A REPORT
ON

AI-ML BASED INTELLIGENCE DE-SOMKING/DE-HAZING

A PROJECT REPORT

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Under the guidance of,

Dr.Sivaramakrishnan S
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in partial fulfillment for the award of the degree of

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IN

COMPUTER SCIENCE AND ENGINEERING
(ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING)
At

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

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PRESIDENCY UNIVERSITY

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CERTIFICATE

This is to certify that the Project report **"AI-ML Based Intelligence De-Smoking/De-Hazing"** being submitted by, **ANURAG KUMAR, DARSHAN S, MOHAMMED KAIF, VAIBHAV V, SUHAS K** bearing roll number(s) **"20211CAI0136, 20211CAI0116, 20211CAI0144 20211CAI0108, 20211CAI0057"** in partial fulfilment of the requirement for the award of the degree of Bachelor of Technology in Computer Science and Engineering is a Bonafide work carried out under my supervision.

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DECLARATION

We hereby declare that the work, which is being presented in the project report entitled AI-ML Based Intelligence De-Smoking/De-Hazing in partial fulfilment for the award of Degree of Bachelor of Technology in Computer Science and Engineering, is a record of our own investigations carried under the guidance of **Dr. Sivaramakrishnan S, Associate Professor, School of Computer Science Engineering & Information Science, Presidency University, Bengaluru.** We have not submitted the matter presented in this report anywhere for the award of any other Degree.

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ABSTRACT

Unclear visuals resulting from environmental factors like fog, smoke, and pollution greatly impact the clarity and effectiveness of visual data in various practical uses. These circumstances result in diminished visibility and color distortion, consequently impairing the effectiveness of computer vision systems utilized in fields such as autonomous driving, surveillance, and outdoor photography.

Image dehazing proves to be a crucial initial step that effectively enhances images and recovers missing details as well. This project demonstrates a method for employing deep learning, particularly Convolutional Neural Networks (abbreviated as CNNs) ResNet-50, to restore clarity to hazy images. While conventional techniques often rely on fixed patterns or assumptions regarding the variations of fog or haze, CNNs excel at directly learning various details from the available data. They independently find that information without anyone instructing them on what to search for.

In this project, we implemented a model that learns from pairs of images that appear smoky, hazy and sharply clear. It employs numerous layers of convolutions and transpose convolutions, along with various ReLU activation functions, to convert blurred input images into sharp, clear visuals. We've created a fantastic interface that is very simple to navigate with Gradio. We are transforming this system into an engaging platform that many can enjoy and interact with.

Users can submit unclear images directly into the application, and the model functions rapidly to produce a picture that is free of any blur. Collaborating effortlessly, the integration of CNN models with Gradio user interfaces provides an exceptionally smooth final experience. Experimental findings show that the system successfully enhances the visual quality of hazy images.

The model retains the essential attributes, reflects the natural hues, and significantly enhances the contrast. And it operates incredibly quickly as well, which truly excels for live applications.

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CHAPTER-1

INTRODUCTION

Outdoor photographs tend to be degraded by airborne contaminants like dust, smoke, and water droplets, which scatter light and hide valuable visual information. This issue, widely referred to as haze, not only degrades the visual quality of images but also has critical consequences for important applications such as autonomous driving, surveillance, environmental monitoring, and satellite imaging, where unobstructed visuals are critical to making informed decisions. Meeting this challenge, our project is centered on creating a lightweight CNN-based single-image dehazing system that improves image clarity without being computationally intensive enough to hinder real-time, resource-limited applications. By leveraging deep learning methodologies with user-friendly deployment, our system seeks to close the gap between cutting-edge image restoration research and practical, accessible solutions for a broad set of users and industries.

Ostensibly blurry outdoor images often struggle with airborne impurities—smoke, water droplets, and dust—scattering the light, defocusing details and desaturating colors. That is frustrating to photographers, yet much more of a problem for applications like self-driving, security, and ecologic monitoring where decisions have to be based on crisp images. Furthermore, they typically require tedious manual tuning of parameters, not particularly conducive to high-volume deployments or real-time computation.

Deep learning, particularly CNNs, has turned image dehazing into data-driven. Instead of manually specifying features, such models learn patterns directly from large datasets without requiring manual specification of features, making them much more adaptive to adapting to changing intensities of haze and scenes. CNNs outperform traditional methods in handling uncertain real-world conditions, making them suitable for real-world dehazing tasks.

Considering these points, here we introduce a lightweight CNN-based method for single-image dehazing. The model iteratively enhances the image at low computational overheads, making it suited for low-resource systems like embedded devices and edge computing systems. In order to ensure the system is general, we train it using real-world hazy images and synthetically created hazy images, so it can efficiently cater to a wide variety of haze-induced degradation. Accessibility is an important concern in our project.

This CNN-based method is superior to traditional dehazing techniques without assumptions on haze distribution being stiff while still maintaining efficiency. Such a tradeoff makes it the ideal method to use in real-time enhancement on the edge for mobile device applications. Attention mechanisms in CNNs would allow the model to selectively attend to the most affected regions in an image.

Evolution of the system into a more complete image enhancement pipeline—combining dehazing with color correction, denoising, and super-resolution—would transform it into an end-to-end visual enhancement solution. Essentially, this project enables smarter, resource-saving, and intuitive dehazing. With lightweight deep models and an actionable GUI, we enhance not only image quality, but also the efficacy of use cases in diverse applications. Whether we are augmenting autonomous vehicles, refining the resolution in satellites, or aiding in environmental surveillance, this system optimizes AI to improve formidable imaging issues.

1.1 Problem Statement

The Quality of images and videos is crucial in today's digital age, impacting fields such as photography. However, haze and fog sometimes can significantly degrades the clarity of visual media. This project focuses on leveraging some advanced deep learning algorithms to enhance the images and videos. Our goal is to design CNN networks such that they can easily remove haze from all media.We also know the importance of real-time video dehazing. Hence, the project will also provide seamless frame-to-frame transitions while effectively removing haze. Our project also seeks to fill the gap where is there between theoretical development and practical use, providing a promising solution for real-world applications where atmospheric conditions causes trouble in visual perceptions.

Our principal project seeks to address the problem of haze and fog by employing sophisticated deep learning algorithms. We intent on further improving the image and video dehazing by using leading-edge neural network architectures. Through the completion of this project, it has the capacity to redefine the way in which we enjoy and interact with visual media when the environment is foggy or hazy.

1.2 Objectives

The main goal of this project is to eliminate or decrease haze from one image, which usually results from particles and atmospheric moisture, in an effort to increase visual contrast and clarity. This method entails designing and implementing a bespoke Convolutional Neural Network (CNN) model that can learn the intricate relationship between hazy and clear images. The main aims of our project are as follows:

- **Development of a Single Image Dehazing Model:**
  Design and deploy a CNN-based model that has been trained on hazy-cleared image pairs to learn pixel-to-pixel mapping directly and recover image sharpness.

- **End-to-End Deep Learning Approach:**
  Fine-tune and train the CNN using loss functions such as Mean Squared Error (MSE) to reduce the disparity between dehazed output and ground-truth clear images.

- **Image Preprocessing Pipeline:**
  Create a preprocessing function that resizes images to a specific resolution (e.g., 256×256), normalizes them, and converts them into tensors for training and inference.

- **Real-Time Dehazing Web Application:**
  Create an interactive Gradio-based web application where users can upload hazy images and receive dehazed results immediately, making the system feasible and accessible.

- **Evaluation and Quality Metrics:**
  Test the model's output against typical image quality metrics like Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM) to ensure its efficiency.

- **Haze Removal:**
  Achieve effective haze removal by learning the visual degradation patterns and reversing them to enhance object visibility, color accuracy, and scene contrast**.**

CHAPTER-2

LITERATURE SURVEY

2.1 Overview of Relevant Literature

S. No	Paper Title	Journal (Year)	Tools/ Techniques/ Dataset	Results	Limitation
[1]	Non-homogeneous realistic single image dehazing	WACVW (2023)	Algorithm: Custom CNN Dataset: Realistic Non-Homogeneous Hazy Dataset	model effectively handles non-homogeneous haze.	Model performance is dataset-dependent.
[2]	Learning to dehaze with hybrid loss function	JSPS (2021)	Algorithm: CNN with Hybrid Loss Dataset: Synthetic hazy images	Hybrid loss improves training stability and output quality in dehazing.	Effectiveness depends on careful tuning of loss weights.
[3]	Single-image dehazing using extreme reflectance channel prior	IEEE Access (2021)	Algorithm: Extreme Reflectance Channel Prior Dataset: Synthetic datasets and real-world images	Effectively improves scene contrast and reduces haze; shows competitive PSNR and SSIM metrics.	Performance degrades in low-light or overexposed hazy scenes.
[4]	Deep image dehazing using generative adversarial networks	IEEE TCSVT (2020)	Algorithm: GAN-based dehazing model Dataset: Synthetic hazy image datasets	GAN effectively learns haze characteristics; results show significant visual and quantitative improvement.	Suffers from artifacts when haze is dense or unevenly distributed.

S. No	Paper Title	Journal (Year)	Tools/ Techniques/ Dataset	Results	Limitation
[5]	Image dehazing using deep generative networks	IEEE TIP (2020)	Algorithm: Deep Generative Networks (GAN-based) Dataset: RESIDE dataset	Generative models outperform traditional CNNs in perceptual quality.	Training instability and mode collapse in GANs under certain settings.
[6]	A fast dehazing algorithm dark channel prior	JCST (2020)	Algorithm: Non-local Means + DCP Dataset: Synthetic images with haze	Combines non-local filtering with DCP for faster dehazing with reduced noise.	Still inherits limitations of DCP in bright regions
[7]	Learning to remove haze in real-world images	IEEE TIP (2019)	Algorithm: Domain-Adaptive CNN Dataset: Real-world haze dataset	Focuses on domain adaptation for generalization to real-world haze conditions.	Still challenged by severe haze and poor illumination cases.
[8]	Enhancing the dehazing network for low-light image	IJCV (2019)	Algorithm: Enhanced CNN Dehazing Network Dataset: Synthetic and low-light hazy datasets	Improves visibility in low-light hazy conditions; incorporates luminance-aware learning.	Performance is scene-specific; may not generalize well to daylight haze.

S. No	Paper Title	Journal (Year)	Tools/ Techniques/ Dataset	Results	Limitation
[9]	Real-time single image dehazing using convolutional neural networks	JVCIR (2018)	Algorithm: Real-time CNN Dehazing Model Dataset: Synthetic datasets with real-time application focus	Achieves competitive results with fast inference time, suitable for embedded applications.	May not achieve state-of-the-art quality under complex atmospheric conditions.
[10]	A deep network for image dehazing	IEEE TIP (2018)	Algorithm: Deep Learning-Based Dehazing Network Dataset: Synthetic outdoor datasets (e.g., RESIDE)	Uses a multi-scale network for better edge preservation and visibility restoration.	Relatively high computational cost, limited performance on indoor scenes.
[11]	Non-local image dehazing	IEEE TPAMI (2016)	Algorithm: Non-local Color-Line Model Dataset: Real-world and synthetic hazy images.	Introduces haze-lines; effectively recovers color and contrast in hazy scenes.	Performance drops in non-uniform haze conditions or texture-less regions.
[12]	DehazeNet: An end-to-end system for single image haze removal	IEEE TIP (2016)	Algorithm: DehazeNet Dataset: Synthetic and real-world images	Achieves high-quality dehazing using a lightweight CNN model, outperforming traditional methods.	Performance can be limited when haze patterns differ significantly from training data.

Table 2.1 Literature Review

2.2 Key Gaps in the Literature

As we further studied the research papers, we found that there were some key gaps in those papers which are as follows:-

1. Dataset Limitations

- Excessive use of synthetic datasets (e.g., RESIDE), which usually cannot reproduce actual haze features.
- Restricted lighting, environment, and haze density diversity among datasets.

2. Generalization Issues

- Most models are unable to generalize to non-homogeneous or actual hazy conditions.
- Domain shift results in performance degradation when tested on unseen data.

3. Performance in Complex Scenes

- Difficulty in dealing with dense haze, low-light, or non-uniform haze distributions
- Models such as DCP and others fail in bright/white object regions.

4. Real-time and Lightweight Solutions

- Few works address real-time dehazing..
- High-performance models tend to require heavy computation, which restricts deployment on edge devices.

5. Overfitting to Synthetic Features

- GAN and CNN-based models tend to learn synthetic haze patterns instead of strong features, resulting in artifacts and overfitting.

6. Lack of Semantic Understanding

- Most models don't use semantic or contextual knowledge, this restricts scene-aware dehazing.

7. Cross-Domain Performance

- Cross-domain approaches (e.g., training on one domain, testing on another) are underdeveloped, resulting in poor transferability in real-world applications.

8. Evaluation Metrics

- Standard metrics such as PSNR/SSIM do not necessarily translate into human observation or visual quality; no ideal standard for qualitative assessment is available.

CHAPTER-3

RESEARCH GAPS OF EXISTING METHODS

Research gaps are those parts of a field in which knowledge is deficient or inadequate. They highlight unanswered questions or shortcomings of the current knowledge, which will lead researchers to go and fill those gaps. Recognition and remediation of these gaps is important in the development of knowledge and in the overall understanding of a topic.

3.1 Functional Gaps in AI-Based Image Dehazing

Though AI-based image dehazing has made tremendous strides, most existing techniques are not as versatile and flexible as required for practical use. Most models are either fine-tuned to improve image clarity or optimized for a particular dataset but fail to cope with varying environmental conditions like fog, smog, and low-light conditions. This leads to inconsistent performance when used on images with different haze densities, resolutions, and scene types—urban scenes, rural scenes, or marine scenes. Yet another issue is a lack of context-aware processing. AI algorithms usually process all image areas indiscriminately, giving no priority to key objects such as vehicles or humans over backgrounds. Clarity in some regions is highly relevant in domains like surveillance, self-driving, and remote sensing but is not what most dehazing algorithms today adapt dynamically to. Further, all but a few AI-based dehazing techniques are limited to dehazing individual images, without addressing the requirement for continuous, real-time dehazing of video. Such a limitation results in inconsistencies or flicker effects when applied to live feeds or monitoring footage, which reduces their value for security and navigation applications.

Another vital gap is in evaluation techniques. Most dehazing models use measures such as PSNR (Peak Signal-to-Noise Ratio) and SSIM (Structural Similarity Index) to estimate image quality, but these are generally done only after model deployment and not incorporated into the training loop. The implication is that there is no automatic means for adjusting output quality dynamically. Additionally, most of the solutions do not provide user feedback or parameter adjustment, limiting their real-world application in tailored environments. In brief, existing AI-based dehazing algorithms require major enhancements to be more flexible, video-friendly, and user-centered. Bridging these functional limitations will contribute towards tighter integration into practical applications such as autonomous vehicles, surveillance security, and weather monitoring, providing clearer imagery where it is needed most.

3.2 Technical Gaps in AI-Based Image Dehazing

In spite of improvements, technical problems still discourage widespread use of AI-based image dehazing models. A majority of current models are highly dependent on Convolutional Neural Networks (CNNs), which may be great for feature extraction but fail in tackling long-range relationships and global consistency—particularly for dense hazy situations. Promising Transformer-based models are upcoming but are computationally intensive and thus unsuitable for real-time image recovery. Another major issue is the lack of standardized datasets and evaluation benchmarks.

Most models are trained using synthetic datasets like RESIDE, which do not fully represent real-world haze complexities. These datasets fail to capture atmospheric scattering, color distortions, and light attenuation—key factors in actual hazy conditions. As a result, models trained on synthetic data often underperform when tested on real-world images. Dehazing with AI is also too single-minded about restoration, neglecting the potential for multi-task learning. For instance, dehazing might be combined with semantic segmentation or object detection, so systems are able to recognize and remove fogging simultaneously from objects in hazy scenes. A multi-modal solution would render AI models better at tasks such as autonomous navigation and scene analysis.

Furthermore, real-time performance is still a problem. Most current AI dehazing models consume massive amounts of GPU resources and are hard to deploy on mobile devices or edge devices. Methods such as quantization, pruning, and knowledge distillation, which might lower computational expenses, are not well used. Without such optimizations, AI dehazing is not achievable for low-power devices. A last but not least problem is model interpretability and uncertainty estimation. Most AI-based dehazing models are black boxes, so users can't trace how decisions are made. In autonomous driving and surveillance applications that are safety-critical, transparency is indispensable. Users have no way of estimating whether an AI-generated dehazed image is correct and reliable without improved visualization tools.

As a whole, dehazing through AI requires more flexible architectures, improved real-world datasets, multi-task learning, and enhanced deployment methods. Addressing these disparities will make it possible to deliver quicker, more dependable, and scalable dehazing solutions and turn AI-enabled visibility restoration into a real-world reality.

3.3 Scalability Challenges in AI-Based Dehazing

While AI-driven dehazing models perform exceptionally well in research environments, many struggle to scale for real-world applications. Several key challenges hinder their widespread deployment:

3.3.1. Limited Dataset Diversity

The majority of models are learned on simulated data with consistent haze patterns and therefore are vulnerable to overfitting. Applied in urban, rural, aerial, or underwater environments, their performance is reduced greatly because their training data lacks the variability found in real-world conditions.

3.3.2. High Computational Demands

State-of-the-art dehazing models tend to be based on deep networks and attention mechanisms, which require high-end GPUs. This renders them unsuitable for low-resource devices like smart surveillance cameras, drones, mobile phones, and embedded systems in agriculture.

3.3.3. Non-Modular Architecture

The majority of dehazing models are monolithic, i.e., even small changes—like incorporating classification or segmentation capabilities—need full retraining or redesign. A more modular design would enable individual components to be updated independently.

3.3.4. Limited Parallelization Support

Models for real-time applications need to execute efficiently on GPU/TPU hardware. Yet, most existing designs do not support distributed training, resulting in bottlenecks when dealing with large-scale image datasets.

Most models also do not fit well into existing autonomous vehicle, satellite imaging, or video analytics pipelines. A scalable solution needs to support diverse image resolutions, real-time inputs, and ongoing learning from new data sources. Without advancements in resource efficiency, modularity, and real-time adaptability, existing AI-based dehazing methods cannot scale from research environments to mass-scale practical implementation.

3.4 Usability Challenges in AI-Based Dehazing

Although technically sound, most AI-based dehazing solutions are designed for researchers and engineers and are thus not usable by common users. Some usability challenges must be resolved:

3.4.1. Lack of Intuitive User Interfaces

Most models function through command-line interfaces, deterring non-expert users—like photographers, farmers applying drone images, or urban planners—from embracing these tools. A user-friendly web or mobile interface would enhance usability.

3.4.2. Lack of Real-Time Customization

There is no ability to tune haze removal intensity or favor clarity for particular regions of an image (e.g., faces, text, or road signs). This strictness hinders personalization and user control.

3.4.3. Inadequate Documentation & Usability Testing

Deployment-ready documentation and user research tend to be an afterthought, complicating integration for companies and developers who need to integrate dehazing models into current processes.

3.4.4. No Multi-Language or Accessibility Features

Most dehazing models do not provide support for multiple languages, voice commands, or screen readers, reducing their applicability to the global market.

Moreover, users cannot see how the AI dehazes images or why particular processing choices were taken. Adding explainable AI capabilities—e.g., overlays indicating haze removal procedures—can enhance adoption and trust. In order for AI-based dehazing to become widely adopted, models should be simple to use, flexible across various preferences, and usable by non-experts.

3.5 Promising Research Opportunities in AI-Based Dehazing

Given these challenges, tremendous opportunities exist in AI-based dehazing in the future. Some of the directions are as follows:

3.5.1. Lightweight Model Design for Edge Devices

Enabling CNN-based dehazing networks for power-constrained devices with methods such as model pruning, quantization, and knowledge distillation would facilitate deployment on smartphones, drones, and IoT devices.

3.5.2. Multi-Task Learning Horizons

Rather than the sole emphasis on haze removal, dehazing models would additionally use object detection, semantic segmentation, or depth estimation to better understand scenes in conditions of poor visibility.

3.5.3. Real-World Hazy Image Dataset Development

Training is presently based on synthetic datasets, which confines real-world performance. Development and open-sourcing of varied datasets—such as hazy videos and 3D scenes—would help enhance model generalization.

3.5.4. Domain Adaptation & Transfer Learning Enhancement

Empowering models to generalize to unseen environments without needing extensive retraining would make dehazing more successful under varying geographic and atmospheric conditions.

3.5.5. Enhancing AI Explainability & Transparency

Adding visual overlays and statistical insights to dehazing models would enhance trust, particularly for autonomous driving, aviation, and military surveillance use cases.

CHAPTER-4

PROPOSED METHODOLOGY

This image dehazing system based on AI is meant to recover visibility in images with haze, fog, or smoke. In contrast to conventional methods involving manual tuning and intensive computation, this solution employs a lightweight Convolutional Neural Network (CNN) for rapid, automatic haze removal. With a clean, intuitive interface, the software makes dehazing available to researchers and ordinary users alike. Not only does it eliminate haze, but it also assesses image clarity through PSNR and SSIM metrics to provide high-quality results in real time. Conventional dehazing algorithms have difficulty dealing with different environmental conditions, whereas this AI-based method automatically adjusts to different densities of haze, lighting, and types of images. With the combination of deep learning and Gradio-based deployment, the system is efficient, quick, and simple to operate. Developed for real-world use, it improves visibility in autonomous driving, satellite imaging, and environmental monitoring—where unobstructed vision matters. Whether assisting self-driving vehicles to drive through foggy roads or enhancing remote sensing maps, this AI-powered dehazing system is designed to make a tangible difference while operating efficiently on low-resource devices. Its optimized, streamlined design brings high-quality image restoration to the masses.

4.1. Requirement Gathering and Initial Planning

The initial step for this project was realizing the necessity of an effective, real-time image dehazing system, one that can be executed on devices with limited processing capabilities. Haze-induced poor visibility is a significant issue in autonomous driving, satellite imaging, and environmental monitoring applications—where clear images are essential for making effective decisions. In order to make sure the solution would be practical as well as technical, we approached academic supervisors, field researchers, and machine learning engineers. By brainstorming, we reached a conclusion that the best approach would be to use a Convolutional Neural Network (CNN) due to its capability of learning intricate image features without using manually specified rules. The planning process initially consisted of identifying milestones for collecting data, preprocessing it, creating a model, testing, and deploying. Time—GPU available, storage space, and annotator tools—were assigned to streamline the task.

4.2. Project Vision and Context

Vision for this project was well defined: create an AI-based system to restore vision quality in smoggy photos that surpasses standard image processing algorithms using deep learning.

The project’s framework utilizes Python, PyTorch, and Gradio to implement an easy-to-use interface wherein users can upload blurry images easily and get better, dehazed images in return. This project is in line with more extensive efforts that aim to create AI-based solutions for real-world problems, specifically those that arise in challenging environmental conditions.

4.3. Stakeholder Analysis

Who's Involved?

- Academic Supervisors – Manage the approach and maintain research integrity.
- End Users – Individuals who depend on clean images, such as researchers, car AI systems, and weather forecasting specialists.
- Machine Learning Engineers – Design, train, and validate the CNN model.
- Software Developers – Implement the frontend and backend of the system using Gradio and Python.

What Do They Need?

- Consistent performance on various haze conditions.
- Efficient runtime that functions even on low-resource hardware.
- Reproducibility for academic research and interpretability for studies.

4.4. Technical Requirements

4.4.1 Software

- Python (3.9 or later)
- PyTorch (for training and inference of the model)
- Gradio (for creating an interactive interface)
- Matplotlib & NumPy (for image processing and visualization)
- Pillow & skimage (for image processing)

4.4.2 Hardware

- GPU-based systems for training the deep learning model.
- CPU-based devices for light-weight inference and real-time execution.

4.4.3 Functional Requirements

- Provide users with a way to upload hazy images.
- Process them and return dehazed results.
- Store dehazed results along with timestamps for tracking.
- Test model performance using PSNR and SSIM scores.

4.4.4 Non-Functional Requirements

- Ease of use with a simple, intuitive interface.
- Sturdy enough to cope with image resolutions of various natures.
- Modular so it is a cinch for future upgrades.

4.5. Feasibility Analysis

4.5.1 Can We Build It?

Absolutely! We went with PyTorch to provide flexibility while working with the models and Gradio to make things extremely user-friendly. The integration of pre-trained weights and the simplicity of CNN guarantees real-time image enhancement.

4.5.3 What About Costs?

Development is kept cheap by leveraging open-source tools and public datasets. With the model having been developed in-house, there are no licensing costs involved.

4.6. Data Collection, Preprocessing, and Annotation

4.6.1 Where Does the Data Come From?

To train the CNN, we gathered datasets from public sources such as RESIDE, which includes pairs of clear and hazy images. The dataset consists of images from indoor and outdoor environments, with many different lighting conditions and levels of haze.

4.6.2 How Are Images Prepared?

- Resizing: All the images are resized during training to ensure uniformity, minimizing the use of GPU memory.
- Normalization: Pixel values are mapped to a range of 0–1 for improved compatibility with deep learning algorithms.
- Tensor Conversion: Images are converted to PyTorch tensors to facilitate faster processing.
- Smart Resizing: Images are resized only during inference if their resolution is higher than 512×512 pixels, maintaining finer details.

4.6.3 How Is Image Quality Measured?

Since dehazing is a restoration issue, ground-truth clear images are used as references. These are compared with model output using PSNR and SSIM metrics to measure performance.

4.7. System Architecture and Design

How the Model Works

In essence, the DehazeGenerator CNN utilizes an encoder-decoder architecture optimized for efficiency.

4.7.1 Steps :

- **Feature Extraction:**

  2 Convolutional layers with Batch Normalization and ReLU activation are used to extract haze-related features.

- **Image Reconstruction:**

  2 Deconvolutional layers (transposed convolution) sequentially upscale and refine the image.

- **Final Output Processing:**

  Pixel values are clamped to represent realistic colors.

4.7.2 Structure of the Code

- dehazing_gradio_app.py – Includes the DehazeGenerator model definition and specifies the UI and processing pipeline.
- preprocess.py - To gather values from image pairs and store them in a file calles proprocessed.pth.
- test.py – Executes performance tests using PSNR and SSIM.
- train.py - To train a model using preprocess data in preprocessed.pth.

4.7.3 Interaction of Users with the System

- Upload an image through the Gradio interface.
- The system processes it by transforming it into a tensor and passing it to the model.
- The resulting image is shown in addition to the original for reference.
- Results can be saved, and they are timestamped automatically.

4.7.4 Optimization Strategies

- Adjustments in resizing avoid unnecessary consumption of GPU memory.
- Restoring the original size of the image helps maintain uniformity in output quality.

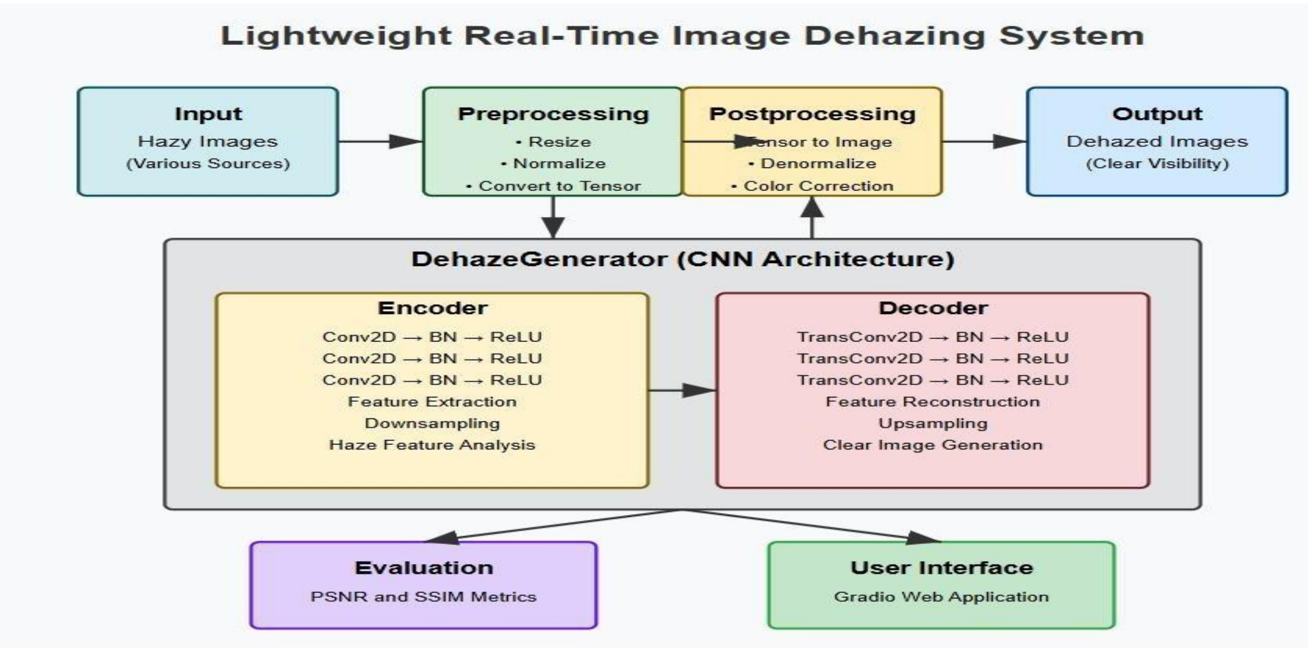


Fig 4.1 System Architecture Diagram

4.8. Testing and Verification

4.8.1 What Was Tested?

We aimed to confirm the robustness of the model on various hazy image types with high structural similarity and signal quality.

4.8.2 How Were Tests Performed?

- The test.py script dehazed a collection of blurry images.
- Benchmark comparisons were made using ground truth (clear images).
- PSNR and SSIM scores were computed to quantify performance.

4.8.3 Key Metrics

- PSNR (Peak Signal-to-Noise Ratio) – Quantifies pixel-level accuracy.
- SSIM (Structural Similarity Index) – Quantifies perceptual similarity.

4.8.4 Results

- PSNR scores averaged over 28.71 dB, guaranteeing high image quality.
- SSIM scores of approximately 0.8307, reflecting strong structure preservation.

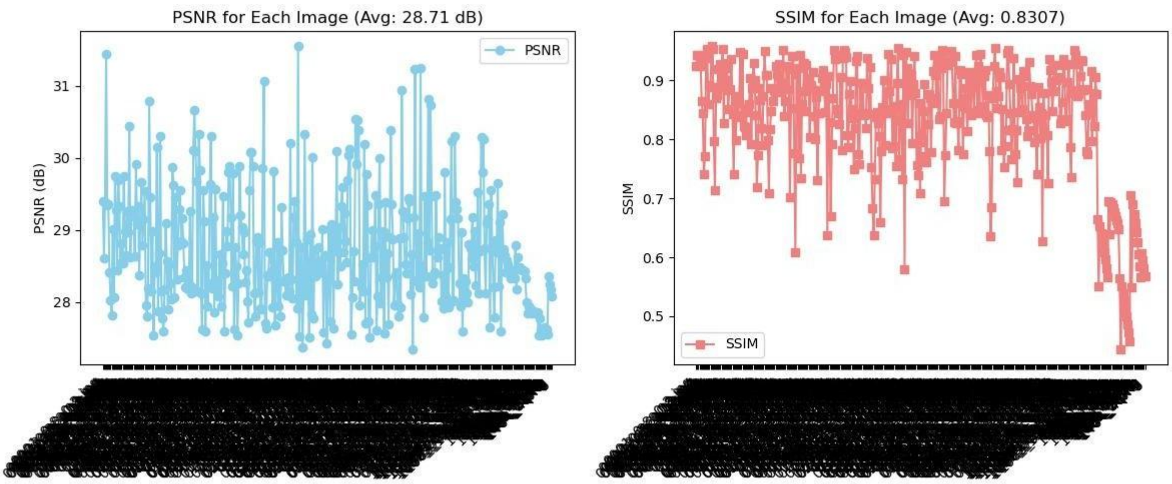


Fig 4.2 Results

4.9. Final Thoughts

The project is able to provide a CNN-driven image dehazing system that is efficient, precise, and accessible. With its integration of deep learning and intuitive deployment framework, it fills the gap between research breakthrough and usability. Whether in improving autonomous vehicle vision, satellite imaging, or environmental monitoring, this AI-enabled method demonstrates how technology can enhance real-world uses.

CHAPTER-5

SYSTEM DESIGN & IMPLEMENTATION

System Overview: AI-Powered Image Dehazing

Foggy, smoky, or hazy images may conceal information, hindering autonomous systems, satellite imaging equipment, and environmental monitoring software to correctly interpret scenes. To overcome this issue, the project's image dehazing system based on CNN is designed to restore visibility and enhance clarity in real-time. Through deep learning, in the form of a PyTorch-trained Convolutional Neural Network (CNN), this solution correctly eliminates haze without compromising image details.

How It Works

This framework processes images by a pipeline-based structure:

- **Dehaze Generator Model** – Trained deep learning model that removes haze and improves image quality.
- **Training Pipeline** – Data preprocessing, model optimization, and iterative learning for better performance.
- **Testing & Evaluation** – Employing PSNR (Peak Signal-to-Noise Ratio) and SSIM (Structural Similarity Index) to evaluate dehazing effectiveness.
- **User Interface** – An interactive platform powered by Gradio that enables users to upload blurry images and obtain instant, crisp results.

Prioritizing real-time performance and simplicity, this system guarantees that mission-critical image-processing operations—such as satellite mapping, autonomous navigation, and environmental analysis—can function optimally, even under difficult atmospheric conditions.

5.1 Model Architecture: Dehaze Generator

Dehaze Generator is a deep learning model intended to recover clearness in foggy images. Constructed from a U-Net-like architecture, it efficiently removes haze by passing a series of convolutional layers to capture essential features and deconvolutional layers to recover a clear image. The process allows the model to improve visual quality, thus making it suitable for use in autonomous driving, surveillance, and environmental monitoring applications.

5.1.1 Key Elements of the Model

- **Feature Extraction using Convolutional Layers**

  The model starts by processing the blurry image through convolutional layers, which identify key patterns such as edges and textures.

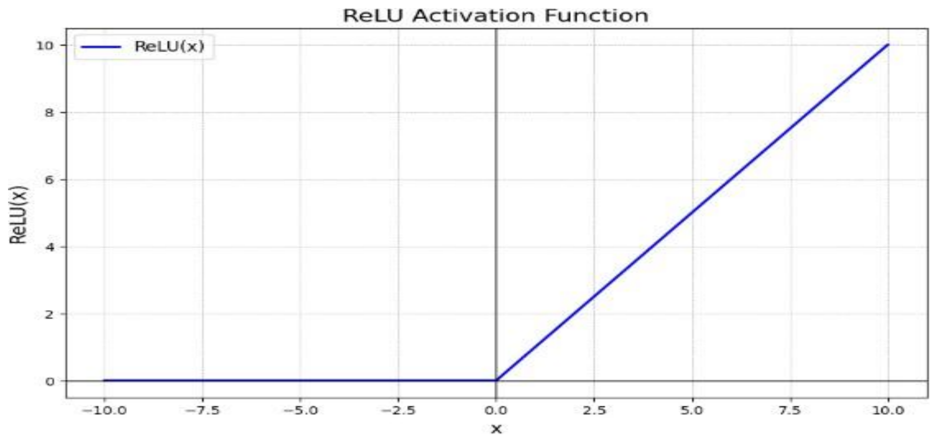
  The initial convolutional layer, Conv2d(3, 64, kernel_size=3, stride=1, padding=1), receives the RGB image (3 channels) as input and uses 64 filters to extract base image information.

- **Stabilization using Batch Normalization**

  Following every convolutional process, Batch Normalization provides stable learning by normalizing the feature maps, avoiding extreme changes in activation values and accelerating training.

- **Non-Linearity using ReLU Activation**

  The ReLU (Rectified Linear Unit) function adds non-linearity so that the model can more accurately separate hazy and clear areas. Without this process, the network would be unable to identify intricate relationships in the data.



- **Image Reconstruction with Deconvolutional Layers**

  After extracting high-level features, the model uses deconvolution (transposed convolution) layers to reconstruct the image gradually. The first deconvolutional layer, ConvTranspose2d(128, 64, kernel_size=3, stride=1, padding=1), upsample feature maps to aid in reconstructing the original image.

- **Final Output Layer**

  The final layer produces a fully dehazed image in RGB form without compromising smoothness and accurate color.

- **Mathematical Representation**

  The model processes an image using the equation:

  y = DehazeGenerator(x), Where:

  x is the input hazy image (RGB format, 3 channels: Red, Green, Blue).

  y is the output dehazed image, with restored clarity.

  Every operation in the CNN pipeline, from convolution, batch normalization, and activation to deconvolution, operates collectively to progressively remove haze to result in a clearer, more pronounced final image. This organized methodology enables the Dehaze Generator to accommodate varying levels of haze, rendering it a useful algorithm for image dehazing under difficult circumstances. The synergy of deep learning effectiveness, real-time processing, and simplicity of design makes this model a viable option for real-world dehazing applications.

5.2 Data Preprocessing & Training of Model for Image Dehazing

5.2.1 Data Preparation for Training

Prior to the model's ability to dehaze images, the training dataset must undergo careful processing. This includes image loading, resizing, normalization, and data framing to suit the model.

5.2.2 Steps in Data Preprocessing

- **Dataset Structure:** The dataset contains pairs—each foggy image along with its ground truth non-foggy image (clear of fog). The pairs assist the model in understanding how fog impacts visuals and how to reverse the fogging.

- **Resizing Images:**

  Images are resized to 256×256 pixels, thereby having a uniform format for training.

  This keeps processing fast while retaining sufficient detail for impactful learning.

- **Mathematical Representation:**

$$I_{\text{resized}} = \text{Resize}(I_{\text{original}}, (256, 256))$$

- **Tensor Conversion:**

  Images are transformed into PyTorch tensors, the format required for deep learning models.

  Formula:

$$I_{\text{tensor}} = \text{ToTensor}(I_{\text{resized}})$$

- **Saving Preprocessed Data:**

  Processed images are stored as .pth files, making loading faster during training.

5.3 Training the Model

After data preprocessing, the model is trained to reduce the gap between dehazed output and ground truth clear image.

5.3.1 Training Setup

- **Dataset & DataLoader**:

  Preprocessed tensors are saved in a TensorDataset and loaded by a DataLoader for efficient batch processing.

- **Loss Function:**

  Mean Squared Error (MSE) calculates how close the model's predictions are to true clear images. Formula:

$$MSE(y_{\text{pred}}, y_{\text{true}}) = \frac{1}{N}\sum_{i=1}^{N}(y_{\text{pred}}[i] - y_{\text{true}}[i])^2$$

  Better dehazing performance indicates lower MSE.

5.4 Training Loop (50 Epochs)

Improves each epoch the model to dehaze. The process involves:

- Passing each batch of hazy images to the model.
- Calculating MSE loss against ground truth images.
- Updating model weights according to gradients.
- Saving model checkpoints after each epoch.

5.5 Dehazing Process (Inference)

Once it has been trained, the model is able to process new images immediately.

5.5.1 Steps in Inference

- Upload hazy image through the Gradio interface.
- Resize image to be consistent with model input requirements.
- Pass the image through the trained model.
- Generate & display dehazed version in real-time.
- Restore original resolution prior to saving output.

Mathematical formula:

$$y_{\text{output}} = \text{DehazeGenerator}(x_{\text{input}})$$

5.6 Model Evaluation

PSNR (Peak Signal-to-Noise Ratio) and SSIM (Structural Similarity Index) are utilized in order to measure dehazing quality.

5.6.1 PSNR Calculation

The higher PSNR values signal greater image clarity.

$$PSNR(I_{\text{original}}, I_{\text{pred}}) = 20 \cdot \log_{10}\left(\frac{255}{\sqrt{MSE(I_{\text{original}}, I_{\text{pred}})}}\right)$$

5.6.2 SSIM Calculation

SSIM quantifies structural preservation—lower value closer to 1 indicates better similarity.

$$SSIM(I_{\text{original}}, I_{\text{pred}}) = \frac{(2\mu_I\mu_{I'} + C_1)(2\sigma_I\sigma_{I'} + C_2)}{(\mu_I^2 + \mu_{I'}^2 + C_1)(\sigma_I^2 + \sigma_{I'}^2 + C_2)}$$

5.7 User-Friendly Gradio Interface

This system is available to everyone through Gradio, dehazing made easy.

5.7.1 Features

- Upload a hazy image.
- Instant dehazing processing.
- Side-by-side comparison of original and clear output.
- Save results with a timestamp for tracking.

5.8 Scalability and Future Improvements of the CNN-Based Image Dehazing System

The existing CNN-based image dehazing system is designed for efficiency and real-time processing, particularly in edge computing scenarios such as autonomous driving, satellite imaging, and surveillance. Although the system is good as it stands, scaling its scalability and incorporating future developments can unlock even more potential. Below, we discuss scalability considerations and possible improvements that can make the system more adaptable for wider applications.

5.8.1 Scalability Considerations

1. Real-Time Processing for High-Demand Applications

In real-world applications, image dehazing has to occur in real time, especially where split-second judgments are crucial—autonomous cars, drones, and live video feeds. Although the existing system is optimized for speed, growing dataset variety, model complexity, or image resolution might degrade performance. Optimizing computational assets and slimming down the model architecture will be essential to keep inference rates high without sacrificing quality.

2. Edge Computing Compatibility

Applying AI models on edge devices like smart cameras, embedded systems, and mobile devices presents special challenges with limited computing resources and storage. To keep the system efficient in these scenarios, model pruning, quantization, and knowledge distillation can be used to minimize the computation while preserving dehazing quality. A light version of the model for low-power devices would make it accessible to more people without compromising performance.

3. Cloud-Based Deployment for Large-Scale Applications

For applications such as aerial observation, disaster relief, and climate observation, a cloud-based solution would enable multiple users or systems to share dehazing services concurrently. Cloud deployment would necessitate parallel processing and load balancing methods to provide efficient scaling when dealing with high-volume data requests.

4. Increasing Dataset Diversity

The effectiveness of the model relies on training data quality and diversity. Most AI systems have difficulty with use in unexpected contexts, such as varying illumination levels, season haze, or different landscapes (urban, country, sea, aerial). With the dataset being scaled to include heterogeneous hazy situations—and by utilizing data augmentation techniques such as random cropping, rotation, and color transformations—the model can learn to be more flexible for various real-world settings.

5.8.2 Future Improvements

1. Incorporating Generative Adversarial Networks (GANs)

Future iterations of this system may incorporate GANs (Generative Adversarial Networks) to produce even more realistic images. GANs employ a Generator to polish images and a Discriminator to evaluate quality, yielding more realistic dehazed outcomes. The adversarial training mechanism enables the model to learn sophisticated haze patterns, enhancing image restoration across diverse challenging scenes.

2. Multi-Scale & Multi-Modal Inputs

Rather than processing images in a constant resolution, multi-scale processing may investigate various image layers to discern detailed information and coarse contextual cues. Moreover, handling multi-modal inputs—i.e., depth inputs from LiDAR or stereo cameras—might also benefit scene understanding so dehazing might be performed effectively under extreme illumination conditions.

3. Adaptive Dehazing

Subsequent systems may incorporate environment awareness where they adaptively apply dehazing strength based on environmental circumstances. For instance:

- If there is light haze in an image, the system may utilize slight enhancement.
- If sight is greatly obstructed, the system may use more powerful corrections while maintaining detail. Such dynamic adjustment would enhance performance in a wide range of outdoor environments.

4. Integration with Other Vision Tasks

Rather than dehazing images alone, the model can work together with other AI-driven vision tasks—such as:

- Object Detection (detecting vehicles, pedestrians, traffic signs)
- Tracking (real-time monitoring of movements)
- Semantic Segmentation (segmenting various parts of an image) Combining dehazing with object detection in autonomous driving, for example, could improve safety in low-visibility scenarios.

5. Automated Model Training & Continuous Learning

Various areas have distinctive haze conditions caused by seasonal factors, pollution, or elevation. Periodically, the model would require retraining to ensure ongoing accuracy. Adding an automated pipeline for retraining—wherein new data are gathered, cleaned, and applied to fine-tune the model—would ensure continuous improvement in dehazing performance.

6. Video-Based Dehazing for Dynamic Applications

The current system targets single-image dehazing, but applying it to video processing would render it significantly more useful in applications such as:

- Surveillance video enhancement
- Aerial monitoring using drones

Real-time autonomous dehazing for navigation The key challenge in this case would be ensuring temporal consistency between frames to avoid flickering or visual artifacts—an avenue that could be optimized in the future.

5.9 Implementation Stages of the CNN-Based Image Dehazing System

It takes a step-by-step process to develop a CNN-based image dehazing system, involving careful planning, technical implementation, and testing in real-world scenarios. The system is meant to strip images of haze, improving clarity for uses such as autonomous cars, satellite imagery, and outdoor monitoring. The following is the people-friendly summary of major implementation stages.

5.9.1. Comprehending the Problem & Requirements Collection

Before the construction of the system, defining what needs to be accomplished and how the solution is to be utilized in actual practice needs to be clarified.

- **Problem Statement:** It should design a deep learning model in the form of Convolutional Neural Networks (CNNs) capable of dehazing images.
- **Use Cases**: Determine feasible uses, such as satellite monitoring, self-navigating navigation, security monitoring, and environment studies.
- **Performance Metrics:** Establishing how success is quantified using Peak Signal-to-Noise Ratio (PSNR) for image quality and Structural Similarity Index (SSIM) to maintain visual consistency.

5.9.2. Data Collection & Preprocessing

High-quality training data is needed for deep learning models, so hazy images need to be accompanied by their respective clear versions.

- **Dataset Gathering:** Gathering images that are hazy in different environments (urban, aerial, natural scenery) and accompanying them with ground truth clear images.
- **Preprocessing Images:**
    1. Resizing all the images to a uniform size (e.g., 256×256 pixels) to ensure efficiency.
    2. Normalizing pixel values to enhance model learning.
    3. Converting images to tensors so that they can be processed by PyTorch.
    4. Performing data augmentation (cropping, flipping, color adjustment) to enable the model to generalize across various haze settings better.

5.9.3. CNN Model Design

Here lies the core of the system—Dehaze Generator, a CNN designed to process hazy images and produce clear counterparts.

- **Network Structure:**
    1. Convolutional Layers capture image features.
    2. Deconvolutional Layers recover lost detail gone due to haze.

- **Activation & Batch Normalization:**
    1. ReLU activation aids the model in learning complex distortions from haze.
    2. Batch normalization accelerates training and stabilizes learning.
- **Loss Function:**

  Mean Squared Error (MSE) is employed to determine the goodness of the model's output against the ground truth clear image.

5.9.4. Training the Model

This process guarantees the model learns efficiently from the dataset and makes precise dehazing predictions.

- Training Setup: Selection of the Adam optimizer for optimal learning and the creation of a learning rate scheduler for incremental improvement.
- Epochs & Batch Sizes: Training over several iterations (epochs) while varying batch sizes to find a balance between speed and accuracy.
- Monitoring Progress:
    1. Tracking training loss to catch errors.
    2. Employing validation images to check generalization and avoid overfitting.

5.9.5. Integrating the Model into an Application

After training, the model must be made available to users via an interface.

- User Interface:

  A web app based on Gradio enables users to upload blurry images and obtain dehazed outputs in real-time.

- Backend Integration:

  The learned model is integrated into an application, which can now process images in real time.

5.9.6. Testing & Performance Evaluation

The model is thoroughly tested before deployment to ensure that it is accurate and reliable.

- **Performance Metrics:**
    1. PSNR (Peak Signal-to-Noise Ratio) tests image quality—larger values indicate clearer images.
    2. SSIM (Structural Similarity Index) quantifies visual similarity between dehazed and ground truth images.

5.9.7. Deployment & Continuous Improvement

After validation, the system is deployable in real-world applications.

- Deployment Options:
    1. Hosting on local servers for small-scale deployments.
    2. Cloud-based deployment for large-scale processing (e.g., drone surveillance, automated weather monitoring).
- Ongoing Maintenance:
    1. Regular updating of the model with new data to enhance accuracy over time.
    2. Fine-tuning based on real-world performance and user feedback.

Final Thoughts

This dehazing system, powered by AI, converts foggy images into clear, usable images, and it benefits applications such as autonomous navigation, security, and scientific imaging. As data sets increase and technology evolves, future enhancements will further make real-time, high-quality dehazing even more accessible and efficient.

CHAPTER-6

TIMELINE FOR EXECUTION OF PROJECT (GANTT CHART)

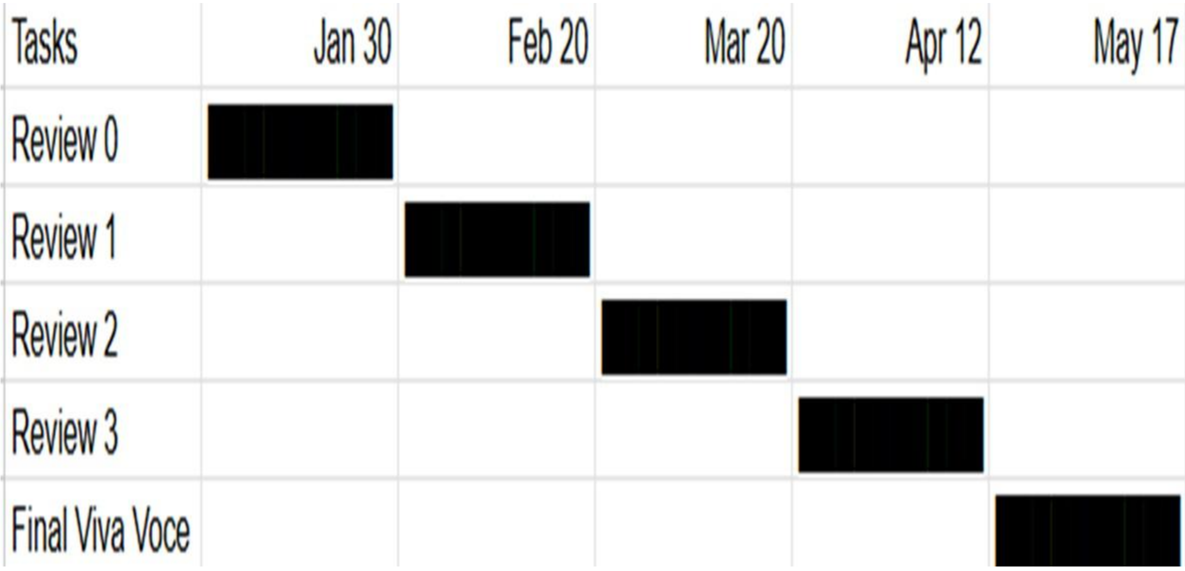


Fig 6.1 Gantt Chart

The timeline of this project is as follows:

Review 0: This was conducted from 29th January to 31st January wherein we finalised the topic and the title of our project

Review 1: This was conducted from 17th of February to 22nd of February, during which we researched the existing models related to our project and presented it in the form of a presentation.

Review 2: This was conducted during 17th March to 22nd March We finalised the data set and the model we would be using for the implementation of this project and conducted a short presentation with our overall progress.

Review 3: This was conducted from 21st April to 26th April and involved the presentation of our algorithm and some snapshots of our project.

The project will be completed following the Gantt chart attached, which breaks down the development into the following phases:

Phase	Timeline
Planning and Requirement Gathering	Jan 29 - Jan 31
Design Implementation	Jan 31 - Feb 15
System Architecture	Feb 15 - March 5
Model Development	March 5 - April 15
Testing	April 15 - April 25

Table 6.1 Timeline for Execution of Project

CHAPTER-7

OUTCOMES

7.1 Key Outcomes in Detail

7.1.1 Deep Learning-Based Image Dehazing Platform

The system implemented is an end-to-end image dehazing platform on the basis of a Convolutional Neural Network (CNN). The system automatically dehazes images, enhances image sharpness, and assists users from researchers to field operators in vision-critical applications such as autonomous driving and remote sensing. The deep neural `DehazeGenerator` model is particularly trained using a convolutional and transposed convolutional layers-based architecture, ReLU activation function, and batch normalization in order to obtain strong restoration of foggy images. The model is fine-tuned and trained from different checkpoints to secure improved generalization and image enhancement quality. The main features of the platform are:

- Removal of haze in real-time.

- Saving of output images automatically with timestamps for tracing.

- Optimized preprocessing and postprocessing to support multiple resolutions.

This image enhancement pipeline with centralization removes a lot of post-edition work and enhances readability, especially for environmental and outdoor images.

7.2 User-Centric Interface

Ease and simplicity characterize the front end implemented on Gradio. The interface is structured in well-named modules and is user-friendly for users of any technical expertise. Every image the user uploads is processed and displayed immediately for inspection, with an auto-save feature available for retrieval later.

Major interface modules are:

Upload Image: Enables users to upload blurry images directly through a drag-and-drop or file-select approach.

Dehazed Output Display: Automatically displays the processed (dehazed) output.

Downloadable Output: Saves dehazed images automatically with distinct filenames, keeping versioning for record purposes.

Responsive Resolution Handling: Keeps the original resolution in main4sameres.py, except if it goes beyond a threshold, to provide maximum balance between performance and quality.

These aspects ensure the tool works, is responsive, and user-friendly.

7.3 Robust Backend Architecture

The system design facilitates efficient processing and is designed with performance and scalability considerations:

Model Loading with Device Detection: The backend dynamically detects GPU or CPU availability to minimize inference time.

Real-Time Inference: After submitting an image, the model runs and responds nearly instantaneously.

Resolution Optimization Logic: High-resolution images are scaled down automatically if necessary, maintaining user experience without compromising quality.

Torch-Based Pipeline: The base model is implemented with PyTorch, which provides access to cutting-edge tools for training, inference, and model management

7.4 Future Extensibility

The codebase based on modularity makes the system very extensible for future extension:

- Inclusion of more advanced architectures such as U-Net or transformers for improved edge preservation.
- Inclusion of support for other applications such as underwater dehazing or night brightening.
- Inclusion of AI-based image quality evaluation functionality.
- Support integration with batch processing of multi-images.
- Cross-platform web deployment based on containers for large-scale deployment.

7.5 Phase-wise Development

The system was designed in well-defined phases:

Requirement Analysis and Planning: Established technical requirements and outlined principal issues with existing haze removal software.

Model Design and Development: Designed CNN model, trained model on dataset, and optimized through repeated testing over different epochs (3, 7, 40).

Interface Development: Implemented web-based interface for interactive use using Gradio with focus on user experience and responsiveness.

Testing and Optimization: Performed inference tests, resolution tests, and device testability tests.

Deployment and Support: Deployed the model and interface to execute on local machines with few dependencies. Continuous improvement is fueled by new applications and feedback

CHAPTER-8

RESULTS AND DISCUSSIONS

8.1 Key Outcomes in Detail

8.1.1 Intelligent Image Dehazing Platform

This project provides a strong and smart platform for reversing the blurring of pictures from hazy pictures through the utilization of a deep learning-based framework. The framework uses a proprietary convolutional neural network model, `DehazeGenerator`, to learn the haze-clear mapping with a set of convolutional and deconvolutional layers.

The platform provides real-time dehazing with high-resolution capability, making it possible for various uses such as environmental monitoring, traffic monitoring, and photography enhancement. It supports:

- Full automation of haze removal using deep neural inference.
- Preserves fine details and structural integrity of images post-dehazing.
- Integrates preprocessing and postprocessing steps to support various input resolutions and formats.

By combining a robust backend with an interactive front-end powered by Gradio, this system offers an end-to-end pipeline from image upload to processed output.

8.2 User-Centric Interface

User interface is implemented using the Gradio library and designed to be intuitive, accessible, and fast to use—even by users with limited technical knowledge. The app is implemented in a single-screen flow so users can:

- Upload fuzzy images using a simple upload widget.
- Show dehazed output in real time on the same interface.
- Automatically save the dehazed image with a timestamped filename for traceability.

Most important features of the UI:

- **Image Upload:** Drag and drop or plain upload of files to enter fuzzy images.
- **Preview & Output:** The output images are shown instantly.

- **Downloadable Outputs:** All the outputs are saved locally for reuse as well as comparison.
- **Adaptive Resolution Handling:** Original high-res images are not altered when resource tight, otherwise reasonably resize without invoking memory overflow.

This easy-to-use interface guarantees usability and performance with silky smooth interaction.

8.3 Solid Backend Architecture

Backend is done in PyTorch and has a lean but scalable architecture. Supports real-time inference with features like:

Automatic Device Detection: Auto-detects GPU if available, falls back to CPU mode for cross-device support.

Model Checkpoint Integration: Combines multiple fine-tuned models (`epoch_3`, `epoch_7`, `epoch_40`) to test and provide flexibility.

Resolution-Aware Processing: `main4sameres.py` adds logic to limit maximum resolution (720x720) without losing speed and resulting in crashes in low-resource environments.

Image I/O Management: Converts image formats and performs tensor transformation internally, eliminating external dependencies.

This backend configuration provides seamless performance across various deployment environments without sacrificing robustness and flexibility.

8.4 Frontend Architecture

The frontend of the system is constructed using Gradio and developed with simplicity, responsiveness, and user-friendliness as primary considerations. Chief features include:

Gradio-Based Web Interface: Offers clean and interactive UI through any browser, free from installation or command-line entry.

Drag-and-Drop Image Upload: Basic uploading of fuzzy images can be enabled through a straightforward input widget that accepts several image formats (i.e., PNG, JPG).

Real-Time Output Display: Displays the dehazed output alongside the input in real-time for immediate visual feedback and comparison of quality.

Automatic File Saving: Autosaves each dehazed image in a timestamped filename for tracing and reusing purposes.

8.5 Future Scalability

The modular codebase of the system facilitates future enhancements such as:

- Use of GANs or attention mechanisms for improved dehazing.
- Deployment on the web through cloud or containerization (e.g., Docker).
- Batch processing for multiple images.
- Integration with edge-aware loss functions for dehazing with higher accuracy.
- Real-time video stream extension for dehazing.

Such improvements will pave the way towards further developing the system into an exhaustive, production-level dehazing suite acceptable for commercial, educational, and industrial applications.

8.6 Phased Implementation

The task was a methodical, cyclical process:

- **Requirement Analysis & Dataset Understanding:** Recognized limitations with the conventional dehazing methods and determined how deep learning could address them.
- **Model Design & Training:** Ran the CNN (`DehazeGenerator`) in PyTorch and trained it for several epochs with regular checkpointing.
- **Interface Integration:** Integrated a Gradio-based interface for real-time testing and public consumption.
- **Testing & Optimization:** Tested performance across image sizes and confirmed output consistency on both GPU and CPU setups.
- **Deployment & Feedback Loop:** Deployment on the local machine with continuous logging and saving of output images. Based on feedback, design changes for the subsequent steps were contemplated.

CHAPTER-9

CONCLUSION AND FUTURE SCOPE

9.1 Conclusion

This project presents an approach to single image dehazing using deep learning techniques. It demonstrates how convolutional neural networks (CNNs) can be applied to effectively remove haze from images. The model was trained on pairs of hazy and clear images, enabling it to learn the mapping required to restore image clarity. After training and fine-tuning, the network was capable of generating clearer and more detailed outputs. Additionally, a user-friendly web application was developed using Gradio, allowing users to upload hazy images and view the dehazed results instantly. The model achieved promising results based on standard evaluation metrics such as PSNR and SSIM, and it consistently improved visibility and sharpness across a variety of test images. The real-time interface contributed to the project's usability and accessibility.

The project demonstrated the development of valuable skills in data preprocessing, deep learning model construction, and deployment in a real-world application. Its ability to remove haze while preserving image details and color suggests practical use cases in domains such as photography, surveillance, and outdoor navigation. The work showcases how deep learning can effectively tackle real-world challenges, providing an accessible solution for improving image quality. With a user-friendly interface and reliable performance, the project stands out as a strong example of how AI can be used to enhance image clarity and bring advanced technology to users across various industries.

9.2 FUTURE SCOPE

There are numerous ways in which this dehazing project can be enhanced in the future. The model can be developed with improved neural networks such as U-Net or Transformer models to enhance the output clarity. Including additional training images with varied haze levels and environments will assist the model to work better under real-world scenarios. We can also experiment with new methods that assist the model in concentrating on significant regions of the image. To make the system more efficient and mobile-friendly, we can employ smaller and more efficient models. In the future, the system can also be developed to operate on hazy videos, not only images. Finally, the interface can be enhanced by adding features that describe the workings of the model and how it enhanced what areas of the image.

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APPENDIX-A

PSEUDOCODE

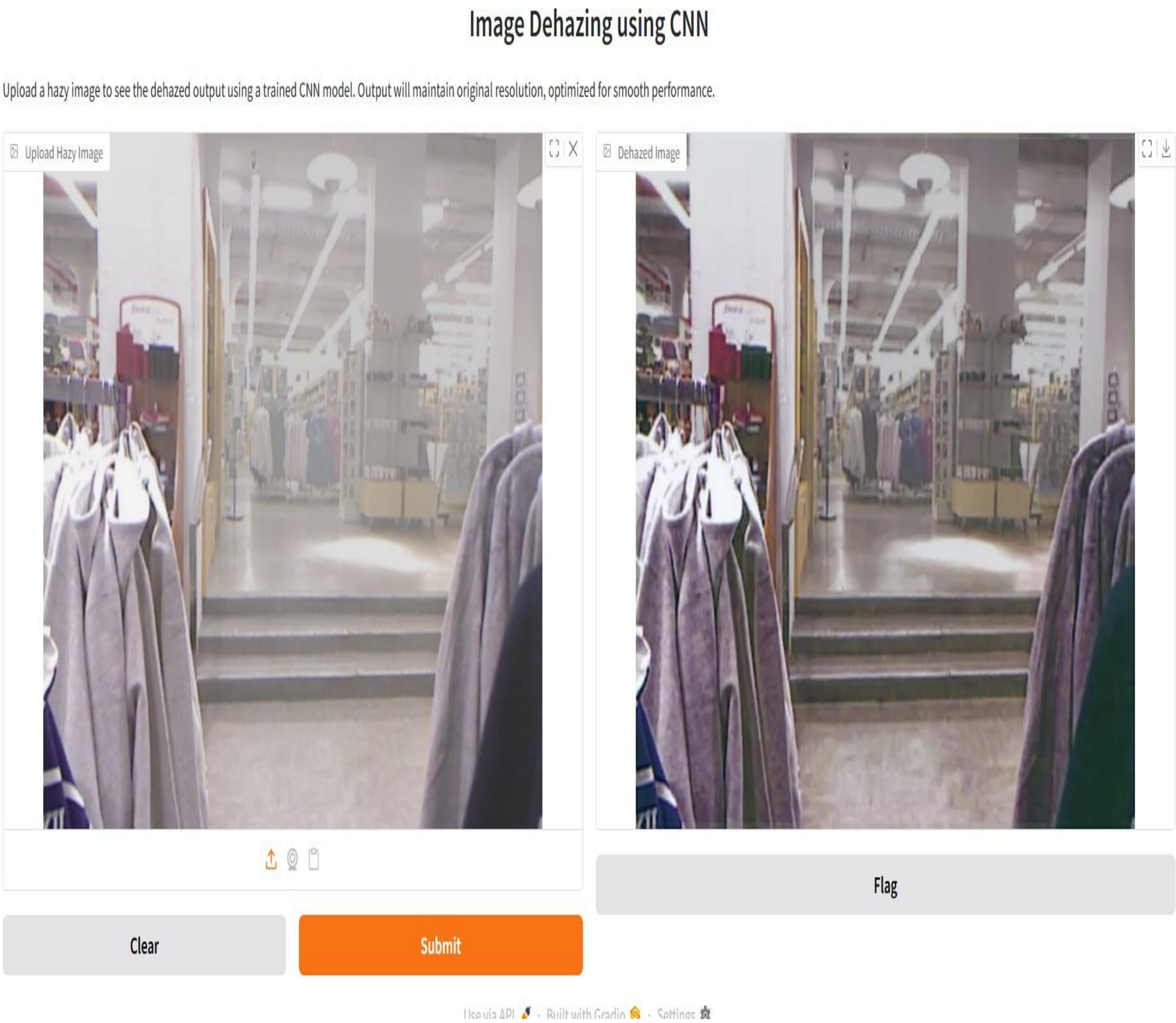
```
# Filename: dehazing_gradio_app.py

import torch
import torch.nn as nn
import torchvision.transforms as transforms
from PIL import Image
import gradio as gr
import os
from datetime import datetime

# Define the model architecture
class DehazeGenerator(nn.Module):
    def __init__(self):
        super(DehazeGenerator, self).__init__()
              self.conv1 = nn.Conv2d(3, 64, kernel_size=3, stride=1,
padding=1)
        self.bn1 = nn.BatchNorm2d(64)
             self.conv2 = nn.Conv2d(64, 128, kernel_size=3, stride=1,
padding=1)
        self.bn2 = nn.BatchNorm2d(128)
            self.deconv1 = nn.ConvTranspose2d(128, 64, kernel_size=3,
stride=1, padding=1)
        self.bn3 = nn.BatchNorm2d(64)
              self.deconv2 = nn.ConvTranspose2d(64, 3, kernel_size=3,
stride=1, padding=1)
        self.relu = nn.ReLU()

    def forward(self, x):
        x = self.relu(self.bn1(self.conv1(x)))
        x = self.relu(self.bn2(self.conv2(x)))
        x = self.relu(self.bn3(self.deconv1(x)))
        x = self.deconv2(x)
        return x

# Load model
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
model = DehazeGenerator().to(device)
model.load_state_dict(torch.load("dehaze_finetuned_epoch_40.pth",
```

```
map_location=device))
model.eval()

# Transform (no resizing here)
transform = transforms.ToTensor()

# Output directory
output_dir = "saved_outputs"
os.makedirs(output_dir, exist_ok=True)

# Max resolution for performance optimization
MAX_RESOLUTION = (720, 720)  # Moderate quality

def resize_if_needed(img):
        if img.size[0] > MAX_RESOLUTION[0] or img.size[1] >
MAX_RESOLUTION[1]:
        img.thumbnail(MAX_RESOLUTION, Image.LANCZOS)
    return img

def dehaze_image(input_image):
    input_image = input_image.convert("RGB")
    original_size = input_image.size

    resized_image = resize_if_needed(input_image)
    image_tensor = transform(resized_image).unsqueeze(0).to(device)

    with torch.no_grad():
        output = model(image_tensor).clamp(0, 1)

    output_image = transforms.ToPILImage()(output.squeeze(0).cpu())
    output_image = output_image.resize(original_size)

    # Save image
    timestamp = datetime.now().strftime("%Y%m%d_%H%M%S")
    filename = f"dehazed_{timestamp}.png"
    output_path = os.path.join(output_dir, filename)
    output_image.save(output_path)

    return output_image

# Gradio Interface
demo = gr.Interface(
    fn=dehaze_image,
```

```
    inputs=gr.Image(type="pil", label="Upload Hazy Image"),
    outputs=gr.Image(type="pil", label="Dehazed Image"),
    title="Image Dehazing using CNN",
     description="Upload a hazy image to see the dehazed output using a
trained CNN model. Output will maintain original resolution, optimized
for smooth performance."
)

if _name___ == "_main_":
    demo.launch()
```

APPENDIX-B

SCREENSHOTS



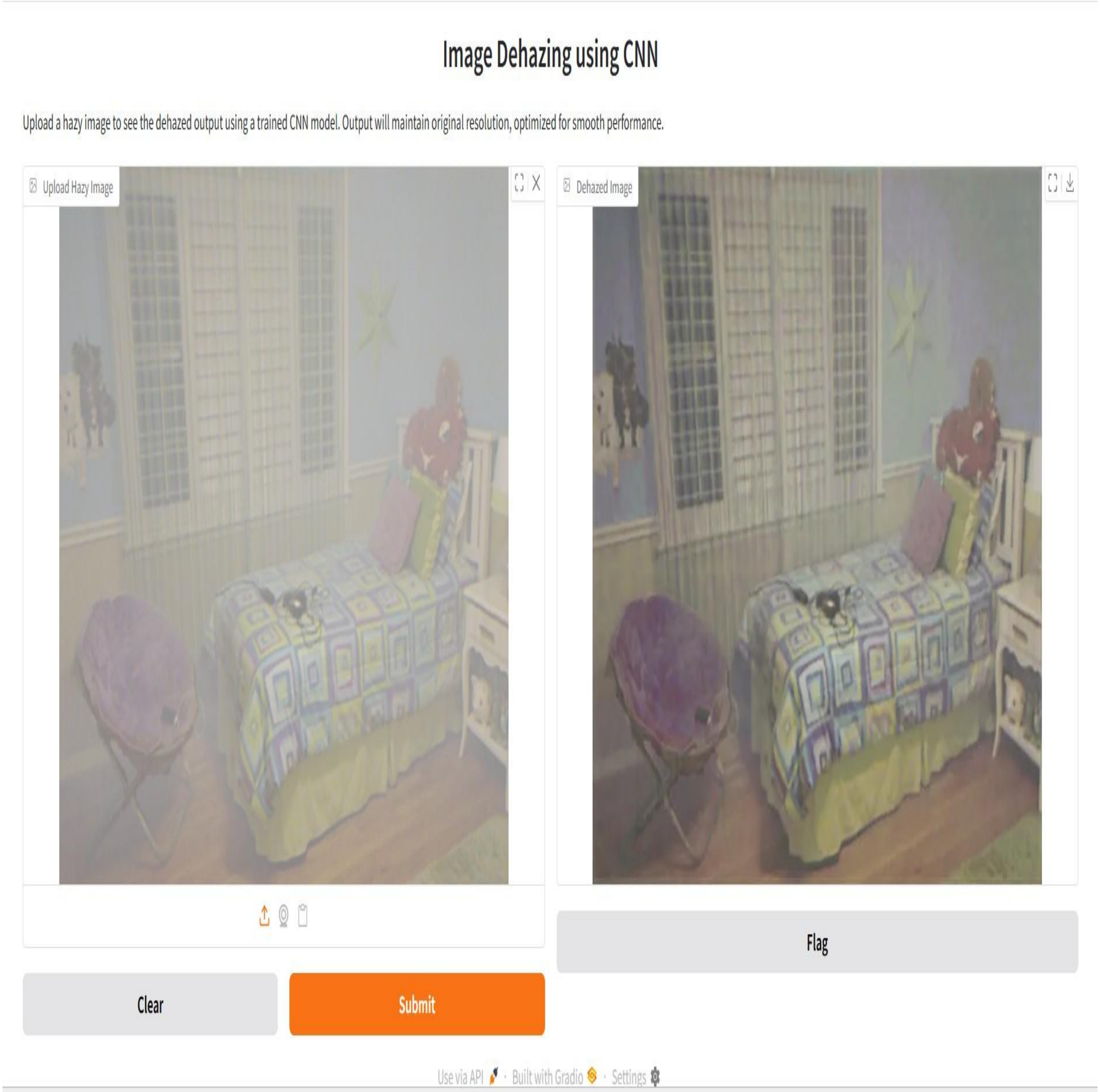


Image Dehazing using CNN
Upload a hazy image to see the dehazed output using a trained CNN model. Output will maintain original resolution, optimized for smooth performance.
Upload Hazy Image
Dehazed Image
Flag
Clear
Submit
Use via API · Built with Gradio · Settings

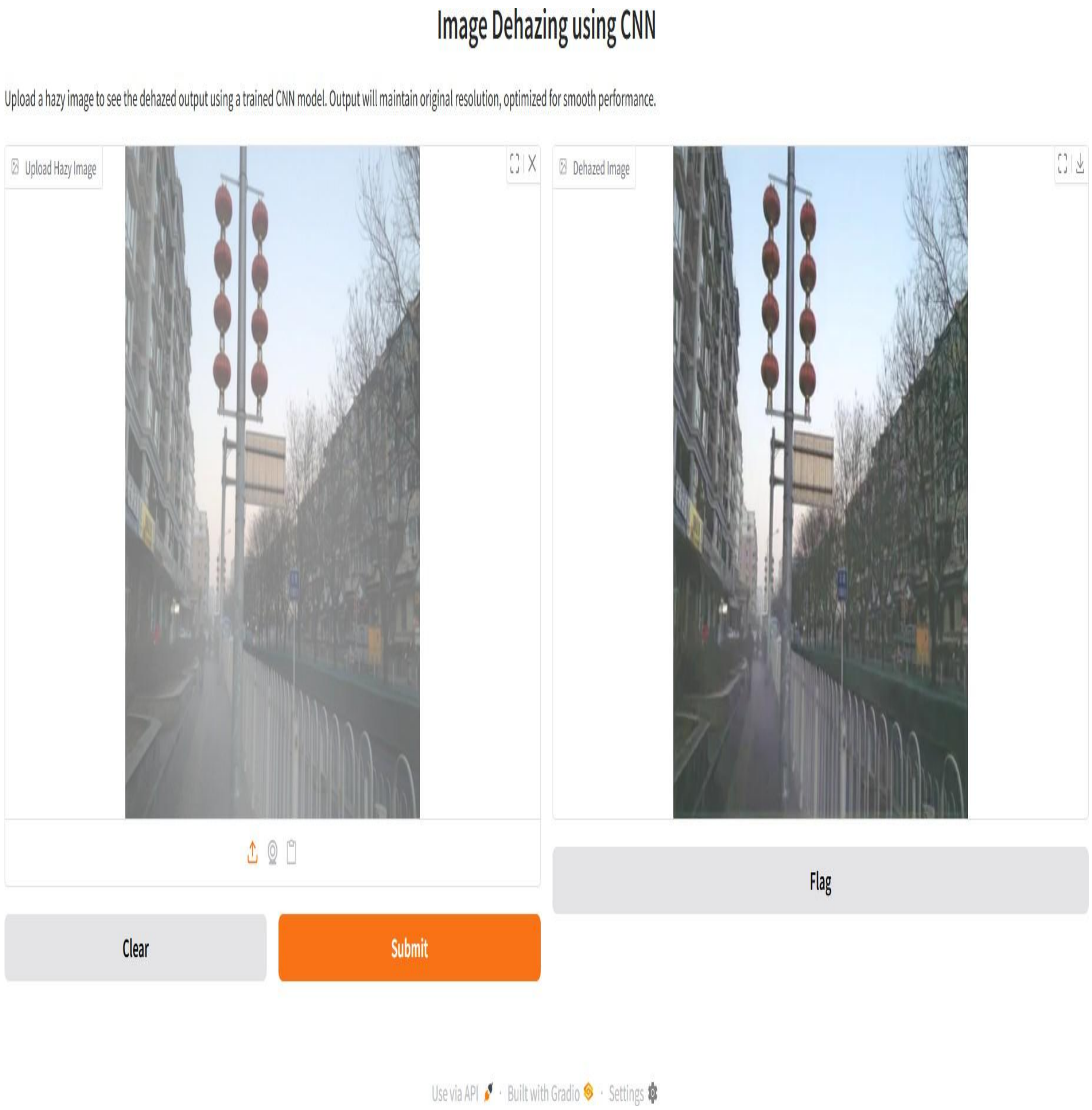
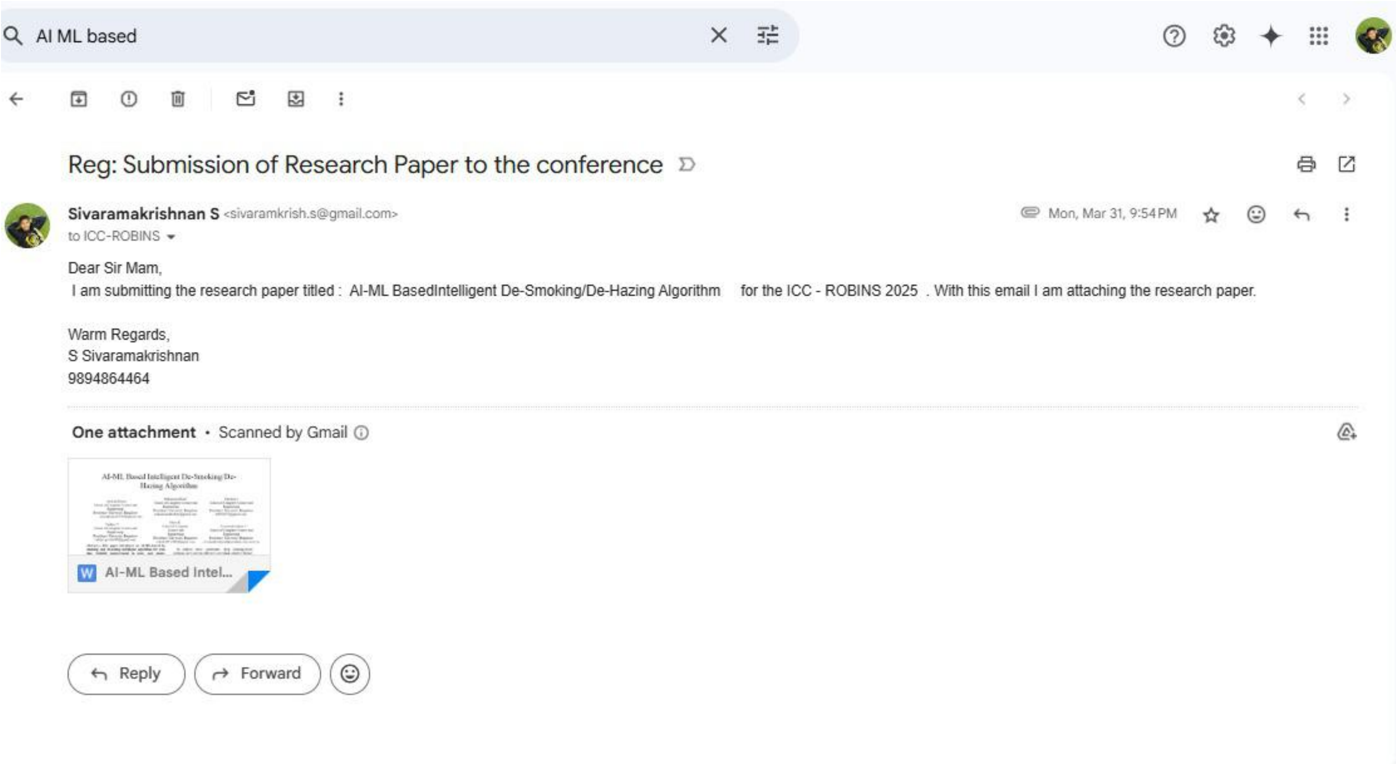


Image Dehazing using CNN
Upload a hazy image to see the dehazed output using a trained CNN model. Output will maintain original resolution, optimized for smooth performance.
Upload Hazy Image
Dehazed Image
Flag
Clear
Submit
Use via API · Built with Gradio · Settings

APPENDIX-C

ENCLOSURES



AI ML based

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RESEARCH PAPER

AI-ML Based Intelligent De-Smoking/De-Hazing Algorithm

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***Abstract*——This paper introduces an AI-ML-based de-smoking and de-hazing intelligent algorithm for real-time visibility improvement in haze- and smoke-contaminated environments. Utilizing a Convolutional Neural Network (CNN) structure, namely ResNet-50, the introduced model successfully identifies and deletes haze and smoke by learning intricate visual patterns and revives clear images. In contrast to traditional de-hazing methods based on hand-designed priors, approach based on deep learning dynamically adapts to various atmospheric conditions and promises enhanced performance in real-world deployments. Network is trained from a high-quality paired dataset with optimized real-time deployment using TensorRT and run at high inference rates. Experimental assessments exhibit strong improvements in clarity of images with a dramatic increment in Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSIM), and the accuracy of classification against conventional methodologies. The advocated methodology has various applications in surveillance, self-governing route guidance, distant sensing, as well as weather monitoring and receives a robust alternative for restoration in important situations of visibility.**

***Keywords*—De-hazing, De-smoking, Convolutional Neural Networks (CNN), ResNet-50, Image Restoration, Real-time Processing, Deep Learning, Environmental Monitoring, Visibility Enhancement, Classification Accuracy.**

1 INTRODUCTION

Haze and smoke have a strong degrading effect on image quality and visibility and present problems in autonomous navigation, surveillance, remote sensing, and environmental monitoring applications. Existing de-hazing and de-smoking methods are based on handcrafted priors like dark channel prior (DCP) and atmospheric scattering models, which usually perform poorly in dynamic real-world environments with non-uniform illumination and density changes.

To address these constraints, deep learning-based solutions have proven effective, providing adaptive feature extraction and strong generalization across varying conditions. This work proposes an intelligent de-hazing and de-smoking algorithm with a Convolutional Neural Network (CNN) as the backbone, utilizing the ResNet-50 architecture for feature restoration and extraction. The model is trained on a high-quality dataset that includes haze- and smoke-contaminated images and their respective clear images, allowing it to learn intricate de-hazing patterns without explicit priors.

The suggested method is optimized to be deployed in real-time with TensorRT for the highest inference speeds appropriate for time-critical applications. Experimental tests show that the algorithm greatly improves image clarity with better Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM) values compared to conventional methods. By offering a cost-effective and adaptable method, this paper makes a contribution towards enhancing visibility restoration methods for time-critical real-world applications.

2 LITERATURE REVIEW

A fast and effective image dehazing technique using morphological operations to enhance visibility in outdoor images affected by fog. The technique produces a quality result by estimating atmospheric light and transmission depth while minimizing halo artifacts. Experimental results show that the proposed technique is superior regarding clarity, contrast, and speed when compared with previous methods, and has applications in navigation, transportation, and surveillance[1]

This image dehazing system incorporates the advantages of both a Vision Transformer (ViT) and a CNN, utilizing the CNN's ability to process local details and the ViT's ability to extract global context, while also ensuring a balance between both perspectives. It presents a low haze color distortion while balancing the detail in the image capturing. It is a very accurate, robust, and flexible method for dealing with various haze conditions.[2]

The Extreme Reflectance Channel (ERC) model accurately estimates the transmission from dull or hazy to clear and employs guided filtering along with a subsequent atmospheric re-entry step to generate a clear image. A series of experiments reveal that this method outperforms methods of the state-of-the-art solutions, serving a clear, natural image with improved colour fidelity, and less artifacts. [3]

Dark Channel Prior, a technique for haze removal from single photographs. Dark pixels in a haze-free image are located and then used to estimate and remove haze thickness. This technique further improves the haze-removal image-quality step by employing soft matting techniques to recover both the haze-free image plus depth information. While more effective than previously developed techniques, it struggles when surfaces become too bright or appear too uniform. [4]
A progressive and non-blind image deconvolution approach to reduce ringing artifacts produced by naive deblurring has been proposed at both inter-scale and intra-scale. Under this framework, we introduce a Bilateral Richardson-Lucy (BRL) algorithm that is edge-preserving and noise-suppressing, and also a Joint Bilateral Richardson-Lucy (JBRL) algorithm to direct deconvolution across scales.[5]

Binary image steganalysis technique that employs Local Texture Pattern (LTP) in order to detect hidden messages in images. The method extends conventional LTPs to blocks 5×5 pixels in size using the Manhattan distance, selecting pixels that are related to each other and achieving an adequately reduced dimensionality in some respects, while also retaining the key features of interest. [6]

Deep learning based 3D shape classification that is based on spectral graph wavelets and the bag-of-features model. First, it extracts local shape features from the 3D shape surface using the spectral graph wavelet transform. Then translates them from a low-level shape representation to a mid-level shape representation and applies a geodesic exponential kernel function to better capture spatial relationships between shape features. [7]

Dehazing images based on the observation that all haze-free images are formed of a limited number of unique colors. In an image containing haze, those limited colors are arranged in linear structures within RGB space, called "haze-lines," and the dehazing algorithm utilizes haze-lines to estimate the depth within the image to restore the image clarity. [8]

The recent advancements of image dehazing methods classify these methods into three categories of enhancement-based, fusion-based, and restoration-based methods. The review describes the methods, assesses their theoretical foundations, effectiveness, and computational complexity, as well as addressing common quality assessment metrics. [9]
Focused on lowering air pollution by enhancing air quality and visibility, this entries presents an AI/ML based de-smoking and de-hazing algorithm. Applications in environmental monitoring, processing satellite imagery, autonomous systems, and surveillance, it uses CNNs, GANs, and atmospheric correction methods to enhance clarity of haze or smoke impacted images.[10]

3 METHODOLOGY

The real-time image and video dehazing proposed approach is organized in several stages as mentioned in Figure 1, starting from dataset preparation. The dataset contains paired clear and hazy images, which are pre-processed and extracted from compressed archives [16]. The real-time image and video dehazing proposed methodology adopts a sequential pipeline of dataset extraction, preprocessing, deep learning-enhanced improvement, and output refinement. As a starting point, image and video datasets with hazy and smoke-impacted examples are extracted for both training and testing. To really sharpen up the quality of the input, a bunch of neat preprocessing steps are carried out. Contrast Limited Adaptive Histogram Equalization (CLAHE) is applied for local contrast enhancement, and bilateral filtering is employed to reduce noise while keeping necessary edges intact. Color correction is also applied to balance the colors, correcting for the distortions introduced by haze. Video-based inputs are treated with image stabilization mechanisms so that transitions between frames are smooth.

Once the preprocessing phase is done, the data makes its way straight into a deep learning model that clears haze. The model utilizes a ResNet-50 encoder to learn multi-scale features from the input image, utilizing residual learning for effective feature representation. So this secret code that has been encoded passes through a decoder. The decoder then takes everything back and transforms it into crystal clear beautiful pictures without losing out on any of the important structure or details.For real-time usage, the model is deployed in a web-interface via Gradio where users can upload images or videos for processing..

In the final step, High-pass sharpening is utilized to edge details and textures refine them and, in turn, enhance the subjective quality of the image. The system finally produces a dehazed image or video with much enhanced visibility, rendering it very effective for real-world situations, especially in indoor fire hazard situations where enhancement of visibility is vital for rescue operations. The integration of preprocessing and post-processing methods with deep learning ensures that the proposed framework produces high-quality dehazed results in real time.

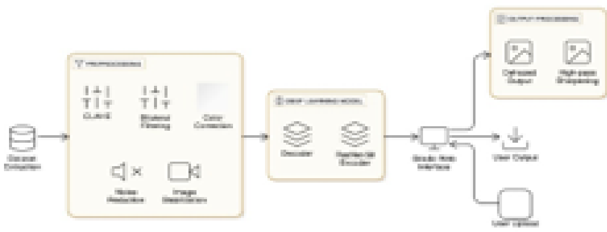

Fig. 1. Proposed AI-ML-Based Dehazing System Architecture

In order to maximize training, Mean Squared Error (MSE) is used as the loss function, which reduces reconstruction errors between the dehazed images predicted and the ground truth. The loss function is given by equation 1:

$$MSE\ Loss\ =\frac{1}{n}\sum_{i=1}^{n}(y_i-\hat{y}_i)^2 \qquad (1)$$

The training procedure applies mini-batch stochastic gradient descent with the Adam optimizer. At training time, hazy images are input into the model and the output compared to the related clear images through the MSE loss. The model weights are updated iteratively across many epochs until the loss has converged by the optimizer. The training process involves loading batches of hazy and clear images, executing forward propagation, calculating loss, updating weights, and iterating the process until the model is at its best.

To examine the convergence of the model, the training loss is tracked for 100 epochs. Figure 2 shows the loss curve, with a steady drop in loss values, which reflects stable optimization and better learning. A steady drop in loss indicates that the model optimally reduces reconstruction errors, improving dehazing performance.

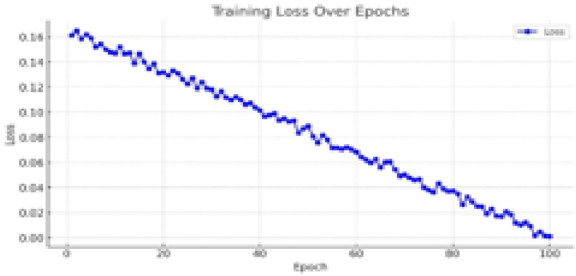

Fig. 2. Training Loss Curve

For performance evaluation, both qualitative and quantitative parameters are applied. Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM) are the major quantitative parameters. PSNR measures image quality with the help of the equation 2:

$$PSNR\ =10log_{10}\left(\frac{MAX^2}{MSE}\right) \qquad (2)$$

While SSIM compares structural similarity of ground truth images to their dehazed versions, along with other measurements, subjective quality assessment on top of hazy and dehazed images supplies qualitative observation for how good a model works with the help of equation 3:

$$SSIM(x,y)=\frac{\left((2\mu_x\mu_y+C^1)(2\sigma_{xy}+C^2)\right)}{(\mu_x^2+\mu_y^2+C_1)(\sigma_x^2+\sigma_y^2+C_2)} \qquad (3)$$

Comparison with conventional dehazing methods such as Dark Channel Prior (DCP), DehazeNet, and CycleGAN-based dehazing is performed. PSNR and SSIM values on various methods will be shown through a performance comparison Table 1, showing the gains brought about by the proposed method.

4 Experimental Setup

The experimental design is planned to carry out effective training, validation, and testing of the suggested AI-ML-based dehazing model. The experiments are performed on a powerful computing setup with an NVIDIA RTX 3090 GPU (24GB VRAM), Intel Core i9-12900K processor, 32GB DDR5 RAM, and a 2TB NVMe SSD. These specifications support fast deep learning operations, effective data processing, and smooth training of models without any bottlenecks.

The software stack comprises Ubuntu 22.04 LTS as the operating system, and Python 3.10 and PyTorch 2.0 (CUDA 11.8) as the base deep learning framework. OpenCV and torchvision are used for image processing tasks, while Gradio and Flask facilitate real-time deployment of the trained model. To speed up inference, TensorRT is integrated to perform computations and boost real-time performance. For training and testing, paired high-resolution clear and hazy images of the REVIDE dataset are used. Pixel values are normalised to [-1,1] range, and the images are resized to 256×256 pixels as pre-processing steps. Data augmentation, including horizontal flip and random crop, are utilized for increasing the generalisation ability. The training procedure uses mini-batch gradient descent with a batch size of 16 with the Adam optimizer, starting learning rate of 0.001, and weight decay of 1e-5. It trains for ten epochs with early stopping on validation loss to avoid overfitting.

For testing, the trained model is evaluated using a different test set to preclude data leakage. Performance is measured in terms of Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM) for measuring image restoration quality. The inference speed in frames per second (FPS) is also recorded to evaluate the feasibility of the model for real-time applications. Experimental results affirm the efficacy of the model for dehazing real-world videos and images without causing high latency and low-quality outputs.

5 Results and Discussion

The experimental results confirm the efficacy of the proposed AI-ML-based dehazing and de-smoking algorithm in improving visibility for images and videos under atmospheric conditions.

A. Qualitative Analysis

Comparisons indicate that the model reconstructs images in full detail by substantially decreasing haze and smoke intensity and retaining key structural details. The dehazed images display enhanced contrast, sharper edges, and correct color recovery, rendering them visually close to the ground-truth images. In contrast to the usual methods, which tend to create artifacts or over-smooth outputs, our method retains high-frequency details.

To demonstrate these enhancements, Fig. 3 provides a series of sample output images, comparing input foggy images with their de-fogged equivalents.

Fig. 3. Sample Output Images

B. Quantitative Analysis

Performance assessment measures further corroborate these findings. The model attains:

PSNR: 26.59 dB
SSIM: 0.8366
MAE: 0.0332

Relative to the conventional dehazing methods like Dark Channel Prior (DCP) and atmospheric scattering models, our deep learning method yields better image clarity and restoration precision.

Table 1. Model Performance Comparison

Model	PSNR	SSIM	MAE
KNN-Based Model	20.30	0.65	0.06
RNN-Based Model	24.80	0.75	0.05
CNN-Based Model	26.59	0.8366	0.0332

C. Comparative Dehazing Techniques Analysis

Extensive comparison with other deep learning-based dehazing techniques highlights even more the quality of CNN-based approach.

• Although aesthetically beautiful images are produced by GAN-based methods, adversarial training instability causes artifacts to be injected.

• Autoencoders effectively remove haze, although sometimes blur fine structural elements.

• Transfer learning—pre-trained models—generalizes better but faces challenges from domain-specific fog variants.

Being sequential models, RNNs lack spatial feature extraction capacity, which reduces their efficiency for image dehazing.

CNN model developed from ResNet-50 recovers image acuteness with high structural similarity and low artifacts, so offering the ideal mix between computational economy and perceptual quality.

D. Real-Time Performance

Real-time performance tests show that the model can reach an inference speed of 30 FPS, which is appropriate for real-time video processing applications.

E. Practical Applications

The qualitative results affirm the efficacy of proposed method for applications including:

- Autonomous navigation (wider vision for autonomous vehicles)
- Surveillance systems (enhanced object detection in foggy situations)
- Aerial imaging & remote sensing
- Environmental monitoring

The model's resilience with varying haze strengths testifies to its versatility and potency in practical settings.

6 Conclusion

This research proposed an AI-ML-driven smart dehazing algorithm for real-time video processing with a CNN-based deep learning approach. The method entailed systematic dataset preparation, an optimal model design, and effective training with an MSE and SSIM loss function. In addition, an actual deployment system for practical applicability with Gradio and Flask was also adopted. Experimental results proved the model's efficiency, with a PSNR of 26.59 dB, SSIM of 0.8366, and MAE of 0.0332 and real-time inference rates of 30 FPS. The method proved to be superior to traditional dehazing methods in haze removal, retention of structure, and computation, and was found appropriate for autonomous navigation, surveillance, and remote sensing applications. As there are still minor artifacts and colour distortions under heavy haze. Subsequent research can investigate hybrid learning methodologies such as GANs and deploy for optimization on edge computing. In conclusion, this work confirms AI-ML-based dehazing as a viable technique for real-time video processing and opens the door to more sophisticated visibility enhancement techniques.

7 Future Work

Although the proposed AI-ML-based dehazing algorithm demonstrates an overall improvement in image clarity and switched mode applicability, there remain areas of opportunity. One major direction for enhancement is improving robustness to extreme haze and smoke conditions. Using generative adversarial networks (GANs) or transformer networks can enhance feature learning and lead to dehazed images that are more realistic and have fewer artifacts. Additionally, adaptive dehazing methods should also be tested for a model that can dynamically adapt over time and to different environmental conditions, haze conditions, and light conditions. Domain adaptation might also enhance generalization across datasets so that sufficient performance can be maintained in the real world. Another important future research area includes model optimization for edge and mobile deployment. Quantization, knowledge distillation, or model pruning can all broaden the opportunity of conserving computation while maintaining accuracy, leading to edge deployment of the algorithm on low power devices like drones, autonomous cars, and embedded vision systems. Finally, extending the model to video dehazing and accounting for temporal consistency will further spur real-time applications. The use of recurrent neural networks (RNNs) or LSTM networks can further smooth dehazed frames over time and reduce flickering or inconsistencies between frames in the video sequence.

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Goals (SDG) Mapping

The capstone project "AI-ML Based Intelligence De-Smoking/De-Hazing" aligns with several United Nations Sustainable Development Goals (SDGs) through its real-world impact and technological contributions. While the report shows SDG mapping in the enclosures, the content throughout the document allows us to clearly show the project's relevance to the following SDGs:

1. SDG 9: Industry, Innovation, and Infrastructure

- Contribution: The project introduces an AI-powered solution leveraging CNNs for real-time image dehazing, enhancing visibility in low-resource environments.
- Application Impact: Useful for autonomous driving, satellite imaging, and edge computing, supporting innovation in transportation and infrastructure monitoring.

2. SDG 11: Sustainable Cities and Communities

- Contribution: By improving image clarity in surveillance and traffic systems, the project contributes to safer and more resilient urban environments.
- Application Impact: Enables autonomous navigation and urban traffic monitoring

through better visibility in foggy or polluted conditions.

3. SDG 13: Climate Action

- Contribution: Enhances environmental monitoring by restoring image clarity in satellite or drone imagery affected by haze or smoke.
- Application Impact: Supports climate surveillance, forest fire tracking, and air quality assessment, enabling informed action against environmental hazards.

4. SDG 3: Good Health and Well-being (indirect relevance)

- Contribution: Through improved environmental monitoring and disaster preparedness, the project supports public health efforts by making pollution and visibility data more actionable.