Minor Project - 1

Title: SharpView – Low Light Image Enhancement using C++

Presented by:

R2142220936 – Sagar Thapliyal

R2142221156 – Aviral Khanna

R2142220937 – Saksham Siwach

R2142220447 – Arshdeep Kaur

Mentored by:

Mrs. Gaytri

Content

Introduction

Technical Concepts (Algorithms) used:

1. **Image Processing –** We will be first collecting low light images from different online as well as physical sources. As we are aware that, normally, the images exist in either JPEG format or PNG format, so we will be processing the images to convert them into PPM format. Then, after enhancing the image, we will be again converting the PPM images to JPEG format.
2. **Image Enhancement –** Starting this with smoothening, which will reduce excessive Gaussian Noise from the image. Then, Gamma Correction, will be implemented to enhance contrast and brightness of the image. Then, we will be using Gray-World Color Correction and Balance Adjustment technique to enhance the color intensities of the image, to achieve the final output.
3. **Continuous Feedback** – We will be asking for the user, whether he/she wants to enhance the image further or not. If user wants to enhance further, the brightness, contrast and shadows of the image gets adjusted and new refined image is produced as an output. On the other hand, if user denies for further improvements in the image, the code execution ends.

Motivation

- **<u>Real-Life Use Case</u>** – Can be used to enhance images captured at night or in low-light conditions, which can be very beneficial in terms of safety and security.
- **<u>For Low-End Devices</u>** – As it uses no external libraries or dependencies, it has very less overhead on the machine and eventually it has a fast processing pipeline. As a result, can also be used easily on a low end device.
- **<u>Deeper Understanding of Image Enhancement Concepts</u>** – As we are implementing each and every technique from scratch, we will gradually develop a greater understanding of each technique and it would benefit us in longer run to work on other image related projects.

Problem Statement

Many digital images, particularly those captured in suboptimal conditions such as low-light, suffer from quality issues such as low brightness, inadequate contrast, noise, and blurriness. Such degraded images are less useful for analysis or viewing. While there are existing solutions and number of applications to enhance images, they often rely on external libraries, which may not be practical for lightweight applications or environments with limited resources.

Area of application

This project can be beneficial in multiple areas like:

- **Surveillance Systems:** In enhancing low-light images captured by security cameras to improve visibility and ultimately contributing in increased safety.
- **Medical Imaging:** In enhancing images for better diagnosis and analysis which are blurry/ not clear due to some reasons or captured under low-light conditions.
- **Mobile Photography:** Improving quality of the pictures that are distorted or captured in poor lighting. Especially useful for low-end devices.
- **Forensics:** Enhancing pictures from crime scenes, which have been taken in dim light conditions, ultimately revealing more details.
- **Remote Sensing:** Improving images captured from drones or satellites during night operations.

Dataset and input format

- **Dataset:** ExDark Dataset, which is the collection of low-light images from various sources, is being used during the testing phase of the project. Otherwise, real-time image data will be used.
- **Input Format:** The input images should be in the PPM format, containing raw RGB pixel data, which can be processed directly by the C++ program without using external libraries.

Literature Review

Cite Related work

Histogram Equalization Methods: Global Histogram Equalization (GHE) enhances the contrast but suffers from over-amplification of the high-frequency gray levels, and thus the problem is reduced by Local Histogram Equalization (LHE), which introduces noise and over enhancement.

Dynamic Histogram Equalization (DHE): DHE divides the histogram into sub-histograms to balance the contrast, especially in medical and satellite imaging.

Recursive Mean-Separate Histogram Equalization (RMSHE): RMSHE has been found to effectively enhance underwater and low light images but introduces noise. One of the Learning-based approach, Deep learning performs far better than traditional methods such as Retinex, but suffers from bias due to training data.

DiffLight: CVPRW 2024 : This one of the latest models which uses a diffusion process for noise removal and a UNet Transformer for improving low-light images. The model does very well in nighttime photography.

Inference from Literature

Limitations of Classical Techniques: While there is a clear benefit of the classical techniques in relation to PPM that is introduced by Global Histogram Equalization, over-amplification is one of the greatest challenges imposed by this technique, similar to the artifacts which may arise during simple pixel-level manipulations in the PPM image processing pipeline.

Advanced Techniques for Contrast Enhancement: Advanced techniques like Contrast Adjustment in this regard have better control with lesser side effects, similar to the contrast adjustment capabilities with the PPM image enhancement project.

Pixel-Level Processing: Gaussian Smoothing and Gamma Correction make the images noise-free and increase brightness which are two main reasons for poor image qualities.

Application to Image Processing: In this project, the brightness of an image is improved and the contrast adjustment and shadow enhancement are also done to better use them in PPM format for viewing. Utilization of Gaussian Smoothing and other pixel-level manipulations in this project reflects the advanced techniques that are used in the modern image enhancement in order to achieve better visual outcome.

SWOT Analysis:

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S — STRENGTHS

- ✓ Machine Independent
- ✓ Versatility
- ✓ Less Overhead on Machine
- ✓ Accurate Computation

W — WEAKNESSES

- ✓ Error Prone
- ✓ Tough Parameter Tuning
- ✓ High Complexity
- ✓ Basic UI

O — OPPORTUNITIES

- ✓ Improvements via Feedback Loops
- ✓ Potential for Real-Time Applications
- ✓ Educational Value

T — THREATS

- ✓ Competition with other libraries
- ✓ Maintenance Challenge
- ✓ Technology Shifts

Objective

Main Objective

To design and implement a lightweight and robust C++ program that performs a variety of image enhancement techniques, which aims to improve the visual quality of degraded or distorted images(containing noise/ blur) captured in low-light conditions, that too without using any external libraries, and ensuring it is suitable for low-end devices (resource-constrained systems).

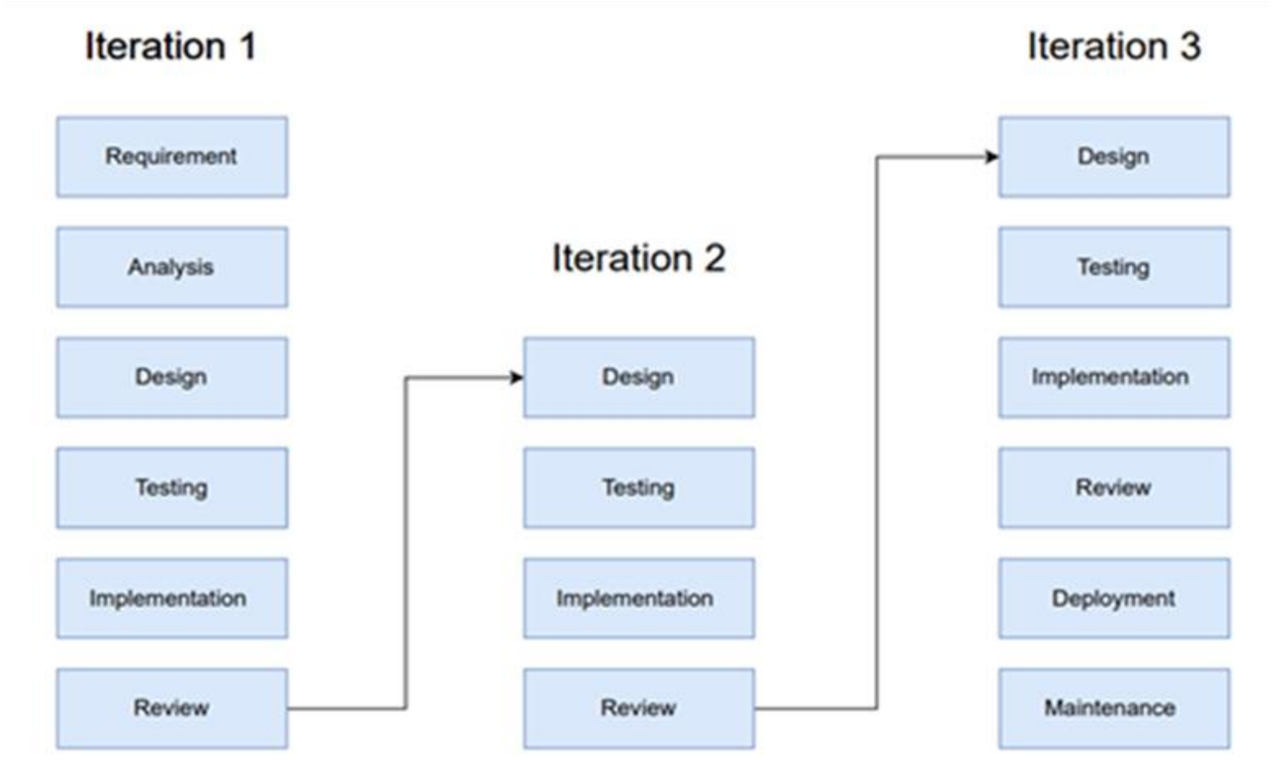
Sub Objective

- Enhance the quality of low-quality or noisy security footage to identify the subjects in the image, such as a likely thief.
- Designs algorithms capable of enhancing specific regions in images which could be face or movement, for better recognition.
- Optimizing the enhancement pipeline such that it would allow for real-time processing for enabling real-time detection of suspicious activity or people.

Methodology

Reference Software model

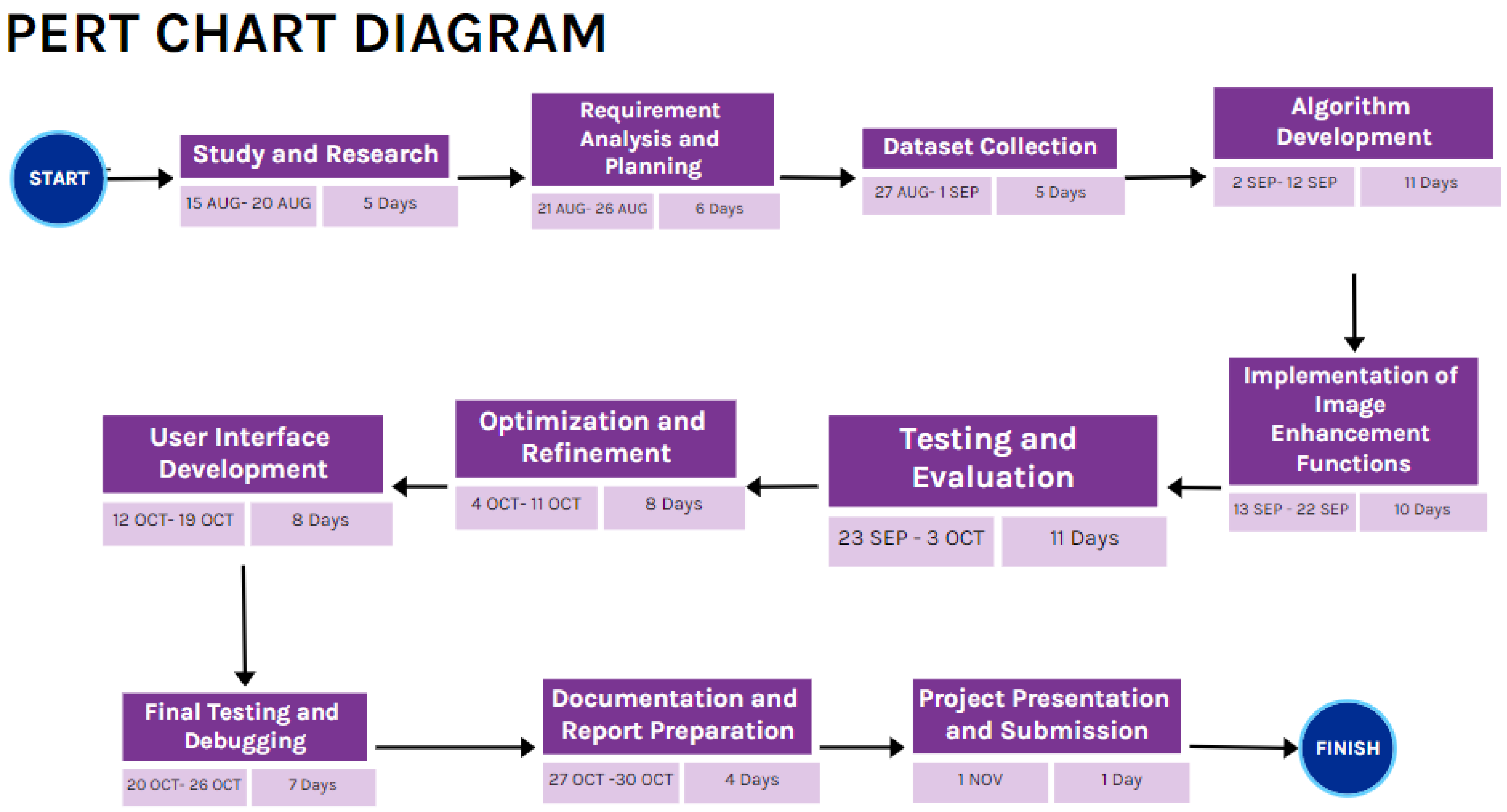
We will be using the Iterative Model to implement our project. The iterative method begins with a basic implementation of a limited set of software requirements in the iterative model, then repeatedly improves the evolving versions until the entire system is built and prepared for deployment.



Steps

1. **Initial Noise Reduction (Gaussian Smoothening):** In this case to extract the region of interest we will be using renowned smoothing filter, Gaussian filter to remove noise from the image.
2. **Gamma Correction:** Gamma Correction will be used to modify brightness and local contrast of the image, simultaneously.
3. **Gray World Color Correction:** For color balance, the channels are tweaked so as to equalize color means, thus creating a naturally colored image.
4. **Continuous Feedback Mechanism:** For improvements, user feedback is taken and accordingly further enhancement is done. If user doesn’t need to enhance more, the code execution stops.
5. **Iterative Refinement:** Last but another enhancement technique that we have adopted is the utilization of Quality metrics (PSNR, SSIM) to enhance the quality of the image to better results.

Timeline



PERT CHART DIAGRAM
START
Study and Research
15 AUG- 20 AUG
5 Days
Requirement Analysis and Planning
21 AUG- 26 AUG
6 Days
Dataset Collection
27 AUG- 1 SEP
5 Days
Algorithm Development
2 SEP- 12 SEP
11 Days
Implementation of Image Enhancement Functions
13 SEP - 22 SEP
10 Days
Testing and Evaluation
23 SEP - 3 OCT
11 Days
Optimization and Refinement
4 OCT- 11 OCT
8 Days
User Interface Development
12 OCT- 19 OCT
8 Days
Final Testing and Debugging
20 OCT- 26 OCT
7 Days
Documentation and Report Preparation
27 OCT -30 OCT
4 Days
Project Presentation and Submission
1 NOV
1 Day
FINISH

Deliverable of Each Step/ Phase

INPUT IMAGE

Gaussian Smoothening

Gamma Correction

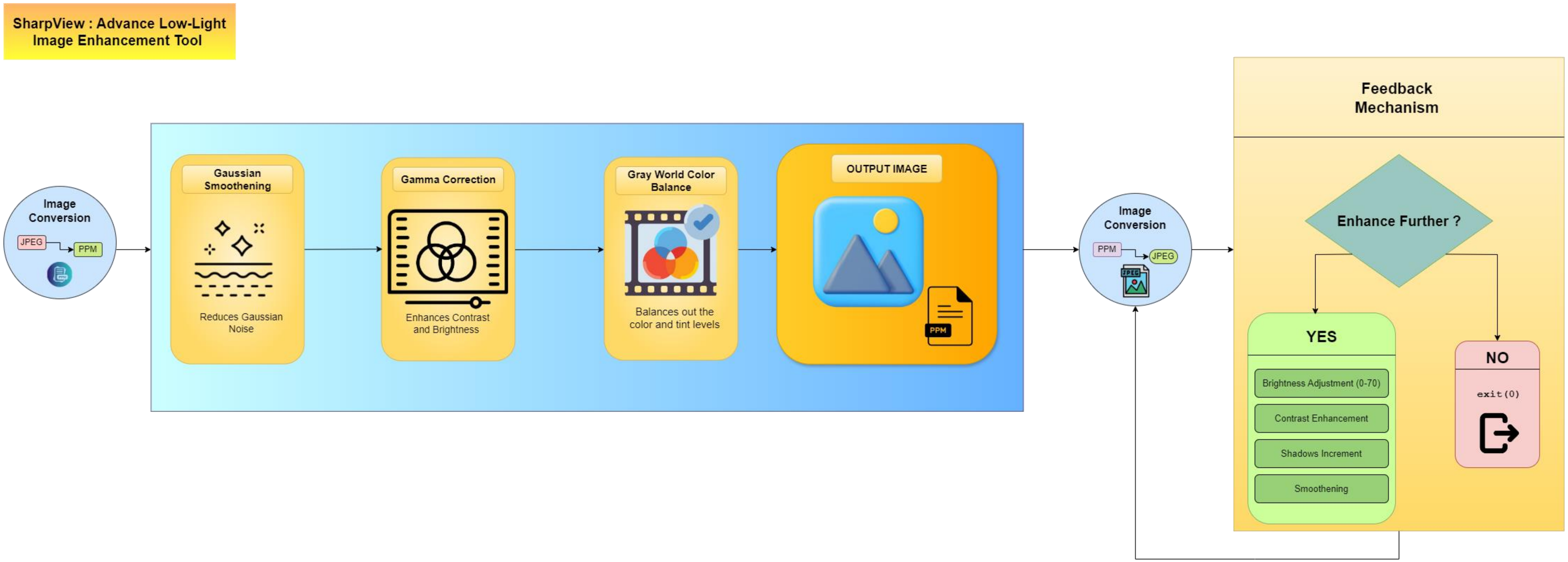
Gray World Color Correction

Working Model

Requirement Analysis (Link of SRS)

https://drive.google.com/file/d/1s31IgkIYVAj7Q8vYRS8Y_4ZVrgWz8FSg/view?usp=sharing

Technical Diagram



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Working Module

BEFORE

AFTER

Real World Application

BEFORE

AFTER

Real World Application

- The project has made significant strides by successfully implementing file operations that allow us to read and write PPM files seamlessly. We developed a pixel structure using dynamic arrays, which efficiently stores RGB values and ensures smooth data handling throughout the process.

- To enhance image quality, we applied Gaussian smoothing to reduce noise and implemented gamma correction to adjust brightness and contrast. To balance out color intensities, we have applied Gray World Color Balance. These techniques have greatly improved the visual clarity of the images. Looking ahead, we plan to introduce features that will give users greater control over brightness, contrast, and shadow adjustments, further enhancing the user experience.

- We also established an intuitive workflow that makes it easy for users to input PPM files, apply necessary corrections, and save their processed images effortlessly. Additionally, we built robust error handling into the system to manage any file errors, unsupported formats, and gamma validation, ensuring a smoother overall operation.

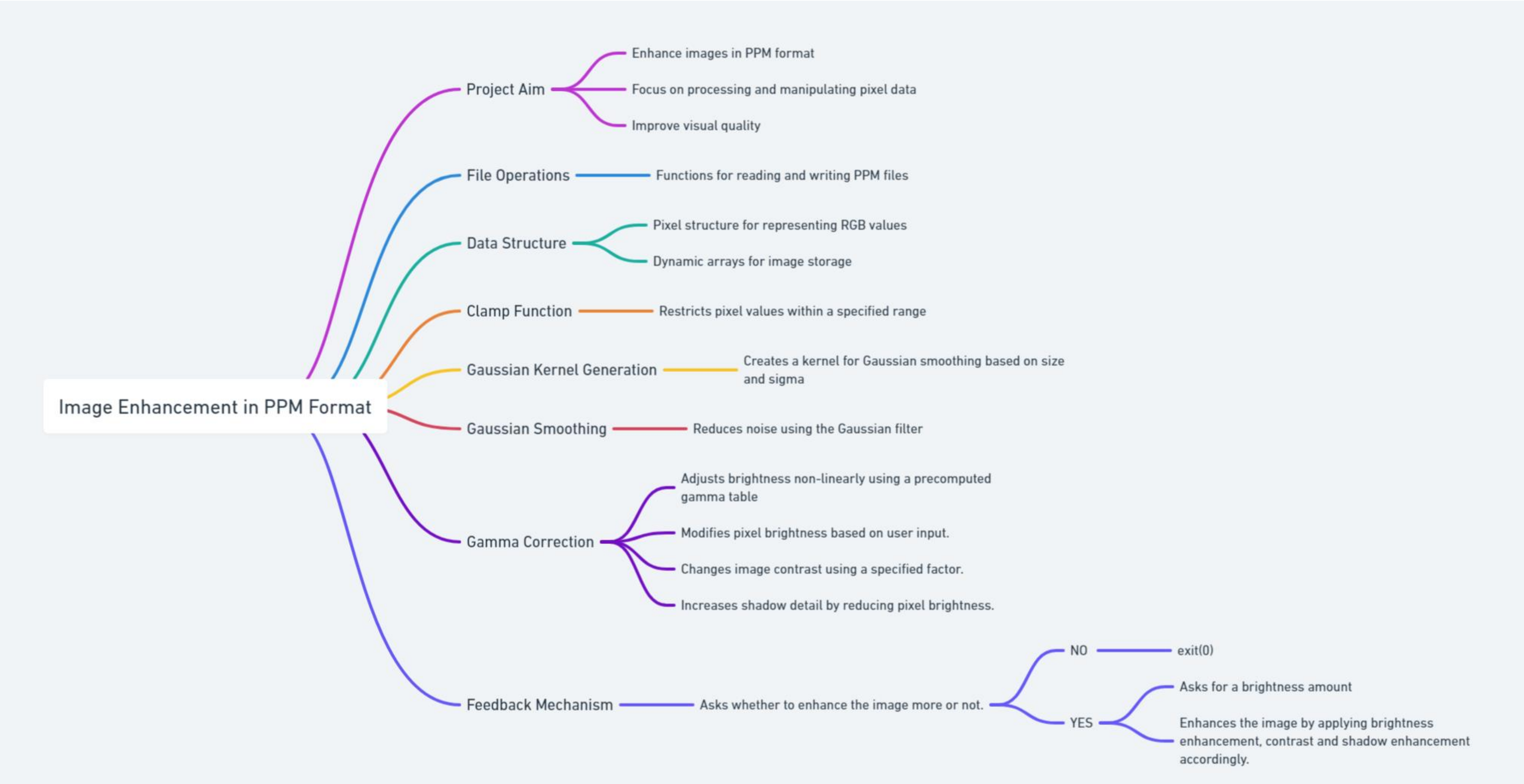
Image Enhancement in PPM Format
Project Aim
Enhance images in PPM format
Focus on processing and manipulating pixel data
Improve visual quality
File Operations
Functions for reading and writing PPM files
Data Structure
Pixel structure for representing RGB values
Dynamic arrays for image storage
Clamp Function
Restricts pixel values within a specified range
Gaussian Kernel Generation
Creates a kernel for Gaussian smoothing based on size and sigma
Gaussian Smoothing
Reduces noise using the Gaussian filter
Gamma Correction
Adjusts brightness non-linearly using a precomputed gamma table
Modifies pixel brightness based on user input.
Changes image contrast using a specified factor.
Increases shadow detail by reducing pixel brightness.
Feedback Mechanism
Asks whether to enhance the image more or not.
NO
exit(0)
YES
Asks for a brightness amount
Enhances the image by applying brightness enhancement, contrast and shadow enhancement accordingly.

Attained Deliverable

Input Image

Final Output Image

Reference

List of cited papers

[1] A Dynamic Histogram Equalization for Image Contrast Enhancement M. Abdullah-Al-Wadud, Md. Hasanul Kabir, M. Ali Akber Dewan, and Oksam Chae, Member, IEEE

[2] Gray World based Color Correction and Intensity Preservation for Image Enhancement N.M. Kwoka, D. Wanga, X. Jiab, S.Y. Chenc, G. Fangd and Q.P. Hae aSchool of Mechanical and Manufacturing Engineering The University of New South Wales, Australia bSchool of Information Technology and Electrical Engineering The University of New South Wales, Australia cCollege of Computer Science Zhejiang University of Technology, 310023 Hangzhou, China dSchool of Engineering University of Western Sydney, Australia eSchool of Electrical, Mechanical and Mechatronic Systems University of Technology Sydney, Australia

[3] Low-Light Image Enhancement: A Comparative Review and Prospects WONJUN KIM , (Member, IEEE) Department of Electrical and Electronics Engineering, Konkuk University, Seoul 05029, South Korea

[4] DiffLight: Integrating Content and Detail for Low-light Image Enhancement Yixu Feng1 Shuo Hou1 Haotian Lin1 YuZhu1 PengWu1 WeiDong2 Jinqiu Sun1 Qingsen Yan1† Yanning Zhang1 1Northwestern Polytechnical University 2Xi'an University of Architecture and Technology

[5] M2Trans: Multi-Modal Regularized Coarse-to-Fine Transformer for Ultrasound Image Super-Resolution Zhangkai Ni, Member, IEEE, Runyu Xiao, Wenhan Yang, Member, IEEE, Hanli Wang, Senior Member, IEEE, Zhihua Wang, Lihua Xiang, and Liping Sun

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Thank You