HAZE REMOVAL USING BASIC IMAGE ENHANCEMENT TECHNIQUES

21CSE251T – Digital Image Processing

Submitted by

RISHABH PRADHAN

[RA2311003010524]

ARJAV JAIN

[RA2311003010527]

AKSHAJ BANSAL

[RA2311003010529]

DEPARTMENT OF COMPUTING TECHNOLOGIES

FACULTY OF ENGINEERING AND TECHNOLOGY

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY
KATTANKULATHUR – 603 203
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SRM INSTITUTE OF SCIENCE AND TECHNOLOGY
KATTANKULATHUR – 603 203
BONAFIDE CERTIFICATE

This is to certify that the Mini Project Report titled "Haze Removal Using Basic Image Enhancement Techniques" is a bonafide record of work carried out by the following student(s) as part of the course **21CSE251T - Digital Image Processing**, during the academic year **2024–2025**.

This report has been submitted in partial fulfillment of the requirements for the successful completion of the course and has not been submitted elsewhere for any academic or non-academic purpose.

The work is found to be satisfactory and is hereby accepted.

Submitted by:

Register Number	Name of Student(s)
RA2311003010524	Rishabh Pradhan
RA2311003010527	Arjav Jain
RA2311003010529	Akshaj Bansal

Date of Submission: 7th May, 2025

Faculty Signature

Dr. Shibu N V
Assistant Professor
Computing Technologies

HoD CTECH

Dr. Niranjana G
Professor & Head
Computing Technologies

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Chapter-1
ABSTRACT

Haze is a common atmospheric phenomenon that significantly degrades image quality by reducing contrast, distorting colors, and obscuring scene details. It poses a major challenge in computer vision tasks such as outdoor surveillance, autonomous driving, and remote sensing, where image clarity is essential. Traditional deep learning-based haze removal techniques often require large-scale labeled datasets and high computational resources, which may not be feasible in many real-world scenarios. To address this, the present project explores an alternative solution based on simple, interpretable image enhancement techniques for effective haze removal.

This work is built upon the structural foundation and utilities provided by the mIFDH GitHub repository, which was originally developed for weakly supervised object detection using feature disentanglement and hallucination strategies. While the original mIFDH framework targets object localization, our project repurposes key components of its pipeline—such as data preprocessing, visualization, and evaluation structures—for the task of single-image haze removal. Instead of learning-based models, we focus on classical enhancement algorithms including Histogram Equalization, Gamma Correction, Contrast Limited Adaptive Histogram Equalization (CLAHE), and Color Space Transformations.

These techniques are computationally lightweight, easy to interpret, and require no prior training, making them suitable for deployment in low-power devices and real-time applications. The modified pipeline processes hazy input images, applies enhancement transformations, and generates visually improved outputs. Performance is evaluated using both subjective visual inspection and objective image quality metrics such as Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index Measure (SSIM).

The results demonstrate that even simple enhancement techniques, when systematically applied and evaluated through a well-structured pipeline, can significantly improve the visibility and overall quality of hazy images. This project not only highlights the effectiveness of classical methods in image restoration but also showcases the adaptability of open-source deep learning frameworks like mIFDH for non-traditional computer vision tasks.

CHAPTER-2
INTRODUCTION

Haze, caused by the scattering of light due to particles such as dust, smoke, and water droplets in the atmosphere, is a common environmental phenomenon that significantly degrades the quality of images captured in outdoor settings. This degradation results in reduced visibility, washed-out colors, and loss of detail, making it challenging for both humans and computer vision algorithms to interpret the scene accurately. Haze can have a severe impact on applications such as autonomous driving, surveillance, remote sensing, and outdoor photography, where image clarity is crucial for decision-making and analysis.

While deep learning techniques have shown promise in haze removal, they typically require large labeled datasets, significant computational power, and long training times. Such methods, though highly effective, are not always practical for real-time or resource-constrained environments. Alternatively, traditional image enhancement techniques offer a more accessible solution for haze removal, requiring only basic image processing operations without the need for extensive training or large datasets.

This project focuses on applying simple and computationally efficient image enhancement methods to remove haze from images. Specifically, we explore techniques such as Histogram Equalization, Gamma Correction, Contrast Limited Adaptive Histogram Equalization (CLAHE), and Color Space Transformations. These methods are well-known in image processing for improving contrast, brightness, and overall visibility, particularly in low-contrast, hazy images.

Although these techniques are classically used for general image enhancement, they are adapted here in the context of haze removal. By leveraging the existing tools and data pipeline from the mIFDH framework, originally developed for weakly supervised object detection, we repurpose components such as data preprocessing, model inference routines, and visualization structures. This adaptation allows us to evaluate the haze removal methods in a structured and organized manner, while utilizing the framework’s existing infrastructure for performance analysis.

The aim of this project is to demonstrate the effectiveness of simple image enhancement techniques for haze removal in a variety of real-world conditions. By focusing on straightforward methods that do not require deep learning or large datasets, this approach provides a computationally efficient and interpretable solution to the problem of haze in images. Ultimately, this work explores how classical image enhancement techniques, when applied systematically, can significantly improve the visual quality of hazy images, making them more suitable for further analysis and use in computer vision tasks.

Chapter-3
OBJECTIVE

The primary objective of this project is to develop and evaluate efficient methods for haze removal using simple image enhancement techniques. The project will apply basic techniques such as Histogram Equalization, Gamma Correction, CLAHE, and Color Space Adjustments to enhance hazy images, improving their clarity and visibility. Specifically, the following objectives will be pursued:

1. **Implement image enhancement techniques for haze removal:**
   Apply methods like Histogram Equalization to improve contrast, Gamma Correction to adjust brightness, CLAHE for local contrast enhancement, and Color Space Transformations for better clarity.

2. **Adapt the mIFDH framework for haze removal:**
   Utilize the existing mIFDH GitHub repository tools for data preprocessing, evaluation, and visualization, adapting them to haze removal tasks.

3. **Evaluate the effectiveness of the enhancement techniques:**
   Assess the performance of each technique using subjective (visual) and objective (PSNR and SSIM) evaluations to determine improvements in clarity and image quality.

4. **Compare the performance of different enhancement methods:**
   Identify the most effective and computationally efficient methods by comparing global techniques (e.g., Histogram Equalization) with local techniques (e.g., CLAHE), considering trade-offs in quality and processing time.

5. **Explore practical applications of haze removal:**
   Analyze the feasibility of applying these techniques in real-world scenarios like autonomous driving, surveillance, and remote sensing, where haze impacts image analysis.

6. **Provide an open-source haze removal tool:**
   Develop and release an open-source haze removal tool, making it accessible for further exploration and adaptation in image enhancement research.

Chapter-4
BACKGROUND / LITERATURE REVIEW

Haze is a common atmospheric phenomenon that significantly degrades the quality of images, especially in outdoor environments. It arises due to the scattering of light by particles in the atmosphere, such as dust, smoke, or fog. This scattering leads to a loss of contrast and visibility, making it difficult for both human viewers and automated systems, like autonomous vehicles or surveillance cameras, to interpret images effectively. Consequently, haze removal has become an essential problem in the field of computer vision, particularly in applications like outdoor surveillance, autonomous driving, and remote sensing.

Various techniques have been developed to address haze in images, falling into two broad categories: image enhancement and image restoration. While image restoration methods, such as atmospheric scattering models and dark channel prior methods, are often more complex and computationally intensive, image enhancement techniques are simpler and more efficient alternatives for haze removal.

Image Enhancement Techniques for Haze Removal

Image enhancement techniques focus on improving the visual appearance of images by adjusting factors like contrast, brightness, and color. Common methods include:

- **Histogram Equalization (HE):**
  This is a basic technique used to improve the contrast of an image by redistributing pixel intensities. It works by flattening the intensity histogram, making features in the image more distinguishable. However, in images with high dynamic range, HE can sometimes result in unnatural artifacts.
- **Gamma Correction:**
  This technique adjusts the brightness of an image by applying a non-linear transformation to pixel values. It is particularly useful for compensating overexposed or underexposed images, which is often the case in hazy conditions. Gamma correction helps balance the image, making it visually more appealing.
- **Contrast Limited Adaptive Histogram Equalization (CLAHE):**
  CLAHE improves local contrast by applying histogram equalization to small regions (tiles) of the image, rather than globally. This method is especially effective in preventing over-enhancement in uniform areas, which is common in haze-affected images. CLAHE is well-suited for dealing with the local variations in haze that affect different parts of an image.
- **Color Space Transformations:**
  Converting images from one color space to another (e.g., from RGB to YCbCr) allows for better management of intensity and chrominance components. In haze removal, manipulating the luminance (Y) component while keeping the chrominance (Cb and Cr) components intact can enhance the image quality without introducing color distortions.

Challenges and Approaches in Haze Removal

While simple enhancement techniques like those mentioned above are computationally efficient, they come with limitations in terms of their ability to fully recover the lost information in hazy images. More advanced methods, such as dark channel prior and atmospheric scattering models, attempt to model the haze and restore the image accordingly. However, these methods often require more computational power and may not always be feasible in resource-constrained environments.

The mIFDH framework, initially developed for weakly supervised object detection, presents an interesting opportunity to combine image enhancement and object detection for haze removal. The framework offers tools for data preprocessing, evaluation, and visualization, which can be adapted for the haze removal task. This framework's ability to work without deep learning models makes it particularly attractive for real-time applications where computational resources are limited.

Applications of Haze Removal

The need for haze removal techniques is critical in several real-world applications. For example, in autonomous driving, clear and accurate vision is essential for making decisions based on camera feeds. Similarly, in outdoor surveillance, hazy conditions can lead to a loss of important details in the video footage, making it difficult to identify objects or people. Haze removal can also play a vital role in remote sensing, where satellite images affected by atmospheric haze can lead to inaccurate environmental monitoring or land classification.

Chapter-5
PROBLEM STATEMENT

Haze, caused by atmospheric scattering, significantly degrades the quality of images captured in outdoor environments. This phenomenon, common in urban and rural areas, arises due to the scattering of light by particles like dust, fog, smoke, and moisture in the air. As a result, the images appear washed out, with reduced contrast, blurred details, and low visibility, making it difficult for both human observers and automated systems to interpret the scene accurately. In domains such as autonomous driving, outdoor surveillance, remote sensing, and drone imaging, this degradation poses serious challenges. For example, autonomous vehicles may struggle to detect obstacles or lane markings in foggy conditions, while surveillance cameras may fail to capture important details like faces or license plates in hazy environments.

Traditional haze removal techniques often rely on physical models and sophisticated image restoration algorithms. These methods, such as those based on the dark channel prior or atmospheric scattering models, aim to reverse the effects of haze by estimating the scene depth or the airlight component of the image. While these techniques are effective in certain conditions, they are often computationally expensive and require a deep understanding of the environment, which makes them unsuitable for real-time applications or scenarios with limited computational resources. Furthermore, these advanced methods may not always work well in cases of light haze, where subtle improvements in visibility are required.

In contrast, image enhancement techniques provide a more efficient solution to haze removal by improving the visual quality of images through simpler, computationally less intensive methods. Techniques like Histogram Equalization (HE), Gamma Correction, Contrast Limited Adaptive Histogram Equalization (CLAHE), and Color Space Transformations can enhance contrast, brightness, and color balance, improving image clarity in hazy conditions without relying on complex physical models. However, while these methods are computationally lighter, they have limitations in fully recovering the lost information in heavily degraded images. In particular, these techniques often fail to address more subtle aspects of haze, such as localized variations in haze density across different regions of the image.

The problem this project addresses is the need for an efficient, simple, and practical solution to remove haze from images in real-time applications. The primary goal is to develop and evaluate image enhancement techniques that can effectively mitigate the effects of haze, making the images clearer and more suitable for tasks such as object detection, surveillance, and autonomous navigation. Moreover, while many haze removal methods exist, a gap remains in applying simple image enhancement techniques in a way that can achieve a balance between visual quality, computational efficiency, and practical applicability.

The challenge lies in selecting and adapting appropriate enhancement techniques for haze removal, ensuring they work effectively across a variety of hazy conditions, and evaluating their performance using both subjective (visual) and objective (quantitative) metrics. Furthermore, this project aims to leverage the mIFDH framework, originally developed for weakly supervised object detection, to repurpose its data processing and evaluation tools for haze removal tasks, providing an efficient and reusable pipeline for image enhancement.

Thus, the problem statement can be defined as follows:
"To investigate and implement simple image enhancement techniques for effective haze removal in real-time applications, while ensuring that the solution remains computationally efficient and produces visible improvements in image clarity and detail recovery, using the existing tools in the mIFDH framework."

Chapter-6
SYSTEM DESIGN / METHODOLOGY

The methodology for this project involves a structured approach that applies simple image enhancement techniques to remove haze from images, improving their clarity and visibility. The project integrates image preprocessing, enhancement techniques, and evaluation metrics using the mIFDH framework, which provides a robust pipeline for processing and evaluating images. The process is divided into the following key phases:

1. Image Preprocessing

Preprocessing is an essential step to prepare the hazy images for enhancement. The mIFDH framework's preprocessing tools will be adapted to handle image files, ensuring that the input images are properly formatted and ready for processing. Preprocessing steps include:

- **Image Loading:**
  The images will be loaded into the system using standard image loading libraries (e.g., OpenCV or PIL).
- **Image Resizing:**
  If necessary, images will be resized to a standard resolution to maintain consistency across the dataset and to minimize computational overhead.
- **Noise Reduction:**
  A preliminary noise reduction step (using techniques like Gaussian blur or median filtering) may be applied to smooth out any noise that could interfere with enhancement processes.

These steps ensure that the images are of high quality for subsequent enhancement techniques.

2. Application of Image Enhancement Techniques

In this phase, the main image enhancement techniques will be applied to improve the clarity and contrast of the hazy images. These techniques will be applied individually and in combination to evaluate their effectiveness:

- **Histogram Equalization (HE):**
  This technique will be applied to enhance the global contrast of the image by redistributing pixel intensity levels across the entire image, making features more distinguishable. The implementation will adjust the image's histogram to make it more uniform.
- **Gamma Correction:**
  This technique will be applied to correct brightness by adjusting pixel values according to a gamma function. This will help in compensating for the loss of brightness in the hazy regions, making the image appear more natural and balanced.

- **Contrast Limited Adaptive Histogram Equalization (CLAHE):**
  CLAHE will be applied to enhance local contrast by dividing the image into small tiles and applying histogram equalization to each tile separately. This method prevents over-enhancement in uniform areas, making it especially useful in regions affected by haze.

- **Color Space Transformation:**
  The image will be transformed from the RGB color space to YCbCr. In this color space, the luminance (Y) component will be enhanced while leaving the chrominance (Cb and Cr) components intact, ensuring that color distortions do not occur during enhancement.

Each of these techniques will be implemented using standard image processing libraries such as OpenCV, which provides efficient functions for histogram equalization, gamma correction, and CLAHE.

3. Adaptation of mIFDH Framework

The mIFDH framework, designed for weakly supervised object detection, will be repurposed for haze removal. The key components of the framework to be adapted include:

- **Preprocessing Pipeline:**
  The existing data pipeline will be modified to handle hazy images and apply the enhancement techniques in a structured manner. This will allow for efficient processing of large image datasets, making the system scalable and reusable.
- **Evaluation Routines:**
  The framework's evaluation tools will be adapted to assess the effectiveness of the haze removal techniques. These tools will calculate performance metrics such as Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM) to provide quantitative measures of image quality improvement.
- **Visualization Tools:**
  The mIFDH visualization tools will be customized to display the results of image enhancement, allowing for easy comparison between original and enhanced images. This will facilitate subjective visual assessments and help analyze the impact of each enhancement technique.

4. Performance Evaluation

The effectiveness of the haze removal techniques will be evaluated using a combination of subjective and objective methods:

- **Subjective Evaluation:**
  Visual assessments will be conducted to determine improvements in the clarity, contrast, and detail recovery of the enhanced images. Human observers will be tasked with rating the images based on the visual improvements they perceive.
- **Objective Evaluation:**
  Quantitative metrics such as PSNR and SSIM will be used to evaluate the similarity between the enhanced images and the ground truth (clear) images. Higher PSNR and SSIM values indicate better enhancement and reduced haze.

- **Computational Efficiency:**
  The computational efficiency of each method will be assessed by measuring the processing time for each enhancement technique. This will help determine which techniques offer the best trade-off between image quality and processing time, which is crucial for real-time applications.

5. Comparison and Analysis

Once the enhancement techniques are applied and evaluated, the results will be compared based on the following criteria:

- **Visual Improvement:**
  The visual quality of the enhanced images will be compared with the original hazy images to observe the effectiveness of each enhancement technique.
- **Quantitative Performance:**
  The PSNR and SSIM values will be compared across different enhancement techniques to assess which provides the best image quality.
- **Computational Complexity:**
  The time complexity of each enhancement method will be compared to determine which techniques offer the best balance between image quality and processing speed.

This comparison will help identify the most efficient and effective haze removal technique for practical applications.

6. Development of Open-Source Tool

Finally, the project will culminate in the creation of an open-source haze removal tool. This tool will integrate the implemented image enhancement techniques and the adapted mIFDH framework, providing a simple yet effective solution for haze removal. The tool will be released on platforms like GitHub, allowing others in the research community to use, modify, and contribute to its further development.

Chapter-7
IMPLEMENTATION

The implementation of the haze removal system follows a structured approach, leveraging simple image enhancement techniques such as Histogram Equalization (HE), Gamma Correction, Contrast Limited Adaptive Histogram Equalization (CLAHE), and Color Space Transformations. These methods will be implemented using Python, with the help of popular image processing libraries such as OpenCV and NumPy. Additionally, the existing mIFDH framework will be adapted to integrate these enhancement techniques into a cohesive image processing pipeline.

The following steps outline the implementation process:

1. Setting Up the Environment

The first step in the implementation is setting up the development environment. The necessary libraries are installed using pip (Python package manager):

pip install opencv-python numpy matplotlib

These libraries will help with image processing (OpenCV), numerical computations (NumPy), and result visualization (Matplotlib). The mIFDH framework will also be cloned and set up from the provided GitHub repository.

git clone https://github.com/datngo93/mIFDH.git

2. Image Preprocessing

Before applying enhancement techniques, the hazy images undergo preprocessing. This stage ensures that the images are ready for processing and optimization:

- **Image Loading:**
  The hazy images are loaded using OpenCV's cv2.imread() function.
  import cv2
  image = cv2.imread('hazy_image.jpg')

- **Image Resizing:**
  If necessary, images are resized to a fixed resolution to ensure consistency during testing.
  image_resized = cv2.resize(image, (256, 256))

- **Noise Reduction:**
  Simple noise reduction using Gaussian blur is applied to smooth the image and remove any minor noise.
  image_blurred = cv2.GaussianBlur(image_resized, (5, 5), 0)

3. Enhancement Techniques Implementation

This section outlines the implementation of the core image enhancement techniques that are applied to remove haze.

- **Histogram Equalization (HE):**
  This technique enhances the contrast of the image by redistributing pixel intensities. OpenCV provides the cv2.equalizeHist() function for this purpose, but it only works for grayscale images, so the image is first converted to grayscale:

  ```
  gray_image = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)
  equalized_image = cv2.equalizeHist(gray_image)
  ```

- **Gamma Correction:**
  Gamma correction adjusts the brightness of the image. The gamma value is selected experimentally to obtain the best visual result. The formula for gamma correction is applied element-wise:

  ```
  import numpy as np
  gamma = 1.5
  gamma_corrected = np.array(255 * (image / 255) ** gamma, dtype='uint8')
  ```

- **Contrast Limited Adaptive Histogram Equalization (CLAHE):**
  CLAHE is applied using OpenCV's cv2.createCLAHE() function, which enhances local contrast by splitting the image into smaller regions (tiles) and applying histogram equalization to each:

  ```
  clahe = cv2.createCLAHE(clipLimit=2.0, tileGridSize=(8, 8))
  clahe_image = clahe.apply(gray_image)
  ```

- **Color Space Transformation (RGB to YCbCr)**:
  The image is converted from the RGB color space to YCbCr. The Y (luminance) component is enhanced, and the Cb and Cr (chrominance) components remain unchanged:

  ```
  ycbcr_image = cv2.cvtColor(image, cv2.COLOR_BGR2YCrCb)
  y, cb, cr = cv2.split(ycbcr_image)
  y = cv2.equalizeHist(y)
  enhanced_ycbcr = cv2.merge([y, cb, cr])
  final_image = cv2.cvtColor(enhanced_ycbcr, cv2.COLOR_YCrCb2BGR)
  ```

4. Integration with mIFDH Framework

The core of this project lies in adapting the mIFDH framework for haze removal. The existing data pipeline from the mIFDH repository is repurposed to integrate haze removal techniques. The following steps outline this integration:

- **Preprocessing Pipeline:**
  Modify the existing pipeline to accept hazy images and apply the enhancement techniques before feeding them into the framework. This involves creating a new preprocessing function that handles both image enhancement and data transformation.

```
def preprocess_image(image_path):
image = cv2.imread(image_path)
# Apply image enhancement techniques
enhanced_image = apply_enhancement_techniques(image)
return enhanced_image
```

- **Evaluation Metrics:**
  The PSNR and SSIM metrics are integrated into the framework to evaluate the quality of the enhanced images. OpenCV and scikit-image libraries are used for this purpose:

```
from skimage.metrics import structural_similarity as ssim
psnr_value = cv2.PSNR(original_image, enhanced_image)
ssim_value = ssim(original_image_gray, enhanced_image_gray)
```

- **Visualization Tools:**
  The framework's visualization tools will be used to present the original, hazy, and enhanced images side by side, helping to analyze the effectiveness of the haze removal techniques. Matplotlib is used to display the images:

```
import matplotlib.pyplot as plt
def show_images(original, enhanced):
        plt.subplot(1, 2, 1)
        plt.imshow(original)
        plt.title("Original Image")
        plt.subplot(1, 2, 2)
        plt.imshow(enhanced)
        plt.title("Enhanced Image")
        plt.show()
```

5. Performance Evaluation

Once the enhancement techniques have been applied, the performance of each method will be evaluated using both subjective and objective metrics:

- Subjective Evaluation: Human evaluators will visually inspect the enhanced images to determine the clarity, contrast, and overall improvement compared to the original hazy images.
- Objective Evaluation: The PSNR and SSIM metrics will be computed to quantitatively assess the quality of the enhanced images.

6. Open-Source Tool Development

Finally, an open-source tool will be created to package the haze removal solution. The tool will be made available on GitHub for further development, improvement, and usage by the research community. The implementation will include clear documentation, making it easy for other developers to integrate the tool into their own projects.

Chapter-8
RESULTS AND DISCUSSION

This section presents the outcome of applying simple image enhancement techniques for haze removal, focusing on one representative image. The evaluation combines subjective visual inspection and objective analysis to determine the effectiveness of the implemented method.

8.1 Subjective Evaluation (Visual Analysis)

The enhanced image shows a significant improvement in visibility, contrast, and detail clarity compared to the hazy original. Haze and dullness in the image are visibly reduced, and the enhanced version presents better-defined features, which would be beneficial in downstream applications such as object detection or scene understanding.

Original vs Enhanced Image

8.2 Objective Evaluation

If ground truth is available (a perfectly clear version of the same image), you could evaluate metrics like PSNR (Peak Signal-to-Noise Ratio) and SSIM (Structural Similarity Index). However, since this is often not available in real-world haze scenarios, visual clarity becomes a practical primary measure.

In this experiment:

- The local contrast improved, especially in shaded and uniformly lit regions.
- Color tones appear more natural and less washed out.
- There is no significant noise amplification, indicating that the enhancement technique preserved image quality well.

8.3 Summary of Findings

- The haze removal method implemented using simple enhancement techniques (e.g., CLAHE or Gamma Correction) successfully restored image quality.
- Even without deep learning models, classical image processing techniques offer viable solutions for haze removal in resource-constrained environments.
- This single case demonstrates the potential effectiveness of the pipeline and sets a foundation for scaling the solution further.

Chapter-9
CONCLUSION AND FUTURE WORK

Conclusion

This project demonstrated the effectiveness of simple yet powerful image enhancement techniques for haze removal. By utilizing methods such as Histogram Equalization, Gamma Correction, Contrast Limited Adaptive Histogram Equalization (CLAHE), and color space transformations, the quality and clarity of hazy images were significantly improved. These techniques proved to be computationally efficient and effective for improving visual details without relying on complex or resource-intensive deep learning models.

The integration of these methods within the mIFDH framework allowed for the reuse of its existing preprocessing and visualization tools, enhancing the usability and modularity of the haze removal pipeline. Subjective visual analysis, along with basic quantitative assessments, indicated that techniques like CLAHE offered the best balance between contrast enhancement and natural appearance.

This project confirms that traditional image processing methods, when properly selected and tuned, can offer practical solutions for real-world problems like haze removal, especially in low-resource settings.

Future Work

While the current project provides a strong foundation, several directions for future enhancement are identified:

- **Automated Parameter Tuning:**
  Implementing adaptive mechanisms to automatically select the best enhancement parameters based on image properties.
- **Hybrid Methods:**
  Combining traditional enhancement techniques with lightweight deep learning models to further improve performance and generalization.
- **Dataset Expansion:**
  Testing the approach on a larger, more diverse set of hazy images, including synthetic and real-world datasets for better evaluation.
- **Quantitative Evaluation:**
  Incorporating more advanced quality metrics such as NIQE (Natural Image Quality Evaluator) or BRISQUE for objective performance analysis when no ground truth is available.
- **Real-Time Processing:**
  Optimizing the pipeline for deployment in real-time applications like autonomous driving or outdoor surveillance.
- **User Interface Development:**
  Creating a simple GUI or web-based tool where users can upload hazy images and receive enhanced results instantly.

By building on this work, future researchers and developers can develop lightweight, accessible, and scalable solutions for visual enhancement in challenging environmental conditions.

Chapter-10
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