Image Dehazing using Image Processing and Machine Learning Techniques

Mid-Review 1

AY 2021-25

GITAM (Deemed-to-be) University

Major Project
Project ID:
A4(Alpha 12)

Project Team:

- Lokeshwar Reddy K
- Tejas V Reddy
- Vinay N S

Department of Electrical Electronics and Communication Engineering

Project Mentor:

- Dr Jaya Parakash Sahoo

Project In-charge:

- Dr Ambar Bajpai

Objective and Goals

Objective

- The primary objective is to develop a lightweight CNN-based model for image dehazing that effectively enhances image quality by preserving brightness, color, and clarity. This model will be designed to operate efficiently in real-time applications, support downstream tasks like object detection, and contribute to advancements in image processing research through comprehensive documentation and publication.

Goals

- Develop an Efficient Dehazing Model : Build a CNN-based model that effectively removes haze from images while maintaining high visual fidelity.
- Enhance Real-Time Usability : Design the model to be lightweight and fast, suitable for applications such as autonomous driving and surveillance.
- Ensure Robustness and Accuracy : Create a model capable of handling complex haze scenarios without introducing artifacts or degrading image quality of the research.

- Benchmark Performance : Validate the model against synthetic and real-world datasets, establishing performance benchmarks and ensuring reliability.
- Support Downstream Tasks : Optimize the dehazed outputs to improve accuracy in related tasks like object detection and tracking in challenging environments.
- Simplify Deployment : Develop a scalable and deployable framework to facilitate the practical application of the model in various industries.
- Contribute to the Research Community : Share insights and advancements by publishing research findings in IEEE conferences and other reputable platforms.
- Document Results Thoroughly : Record methodologies, findings, and performance metrics to ensure transparency and reproducibility of the research.

Project Plan

Phase	Timeline(Dec'24 – Mar'25)	Activities
Project Planning	Week 1-Week 2	Literature review, defining objectives, and preparing the research framework.
Data Collection	Week 3-Week 5	Collecting the foggy(hazy) real time datasets.
Algorithm Development	Week 6-Week 7	Testing the RESIDE datasets and Writing the algorithm as per adopted steps.
Testing and Validation	Week 8-Week 10	Testing the collected real-time data with the trained reside datasets.
Implementation	Week 11-Week 13	Implementation of the project with the collected datasets and ensuring the proper output.
Documentation	Week 14-Week 18	Documentation of the results of the project and preparing the document for IEEE conference.

Literature Survey (Improved post minor project)

<table>
<tr><th>Sl.no</th><th>Title of the Paper</th><th>Year</th><th>Author</th><th>Key Findings</th><th>Research Gap</th></tr>
<tr><td>1.</td><td>DehazeNet: An End-to-End System for Single Image Haze Removal</td><td>2016</td><td>• Bolun Cai
• Xiangmin Xu
• Kui Jia
• Chunmei Qing
• Dacheng Tao</td><td>❏ Approach :Developed an end-to-end CNN to estimate medium transmission maps directly from input hazy images. Used the atmospheric scattering model for haze-free image recovery.

❏ DecompositionTechnique:
1. Feature Extraction
2. Multi-scale mapping
3. BReLU activation
4. Guided Image Filtering

❏ Results:
• Achieved superior performance compared to seven existing methods, in terms of both haze removal and preservation of image details.
• High-quality dehazing with sharp contrasts, applicable for industrial systems like autonomous vehicles and surveillance.</td><td>❏ Struggles with distant objects in images with progressively increasing haze.
❏ Suggests future work in developing lightweight models and unsupervised methods to reduce reliance on labeled datasets.
❏ Limited availability of real-world haze-clear image pairs for training.</td></tr>
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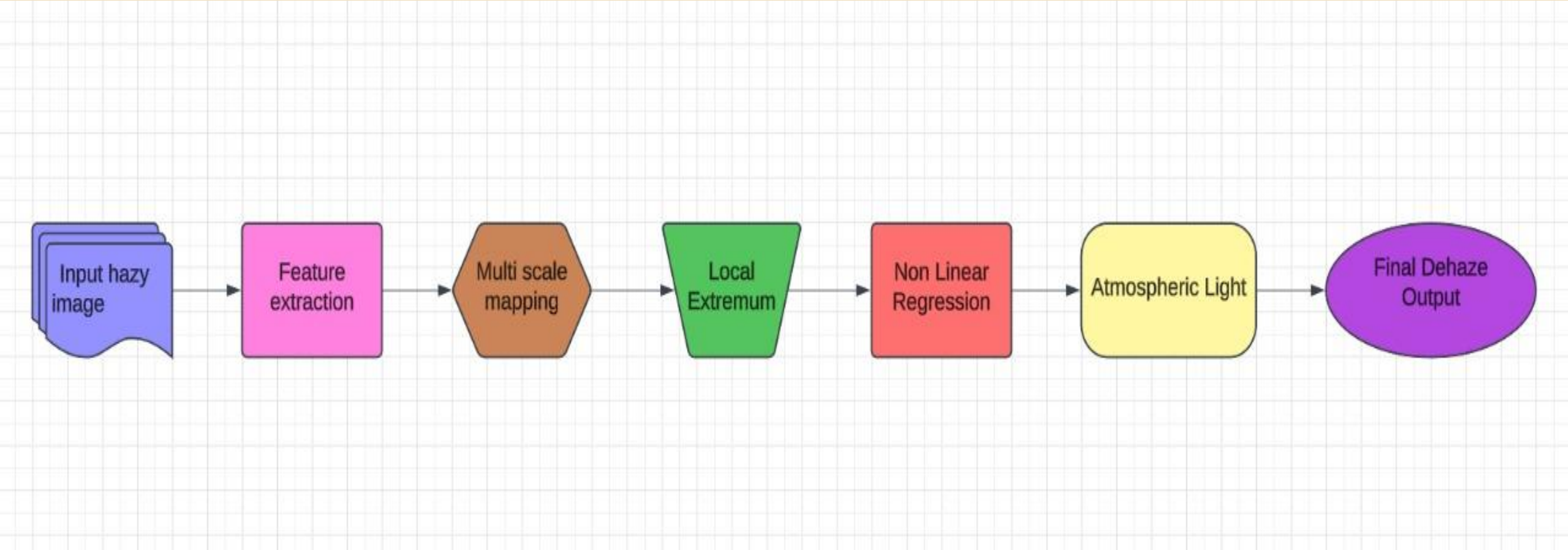
Literature Survey (Improved post minor project)

Sl.no	Title of the Paper	Year	Author	Key Findings	Research Gap
2.	Single Image Dehazing via Fusion of Multilevel Attention Network for Vision-Based Measurement Applications	2023	• Geet Sahu • Ayan Seal • Joanna Jaworek-Korjakowska • Ondrej Krejcar	❑ **Approach :** • An encoder-decoder network (UNet) is the backbone. • The model incorporates multiscale attention mechanisms (SA and CA) for haze feature extraction and refinement. ❑ **Technique:** • SA-Unet and CA-Unet • Combined outputs using elementwise addition for superior performance. • Structural Similarity Index (SSIM) used as a loss function to improve optimization and convergence. ❑ **Results:** • Demonstrated robustness to varying haze densities, atmospheric light conditions, and image scales. • Processes a 640×480 image in approximately 1.5 seconds on a CPU.	❑ The assumption of a globally constant atmospheric light limits accuracy for certain real-world scenarios. ❑ The model does not directly learn the atmospheric scattering parameters, which could enable end-to-end optimization.

Literature Survey (Improved post minor project)

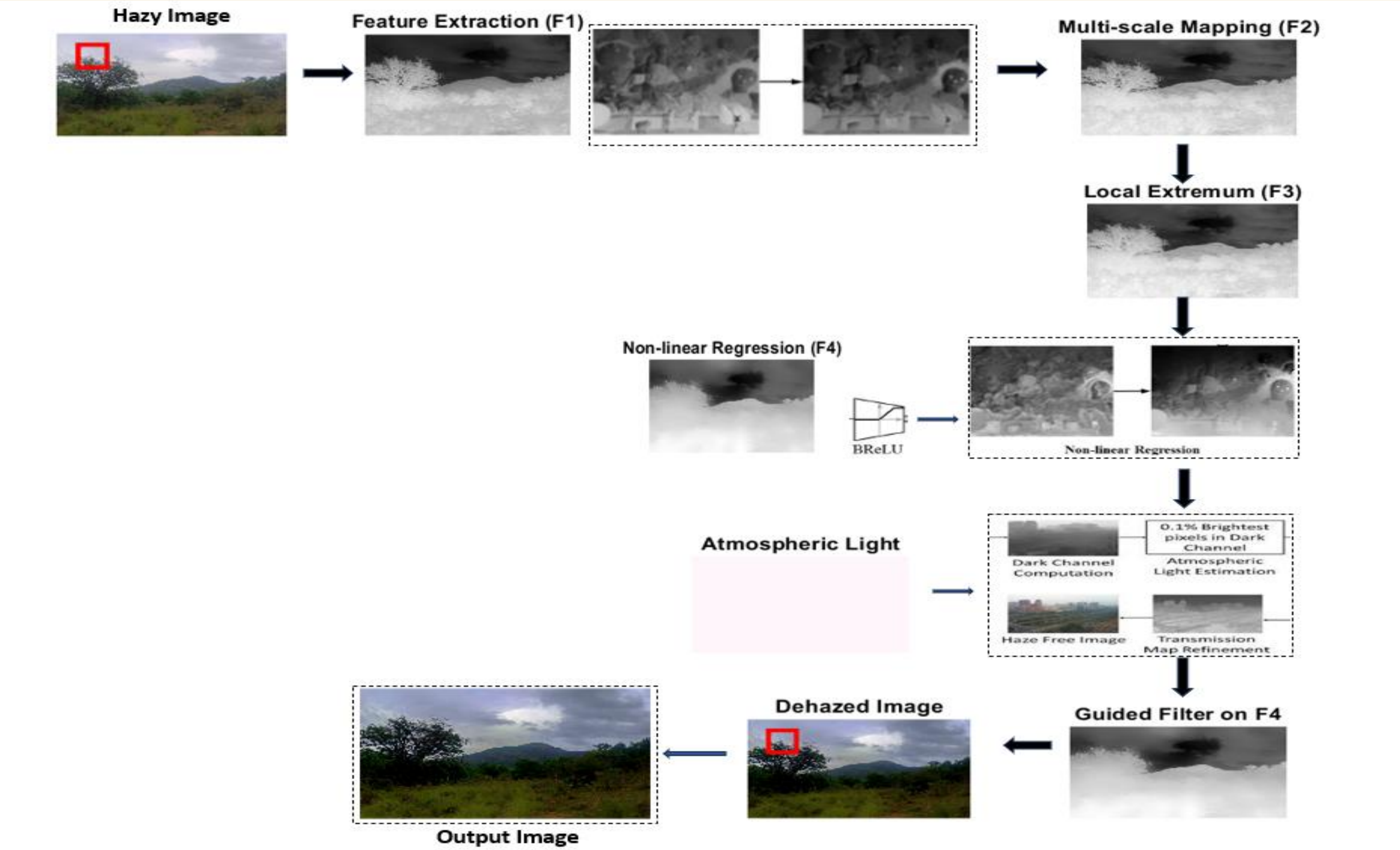
Sl.no	Title of the Paper	Year	Author	Key Findings	Research Gap
3.	LID-Net: A lightweight image dehazing network for automatic driving vision systems	2024	• Fazhan Tao • Qi Chen • Zhigao Fu • Longlong Zhu • Baofeng Ji	❑ **Approach:** LID-Net employs a multi-scale architecture • Haze Extraction (HE) blocks • Haze Removal (HR) blocks ❑ **Technique:** • Directly learning the mapping between hazy and clear images without relying on the atmospheric scattering model, thus avoiding color distortion. • Utilizing a combination of standard and dilated convolutions to expand the receptive field and extract global information from hazy images. ❑ **Results:** • LID-Net demonstrated superior performance in dehazing effectiveness compared to traditional methods and other deep learning approaches, as evidenced by experiments conducted on two real-world foggy weather datasets.	❑ The study addresses limitations in traditional image dehazing methods, which often rely on simplistic assumptions about haze distribution and fail to generalize across different environments. ❑ LID-Net's approach mitigates these issues by not depending on the atmospheric scattering model, thus providing a more robust solution for various driving conditions.

Flow chart



Input hazy image
Feature extraction
Multi scale mapping
Local Extremum
Non Linear Regression
Atmospheric Light
Final Dehaze Output

Architecture



Use Cases & Testing

Use Cases

- **Photography and Videography**:

DehazeNet can enhance image quality in outdoor photography and video capture under hazy conditions, making it ideal for professional and consumer-level applications.

- **Surveillance Systems**:

Improves visibility in surveillance footage captured in foggy or smoggy environments, aiding security and monitoring tasks.

- **Autonomous Vehicles**:

Enhances the clarity of images captured by cameras in autonomous cars, ensuring better scene understanding in adverse weather conditions.

Test Cases

Datasets:

- DehazeNet was tested on synthetic datasets (e.g., RESIDE) and real-world hazy images to ensure both quantitative and qualitative reliability.
- Synthetic datasets allowed ground-truth comparisons, while real-world images validated its robustness.

Quantitative Evaluation:

- Metrics like PSNR (Peak Signal-to-Noise Ratio) and SSIM (Structural Similarity Index) were used to objectively evaluate the dehazing quality.

Qualitative Evaluation:

•Visual inspection confirmed that DehazeNet effectively restores clarity, contrast, and colour fidelity in hazy images.

Cross-Condition Testing:

•Tested under diverse conditions such as varying haze densities, lighting environments, and weather types (e.g., fog, smog).

Real-Time Application:

•Testing showed that DehazeNet performs efficiently enough for real-time or near-real-time applications, making it suitable for dynamic systems like autonomous vehicles and live video feeds.

Implementation and Results – Iteration 1

Iteration 1 : Results

1. Data Preparation

•**Datasets Used:**

- **Synthetic Hazy Images:** SOTS dataset (from RESIDE benchmark).
- **Real-World Hazy Images:** Collected using online repositories and personal contributions.

•**Preprocessing:**

- Resize images to 1200x1600x1200.
- Split datasets into training, validation, and testing sets.

2. Model Design

•**Architecture:**

- A lightweight convolutional neural network (CNN) with fewer parameters for real-time efficiency.
- Incorporates residual blocks to enhance feature extraction.
- Includes brightness compensation layers to adjust for color and clarity preservation.

•**Key Features:**

- **Convolutional Layers:** Extract spatial features..
- **Activation Function:** Leaky ReLU for non-linearity.
- **Output Layer:** Reconstructs the dehazed image.

Implementation and Results – Iteration 2

Iteration : Results + Validation against the use cases and test cases

3.Training

•**Loss Function:**

- Combination of Mean Squared Error (MSE) for pixel-wise accuracy and Structural Similarity Index Measure (SSIM) loss for perceptual quality.

•**Optimizer:**

- Adam optimizer with an initial learning rate of 0.0001.

4. Evaluation Metrics

•**PSNR (Peak Signal-to-Noise Ratio):** Measures image reconstruction quality.
•**SSIM (Structural Similarity Index):** Evaluates the perceptual similarity of dehazed images.

Contribution

Team Progress and Movement

- Completed Testing and Validation for datasets.
- Explored with Real-Time collected datasets.
- Developed an Algorithm for Image Dehazing.
- Paper Documentation is in progress.

Individual Contribution

Key contributions: **Lokeshwar Reddy K**

- Algorithm development
- Design and Implementation

Key contributions: **Tejas V Reddy**

- Experimental Evaluation
- Testing and Validation

Key contributions: **Vinay N S**

- Collecting datasets
- Documentation

Conclusion & Future Work

Summary and Conclusion

Overview:
•Introduced a novel CNN-based, end-to-end system for single-image haze removal.
•Achieved significant improvements in clarity, contrast, and color restoration compared to traditional methods.

Performance and Applications:
•Demonstrated superior results on quantitative metrics (PSNR, SSIM) and visual comparisons.
•Suitable for real-time applications like surveillance, autonomous vehicles.

Future Work

Dynamic and Video Processing:
Extend the model to handle real-time video sequences with temporal consistency.

Adaptability to Complex Scenarios:
Enhance performance under varying weather conditions, nighttime haze, and multi-light source settings
.
Efficient Model Design:
Develop lightweight versions for deployment on edge devices like drones and mobile systems.

Multi-Challenge Integration:
Combine haze removal with solutions for blur, rain streaks, or other image degradation issues.

THANK YOU

Have a Great Day !