Computer Vision-Based Real-Time Air Quality Index Estimation From Satellite Imagery

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Outline

1. Introduction
2. Problem Statement
3. Motivations
4. Critical Analysis Of The Related Works
5. Identifying Gaps
6. Research Questions
7. Objectives
8. Proposed Methodology
9. Thesis Plan
10. Gantt Chart
11. Budget
12. Future Activity
13. Question & Answer
14. References

Introduction

Air Quality Index

The Air Quality Index (AQI) is a standardized system used to measure and report air quality levels in a specific area. It provides a clear, numeric way to communicate how polluted the air currently. The AQI focuses on health effects that can happen within a few hours or days after breathing polluted air.

Air Quality Components [Gupta et al., 2023]

Pollutant	Full Name
$PM_{2.5}$	Particulate Matter ($\leq 2.5\ \mu$m)
PM_{10}	Particulate Matter ($\leq 10\ \mu$m)
NO_2	Nitrogen Dioxide
SO_2	Sulfur Dioxide
CO	Carbon Monoxide
O_3	Ozone
NH_3	Ammonia
Pb	Lead

Introduction

AQI Measurement Levels [Gupta et al., 2023]

AQI Range	Air Quality Level	Health Effect
0–50	Good	Safe for everyone
51–100	Moderate (Asthma)	OK for most, but sensitive people may feel issues
101–300	Unhealthy	Can affect everyone, especially those with breathing problems
Above 300	Hazardous	Dangerous for all, stay indoors

Problem Description

Problem Description

- Traditional AQI monitoring systems rely on ground-based sensors [Mondal et al., 2024]
- Existing models often focus on only one or two pollutants (like PM2.5) [Ioannou et al., 2025]
- Dependence on tabular Data Instead of Visual Features [Rowley and Karakuş, 2023]

Motivations

Key Motivations

- **Air pollution causes ~7 million premature deaths annually**, making it a leading global health threat [World Health Organization, 2021].
- **Over 140 countries lack PM2.5 monitors**, resulting in critical data gaps that hinder policy and public health responses [United Nations Environment Programme, 2022].
- **Cities like Dhaka exceed WHO PM2.5 limits by 1500%**, exposing millions to hazardous air daily [IQAir, 2023].
- **Satellite data enables wide-area, real-time monitoring**, especially valuable where ground sensors are unavailable [NASA Earth Observatory, 2022].

Critical Analysis of Related Works (1/11)

Emec et al. (2025) proposed a novel ensemble machine learning method for accurate air quality prediction. [Emeç and Yurtsever, 2025]

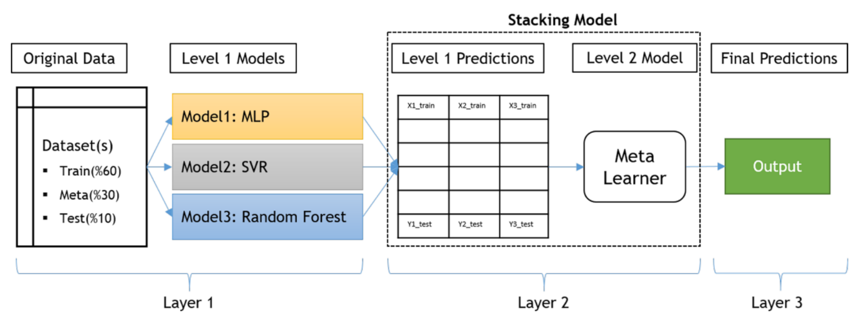

Figure 1: 3-layer stack batch learning architecture by temporal fow for air quality PM2.5 prediction

Critical Analysis of Related Works (2/11)

Contributions

- Proposed a novel stacking ensemble model
- Detailed experimental setup
- Provides a replicable framework

Limitations

- Limited to two cities
- No hourly resolution

Critical Analysis of Related Works (3/11)

Rowley et al. (2023) proposed a multimodal AI approach using satellite imagery for air quality prediction. [Rowley and Karakuş, 2023]

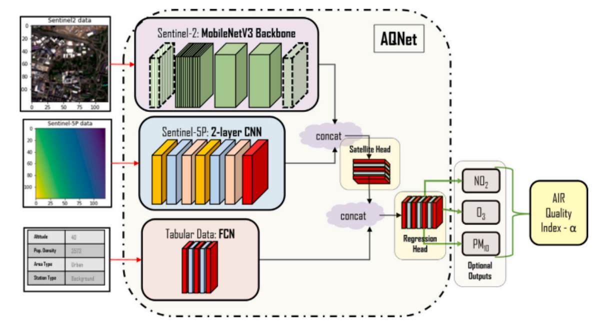

Figure 2: AQNet model Architecture

Critical Analysis of Related Works (4/11)

Contribution

- Proposed a new multimodal AI Model (AQNet)
- Showed that simpler Models can compete

Limitations

- No weather or meteorological data used
- Limited to CNN + FCN architecture

Critical Analysis of Related Works (5/11)

Iacovos Ioannou et al. proposed a two-stage vision-based air quality monitoring system that integrates deep learning techniques for accurate AQI classification and prediction using aerial imagery and multi-gas data. [Ioannou et al., 2025]

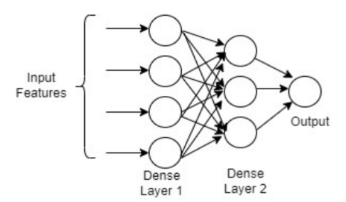

Figure 3: Structure of ANN.

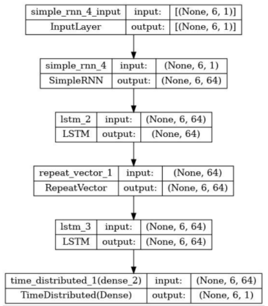

Figure 4: Architecture of RNN-B-LSTM.

Critical Analysis of Related Works (5/11)

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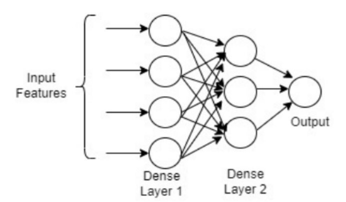


Figure 3: Structure of ANN.

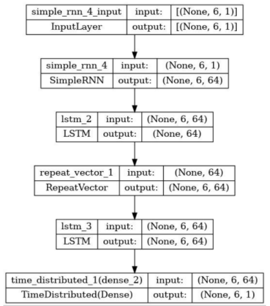


Figure 4: Architecture of RNN-B-LSTM.

Critical Analysis of Related Works (6/11)

Contribution

- Developed a two-stage deep learning model for AQI estimation using aerial images
- Proposed and validated a hybrid model
  - ANN achieved 99.14% classification accuracy
  - RNN-B-LSTM achieved 98.73
- Utilized multiple pollutant gases along with temperature and humidity

Limitations

- Limited geographic scope
- Image quality sensitivity

Critical Analysis of Related Works (7/11)

Anju S. Mohan et al. proposed En3C-AQI-Net, a three-channel ensemble deep learning model combining DeiT, CNN, and meteorological analysis for accurate AQI prediction and classification using outdoor images in Delhi. [Mohan and Abraham, 2024]

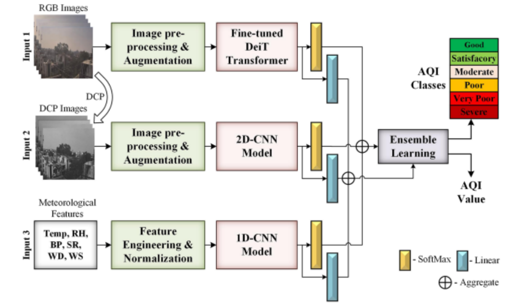


Figure 5: Structure of En3c-AQI-Net.

Critical Analysis of Related Works (8/11)

Contribution

- Developed En3C-AQI-Net, a multi-branch ensemble model
- Utilized DeiT – a transformer-based vision model – rarely used in AQI tasks.
- Incorporated DCP image features, often used in dehazing
- Applied SHAP values to interpret meteorological feature contributions
- Addressed class imbalance using weighted categorical cross-entropy

Limitations

- Focused only on Delhi, limiting generalizability
- Model Bias Risk

Critical Analysis of Related Works (9/11)

Joyanta Jyoti Mondal et al. proposed a lightweight DCNN-based model that predicts PM2.5 concentration from smartphone-captured images, creating the first such dataset in Dhaka and outperforming transformer and CNN baselines [Mondal et al., 2024]

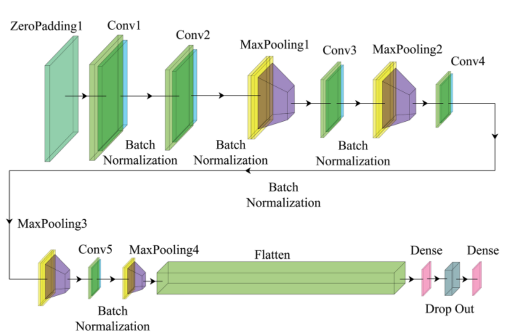


Figure 6: Illustration of the proposed deep CNN architecture

Critical Analysis of Related Works (10/11)

Contribution

- First real-world smartphone-captured image-based PM2.5 dataset for Dhaka
- Proposed lightweight, resource-efficient DCNN that outperforms ViT, INN, other CNNs like RestNet-50,VGG-19, MobileNetV2
- Used image features like transmission, blue sky hue, sky gradient, contrast, entropy, humidity

Limitations

- Doesn’t work well at night due to poor lighting and noisy images
- Sun glare or reflections can degrade model accuracy
- Model trained only on Dhaka data that may not generalize to other cities
- Dependent on camera quality as low-resolution phones may reduce performance

Critical Analysis of Related Works (11/11)

Table: Summary of Related Works on Image-Based AQI Estimation Models

Authors	Dataset	Contribution	Limitations
[Emeç and Yurtsever, 2025]	Beijing: 3,397 daily records, Istanbul: 3,591 daily records	Proposed a stacking model for accurate PM2.5 prediction	Tested on limited cities with coarse data
[Rowley and Karakuş, 2023]	NO_2 Dataset, 3-Pollutant Dataset (NO_2, O_3, PM_{10})	Proposed a new multimodal AI model (AQNet)	Limited to CNN + FCN architecture
[Ioannou et al., 2025]	VisionAir: 2,797 non-HDR aerial images from 5 Delhi sites with pollutant and meteorological data	Two-stage model (ANN + RNN-B-LSTM) estimates AQI from aerial images with 99.14% classification and 98.73% prediction accuracy	Performance limited by class imbalance and training on images from only one urban region (Delhi)
[Mohan and Abraham, 2024]	Delhi: 21,620 labeled outdoor images, AirSetDelhi Dataset, Image + Meteorological Dataset	En3C-AQI-Net: ensemble of DeiT, 2D-CNN, 1D-CNN for AQI estimation & classification images & meteorological data	Model limited by geographic focus (Delhi-only), risk of bias
[Mondal et al., 2024]	Dhaka: 1,818 labeled images (1,473 train, 163 val) $PM_{2.5}$ Dataset, single-pollutant ($PM_{2.5}$)	Lightweight CNN predicts $PM_{2.5}$ AQI from Dhaka images.	Limited to Dhaka; poor performance on nighttime and noisy images.

Identifying Gaps

Key Gaps

- No consideration of weather conditions [Ioannou et al., 2025]
- Lack of real-time processing Capability [Rowley and Karakuş, 2023]
- Lack of nighttime or HDR images, limiting model performance under low-light conditions [Mondal et al., 2024]
- Model trained on geographically limited datasets, reducing generalizability to diverse regions [Mondal et al., 2024]

Research Question

Key Questions

- Can a computer vision system use satellite images to estimate air quality without needing many ground sensors?
- Will the system give correct air quality results in different places and weather conditions?
- Can this system help people and groups take better actions by showing real-time air quality levels?

Objectives

Key Objectives

- To build a computer vision model to estimate AQI from satellite images.
- To detect air pollution features like AQI and PM 2.5 concentration.
- To monitor AQI in areas with few or no ground sensors.

Proposed Methodology

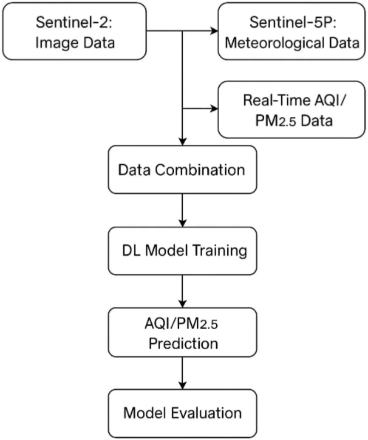


Figure 7: Proposed Methodology for our thesis

Thesis Plan

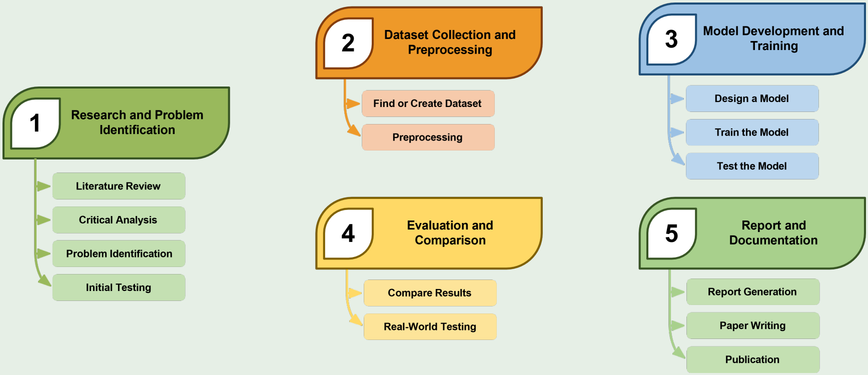
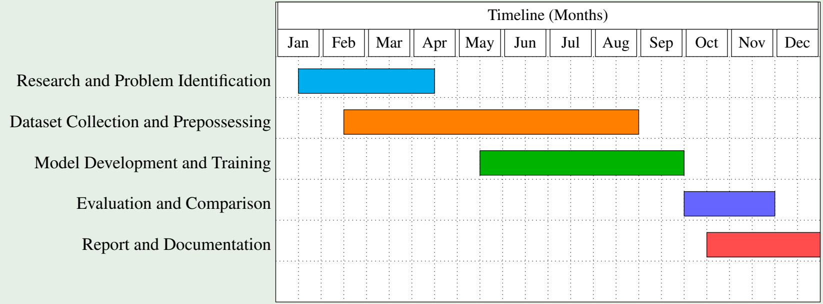


Figure 8: Thesis Plan

Gantt Chart

Gantt Chart for Our System



Budget

Budget Plan of Our System

Category	Item/Service Description	Cost Amount (TK)
Hardware	PC GPU Upgrade	60,000
	Additional 16GB RAM	8,000
	High-Performance Processor	35,000
	External Hard Drive (1TB)	5,000
Dataset Collection	Labor for Dataset Collection/Actors	25,000
	Cloud Storage (3,000/month × 12)	36,000
Software and Tools	Research Tools or Libraries	10,000
	Programming Software/Tools Licenses	5,000
Model	Cloud GPU Instance (NVIDIA T4, 1 month)	45,000
Miscellaneous	Printing and Documentation	5,000
Total		**234,000 BDT**

Future Activity

Planned Activities

- Collecting relevant datasets
- Creating the machine learning model
- Training and tuning the model
- Comparing with existing approaches
- Writing and publishing the research paper

Thesis Progress

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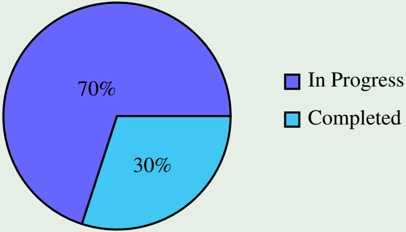
Thesis Progress



Question & Answer

Any Questions?

Question & Answer

Thanks...

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