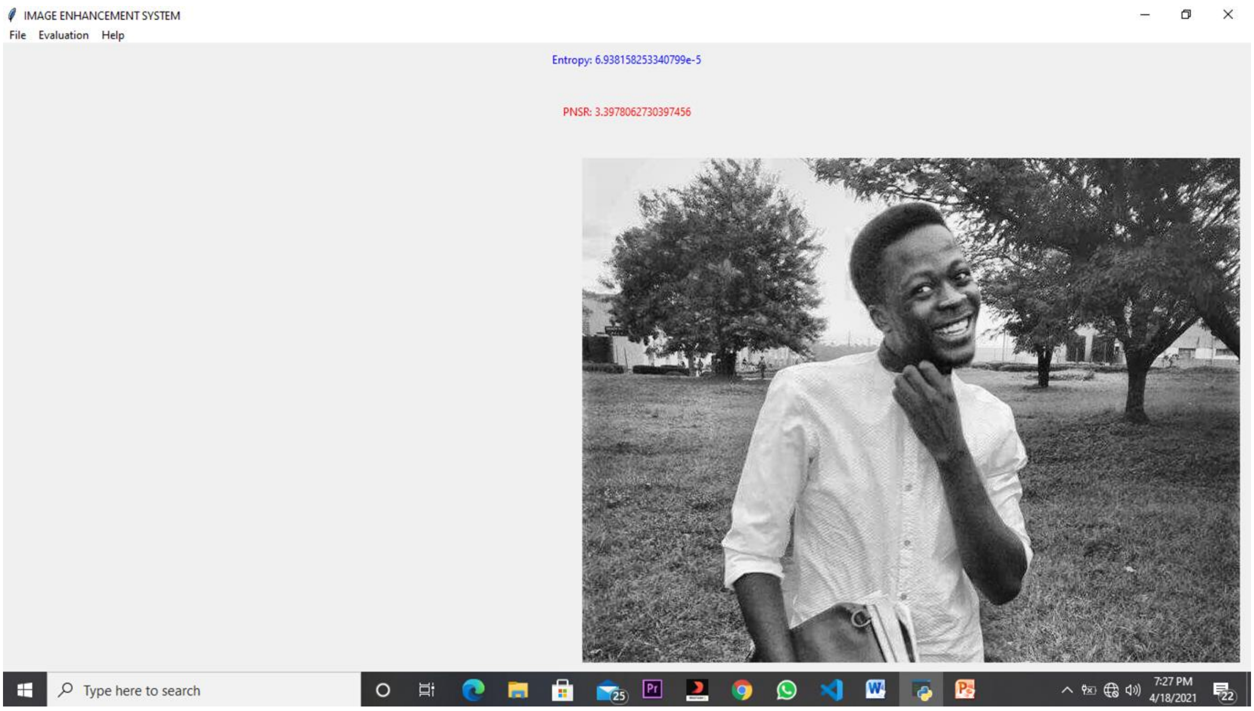


Figure 12: Enhanced Image.

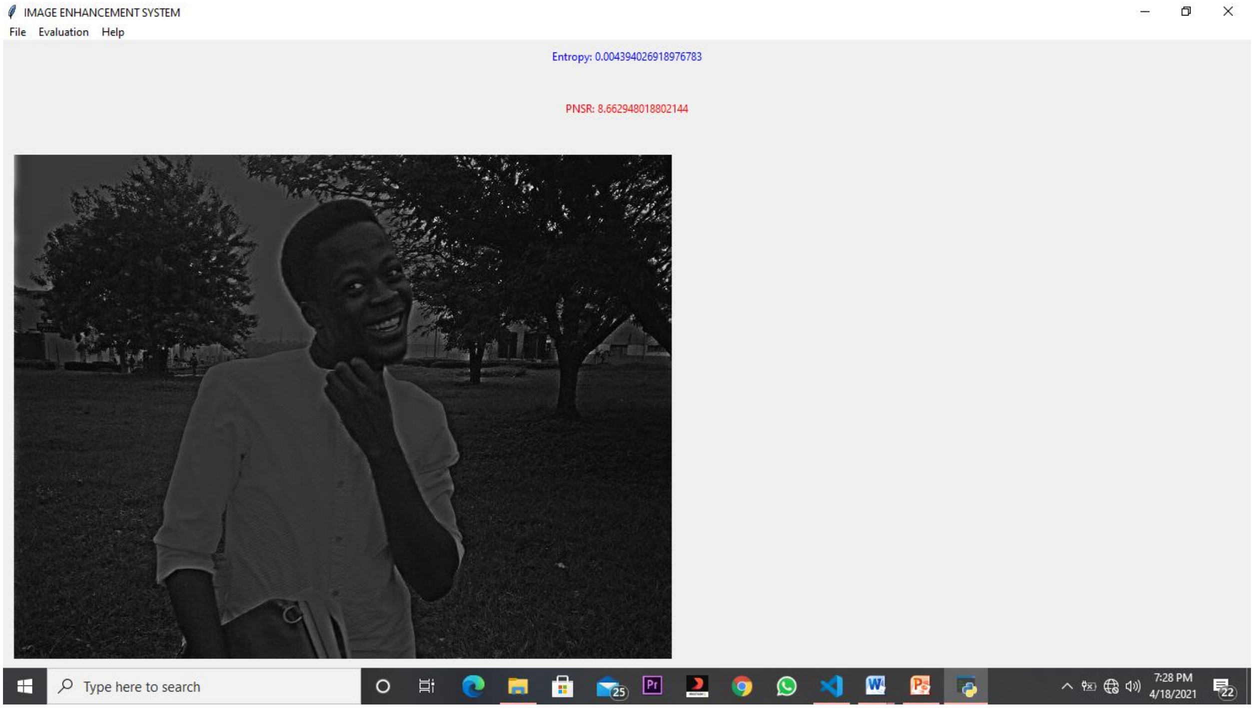


Figure 13: Enhanced Image.

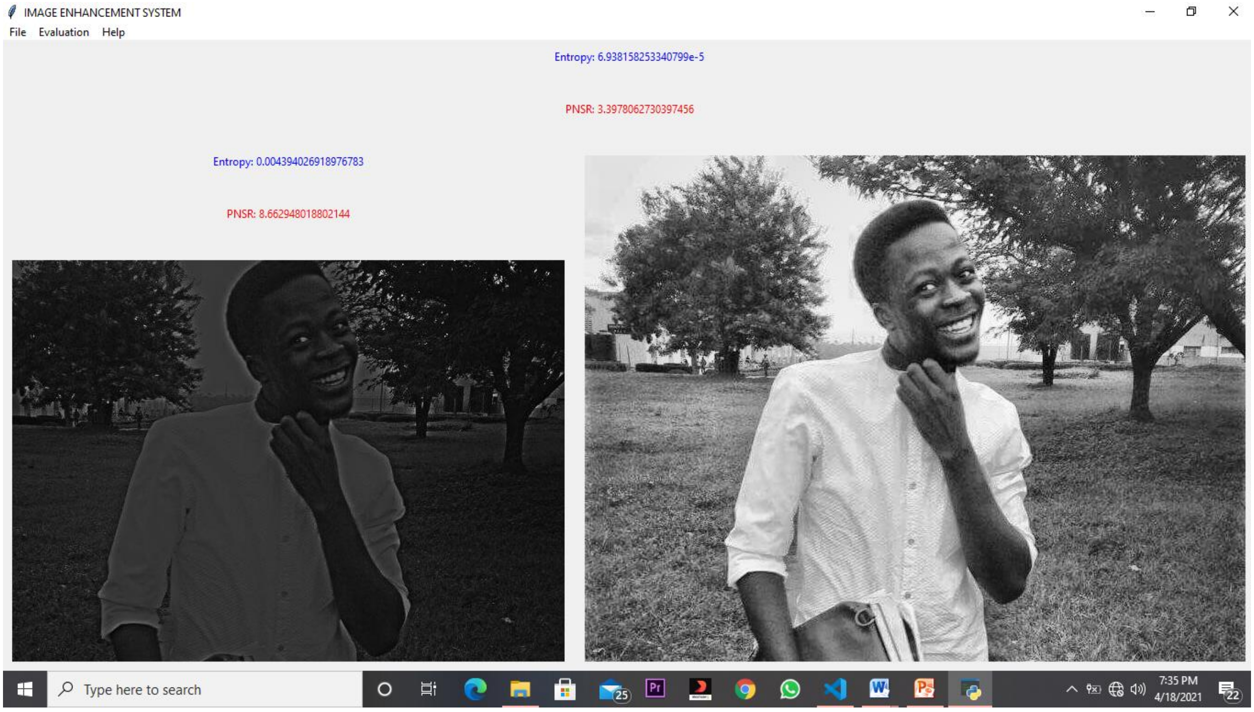


Figure 14: Enhanced Images

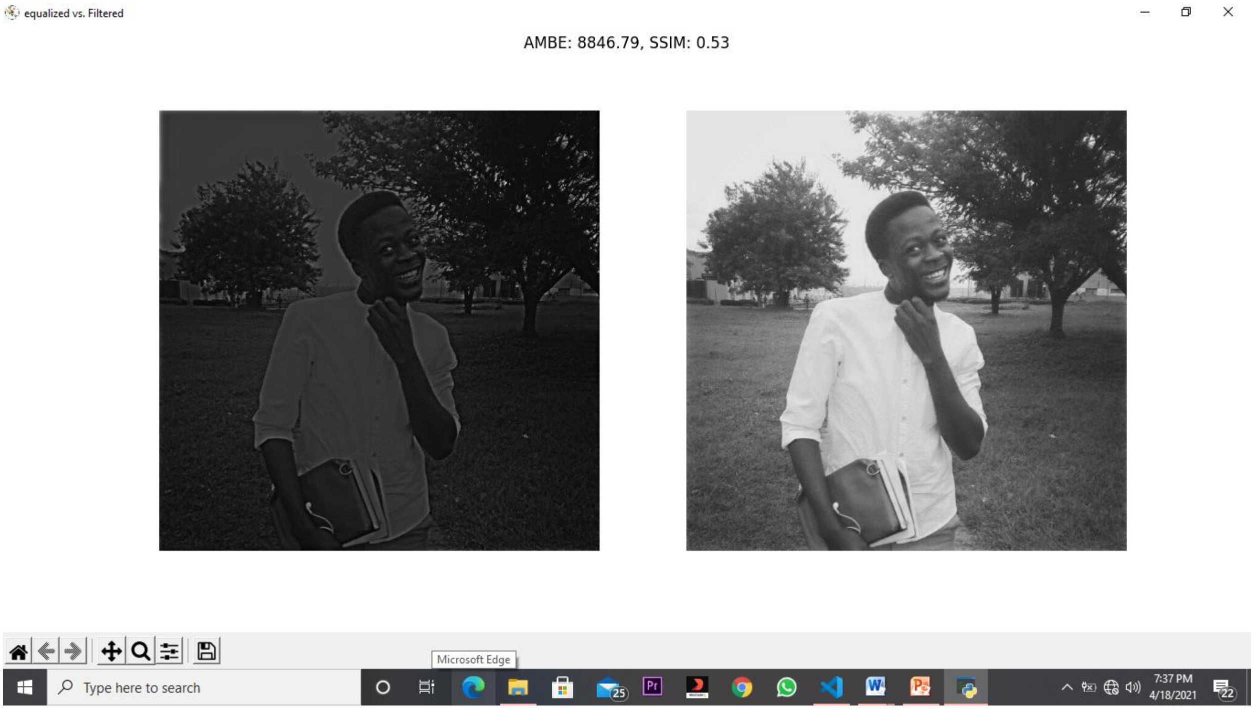


Figure 15: Image AMBE and SSIM.

DISCUSSION

The outcome of the proposed Image Enhancement System's implementation is a significant improvement in image quality. Test results (tables 1-4) demonstrate the system's capability to enhance contrast using dual methods, as well as its ability to process and output essential image quality parameters. These findings confirm that the system meets its specified requirements.

System Requirements

System requirements encompass the essential specifications that a computer must meet to facilitate the seamless execution of software or hardware applications. These requirements ensure that the system can support the application, enabling efficient and smooth operation. Failing to meet these requirements can lead to installation issues or suboptimal performance. This research work involves the hardware and the software requirements.

Hardware Requirements: For effective and efficient operation of the Image enhancement system, the following are the minimum hardware requirement specification;

a. **Memory:** 4GB RAM and above
b. **Processor** 800MHz or 1.5GHz
c. **Hard Disk (HDD):** 100GB and above

d. Enhanced Keyboard.
e. Monitor(Screen)

Software Requirements: The minimum software requirement specification for implementing the system includes;

a. Python IDE (Integrated Development Environment)
b. Visual Studio Code Editor
c. A window 8 or higher version of windows OS for faster processing

User documentation

Documentation is a critical phase of the System Development Life Cycle (SDLC), serving as a means of communication, instruction, and record-keeping for reference and operational purposes. System documentation encompasses a comprehensive range of documents, from requirements specifications to final acceptance test plans, providing a detailed description of the system. This documentation is essential for understanding and maintaining the program, facilitating easy tracking of the system's progress and explanation of its workings.

System Changeover

System changeover is the process of transitioning from an old system to a new one. This involves replacing the existing system with the newly developed information system. During this stage, the old system is phased out, making way for the adoption of the new system. In this research, a parallel changeover approach was employed.

A Parallel Change over: The parallel changeover method involves operating both the old and new information systems simultaneously for a predetermined period. This allows for a side-by-side comparison until the new system is fully adopted, and the old system is phased out. A significant advantage of this approach is that any initial failures of the new system will not disrupt user operations, as they can continue to use the existing system until they become familiar with the new one.

CONCLUSION

After series of testing and experimentations the experimental result of this work has shown that Homomorphic Filtering is able to enhance a low contrast image better compared to

General Histogram Equalization based on the values of the parameters obtained from the developed system. Such image qualities whose contrast has been enhanced say in medical environment can now lead doctors and other medical personnel to now carry out the right diagnosis on their patients. In terms of correctness of results, the image contrast enhancement system using Homomorphic Filtering is more certain in enhancing low contrast images based on the gathered data. . In terms of the adequacy of contents of the system, the image contrast enhancement system provides more in-depth information about the image.

In terms of user-friendliness and usefulness users find it attractive and an interesting application based on the futures and of the system.

Recommendation

In the future, we would like anyone to continue in this field and increase the enhancement accuracy of the system developed. Further research should develop a system that may output a more clear view of images. The researcher hereby recommends doctors, other medical personnel and researchers to adopt the system for image enhancement.

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