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Urban Blue Green Areas Segmentation for AQI Improvement

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Abstract

The urban landscape of Lahore faces the challenge of deteriorating air quality due to rapid urbanization. We propose a strategic development approach centred around the Urban Blue-Green Areas Segmentation to address this issue. Blue-Green areas are the blue-green land cover, encompassing parks, gardens, green rooftops, and water bodies, that offer natural air purification, shade, cooling, and healthy living conditions.

Our Proposed approach outlines our plan to benefit from advanced technologies such as remote imagery, geographic information systems (GIS), and machine learning to identify suitable areas within Lahore for urban forests or green zones. Through segmentation of land cover, we have quantified blue-green spaces and their correlation with the Air Quality Index (AQI). We aim to identify areas suitable for afforestation and calculate the needed increases in the green cover to improve AQI level, assess the impact of afforestation and deforestation on AQI, and hence, develop a user-friendly web application.

The project is aligned with global findings and research indicating the significance of blue-green areas in improving AQI and reducing the carbon density. The aim is not only to revitalize Lahore's urban atmosphere but also to set an example for other cities facing similar air quality challenges.

Executive Summary

The urban landscape of Lahore faces a severe issue of deteriorating air quality born from the rapid urbanization and un-monitored industrial growth. As remedy to this critical issue, we propose a strategic and innovative approach based upon Urban Blue-Green Areas Segmentation. This report drafts a comprehensive plan to mitigate air quality risks and improve the overall well-being of the urban areas through the informed decisions regarding development and preservation of green zones, including parks, gardens, green rooftops, and water bodies.

The blue-green areas play a vital role in providing natural air purification, shading, cooling, and enhancing the well-being of the urban community. To achieve this, we intend to benefit from advanced technologies such as remote imagery, geographic information systems (GIS), and machine learning to identify the areas within Lahore for the development of these blue-green zones.

Our proposed plan involves a systematic land cover segmentation process to quantify existing blue-green spaces and determine their correlation with the Air Quality Index (AQI). Through this approach, we aim to identify areas needing afforestation and calculate the necessary increase in blue-green cover to naturally improve AQI levels. Additionally, we have assessed the environmental impact of afforestation and deforestation on urban atmosphere, providing valuable insights for sustainable and informed decision-making.

One of the key milestone of this project is the development of a user-friendly web application to make information readily accessible and engage the public in the venture to improve air quality. This application serves as a vital tool for promoting community role and awareness regarding the significance of blue-green areas and their impact on the urban air quality.

Our project is in complete alignment with global findings that emphasize the pivotal role of blue-green areas in improving AQI and reducing carbon density [1]. Beyond rejuvenating Lahore's urban environment, this endeavor aims to set an exemplary standard for the other cities facing similar air quality challenges, not only locally in Pakistan but globally.

By implementation of this innovative approach, we intend to elevate the quality of life for Lahore's residents, create a sustainable and healthy urban environment, and contribute to a healthier, greener, and more sustainable future for our city Lahore. Running inferences on satellite images to gain urban planning insights and saving results are core features of the system which are proposed to be implemented by building U-Net based segmentation pipeline considering all standard design, development and testing strategies. Extraordinary results like Accuracy of 0.983659267, F1 score of 0.942806363, IoU score of 0.91325742 were achieved on test dataset. We can achieve a positive transition that establishes a precedent for cities globally to address their air quality challenges and adopt a sustainable and eco-friendly

urban paradigm by working together and integrating state-of-the-art technologies.

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Chapter 1 Introduction

The urbanization wave in Lahore is causing a significant issue - deteriorating air quality resulting from swift and extensive urban development [2]. As the city advances in infrastructure and industry, the Air Quality Index (AQI) displays a worrying trend, indicating heightened levels of pollutants that pose severe health risks to the city [3]. This growing concern requires urgent and well-considered measures to tackle the rising threat to public health and environmental sustainability.

To address this issue, we propose an innovative approach of Urban Blue-Green Areas Segmentation. This data-driven approach aims to reclaim the city's once healthier atmosphere, utilizing cutting edge technologies such as remote imagery, geographic information systems (GIS), and machine learning algorithms. The goal is to identify and segment potential areas within Lahore which will be useful to the creation of urban forests with accuracy [4]. The central focus of our project lies in the high precision land cover segmentation, aiming to quantify and outline blue-green areas and asses their relationship with AQI levels. The insights gained so ,will identify areas needing afforestation, facilitating a calculated increase in green cover to mitigate air quality issues. Furthermore, we aim to evaluate the impact of afforestation and deforestation on the air quality index, providing critical data for informed environmental decision-making and urban planning.

The primary objectives include the accurate segmentation of Lahore city's urban land cover using cutting edge techniques rooted in computer vision and artificial intelligence. Later steps encompass quantifying blue-green areas and analyzing their relationship with the AQI levels of the city. By employing correlation analysis and regression techniques, we aim to develop a powerful mathematical model that provides accurate predictions for optimizing green cover in order to attain desired AQI levels. This project focuses to create a user friendly web application, providing accessibility and actionable insights to the stakeholders and the general community.

The gravity of this project resonates on a global scale, being completely aligned with the global researches that emphasize the vital role of blue-green spaces in improvement of AQI [5]. Lahore, an expanding capital, stands to benefit significantly from this approach driven endeavour. It is not only an initiative to reclaim Lahore's once healthy urban environment but also to set a precedent for other cities facing similar air quality issues.

1.1 Purpose of this Document

In alignment with the comprehensive goals, this document aims to thoroughly outline the methodologies, techniques, and strategies supporting the development and execution of the ”Urban Blue-Green Areas Segmentation for AQI Improvement” project. It explains the purpose, objectives, and the extensive scope of the project while outlining the role of advanced technologies and data-driven approaches in the realm of environmental sustainability.

1.2 Intended Audience

The intended audience for this project includes stakeholders invested in environmental improvement, urban planners, policy makers, environmentalists, and researchers in the field of air quality and sustainable urban development.
Understanding the importance of blue-green areas and their correlation with AQI is crucial for individuals and organizations striving to enhance urban air quality.

1.3 Definitions, Acronyms, and Abbreviations

Following are listed definitions, acronyms, and abbreviations that are used in this chapter.

1.3.1 Definitions

Basic definitions for key terminologies have been listed down below.
Air Quality Index: In a specific location, a numerical scale that communicates the air quality of the air is called as Air Quality Index, representing the concentration of pollutants present in the air. It offers a simplified way to understand the air quality and its potential impact on health.
Geographic Information Systems: Geographic Information Systems is a technology that allows for the gathering, analysis, interpretation, and visualization of Geo-spatial data. It integrates various types of data to provide insightful perspectives for decision-making and planning related to geographic locations.
Remote Sensing: Acquiring the information about an object or a phenomenon from a distance is known as Remote Sensing, which is typically done using sensors on aircraft or satellites. It is widely used for Earth observation, environmental monitoring, and land use analysis.
Afforestation The term Afforestation is defined as a process of growing a new patch of forest or stand of forest plants, in a region having no forest before. It is a vital strategy to combat deforestation and mitigate the impacts of climate change.
Deforestation: Deforestation is the clearance, removal, or destruction of a forest or stand of trees, typically to make way for agricultural expansion, urban development, or logging.
Particulate Matter: Particulate Matter concentration refers to the amount of tiny solid and liquid particles suspended in the air, including pollutants like dust, smoke, and fine particles. It is typically measured in micro-grams per cubic meter ($\mu g/m^3$) and is crucial for assessing air quality and its impact on human health.

Carbon Density: Carbon Density refers to the amount of carbon (usually in the form of carbon dioxide) present per unit area, often used to measure the carbon footprint or impact on the environment.
Regression Techniques: Regression Techniques involve statistical methods used for analyzing the relationship between variables. In this project, regression techniques will help in understanding how changes in blue-green areas affect AQI levels.
Correlation Analysis: A statistical method applied to measure and analyse both strength and the direction of existing relationship between two variables of numerical type, is defined as Correlation Analysis. It helps in understanding the association between blue-green areas and AQI.

1.3.2 Acronyms and Abbreviations

Basic acronyms and abbreviations used across this chapter have been listed down below.
AQI: Air Quality Index
GIS: Geographic Information Systems
API: Application Programming Interface
SDG: Sustainable Development Goal

1.4 Conclusion

Lahore being heavily urbanized city stands at the top of the list of the most polluted cities since no counter action have been taken to mitigate effect of urbanization. Numerous researches and studies prove the key role of management of blue-green areas for air quality improvement which is supported by the insights, intricate segmentation of blue-green areas using advanced machine learning techniques, is offering.

Chapter 2 Project Vision

This chapter briefs about the problem and its detailed description. It specifies comprehensive goals and objectives of the project that are primarily set to be achieved along with the secondary one which may become motive for expansion of domain and scope. It also identifies the area of the domain to which the project belong and its scope.

2.1 Problem Domain Overview

The project resides at the intersection of environmental science, remote imagery analysis, and machine learning algorithms, with a central focus on analyzing remote imagery to establish a meaningful relationship between green and blue areas within these images and the Air Quality Index (AQI). It relies on remote imagery data sourced from satellites and historical AQI data, aiming to develop a machine learning algorithm capable of accurately segmenting green and blue areas within these images and subsequently correlating them with AQI data obtained through APIs. Key stakeholders include environmental researchers, urban planning authorities, policymakers, and the general public interested in understanding the impact of natural environmental features on air quality. Several considerations include data privacy, constraints on machine learning model training, and the availability of accurate AQI and remote imagery data.

2.2 Problem Statement

Due to rapid urbanization and increased vehicle ownership, Lahore has witnessed a severe spike in air pollution, with an AQI exceeding 300, making it one of the most polluted cities globally. This alarming situation poses significant health threats, including cardiovascular and respiratory diseases, to the urban community. Pakistan needs to feel the urgent need to efficiently optimize urban blue-green areas, such as parks and water bodies, to mitigate air quality issues. However, the manual evaluation of the relationship between AQI and blue-green spaces is both costly and in-effective. Our project focuses to address this issue by developing a machine learning algorithm to establish a meaningful correlation between AQI and green-blue spaces. This will enable the government and urban planners to efficiently manage and plan urban green-blue areas, benefiting from the natural environment to combat air pollution effectively. Using remote imagery and historical AQI data, our project proposes segmenting green and blue areas, recording AQI levels at these locations, and translating the data into a mathematical model that represents the AQI-green-blue areas relationship, in Lahore.

2.3 Problem Elaboration

The pressing issue of the air pollution in Lahore, caused by rapid urbanization and increased vehicle ownership, has turned to a critical point, reaching an alarming Air Quality Index (AQI) level consistently exceeding 300. This situation has both immediate and long-term health consequences, including an increase in cardiovascular and respiratory diseases among the city's residents. Recognizing the gravity of the situation, the government of Pakistan and urban planners should prioritize the optimization of urban green and blue spaces as potential remedies to mitigate air pollution.

However, the existing manual methods for assessing the relationship between AQI and these green-blue spaces have proven to be both cost-inefficient and ineffective, leaving a substantial gap in the understanding of how these natural features influence air quality. In response, our project assumes the mantle of this challenge by embarking on the development of a sophisticated machine learning algorithm, fine-tuned for Lahore's unique environmental context. The primary objective is to forge a coherent and data-driven correlation between AQI and these green-blue spaces, thereby equipping the government with actionable insights to proactively manage and optimize these environmental assets.

To achieve this, our project harnesses the power of remote imagery and historical AQI data as indispensable sources of information. The proposed algorithm will segment green and blue areas within the imagery, followed by precise AQI measurements taken at these identified locations. Through a comprehensive analysis of these data points, we aim to construct a robust mathematical model that encapsulates the intricate relationship between AQI levels and the presence of green-blue spaces within Lahore. This innovative approach holds the promise of offering the government a valuable tool for evidence-based decision-making, thereby facilitating more effective and targeted interventions to combat the escalating air pollution crisis in the city.

By elaborating on the problem statement, we have provided a more detailed and comprehensive understanding of the issue, its consequences, the government's objectives, and the proposed project's methodology. This in-depth analysis sets the stage for a thorough and informed approach to solving the problem of air pollution in Lahore.

2.4 Goals and Objectives

Our initial project's objectives include:

- Performing land cover segmentation of Lahore city using satellite imagery.
- Improving accuracy and preciseness of already built models performing such segmentation tasks.

Once blue-green areas of the city are identified, we will be:

- Calculating percentage of afforested or deforested land.
- Devise a relationship of identified blue-green cover with AQI (Air Quality Index) in an area.
- Calculate increment needed in blue-green cover to improve AQI to a given level in an area.
- Determine the change in AQI resulting from afforestation or deforestation as specified.
- Investigate the effect of Green cover type (species) on AQI.

2.5 Project Scope

This project encompasses the development of a machine learning algorithm to perform land cover segmentation, the establishment of a correlation between green-blue spaces and the Air Quality Index (AQI), and an investigation into the impact of different green cover types on AQI, as well as the effects of afforestation and deforestation in Lahore. Our project consists of the following modules:

- Develop a machine learning algorithm capable of performing land cover segmentation of Lahore city using satellite imagery.
- Establish a meaningful correlation between the segmented green-blue spaces and the Air Quality Index (AQI) in Lahore.
- Quantify the change in AQI resulting from afforestation or deforestation activities within the city.

This project scope will be used as a guide throughout the development

2.6 Sustainable Development Goal (SDG)

The Sustainable Development Goals (SDGs) relevant to the project are primarily associated with environmental sustainability, urban development, and public health. Here are some of the key SDGs that align with the project's objectives:

2.6.1 Good Health and Well-being

The project addresses the impact of air quality on public health, aligning with the goal to ensure healthy lives and promote well-being for all.

2.6.2 Sustainable Cities and Communities

By optimizing green-blue spaces and improving air quality, the project contributes to creating more sustainable and resilient cities and communities.

2.6.3 Climate Action

The project indirectly supports climate action by mitigating air pollution, which is a significant contributor to climate change.

2.6.4 Life on Land

The project's focus on green spaces, afforestation, and land cover analysis contributes to the goal of protecting and restoring terrestrial ecosystems.

2.6.5 Partnerships for the Goals

Collaboration between various stakeholders, including environmental researchers, urban planners, policymakers, and the public, is essential for achieving the project's objectives and aligns with the goal of fostering global partnerships. These Sustainable Development Goals provide a framework for the project's efforts to improve air quality, enhance urban sustainability, protect the environment, and promote public health in Lahore, aligning it with broader global development priorities.

2.7 Constraints

- Availability of accurate and up-to-date satellite imagery and AQI data.
- Compliance with data privacy regulations and ethical considerations.
- Limited resources, including budget and human resources.
- Adherence to project timelines and milestones.
- Potential technical challenges in machine learning model development.
- The need for collaboration and coordination with relevant authorities and stakeholders

2.8 Business Opportunity

This project offers a multitude of business opportunities. Environmental consulting firms can provide expertise in interpreting project data for government bodies and urban planners. Green infrastructure development firms can invest in projects to optimize green-blue spaces. Businesses can develop and market air quality monitoring solutions, green technologies, and products. Urban planners and architects can integrate project insights into sustainable urban designs.

Opportunities also exist in Eco-tourism, environmental education, and software development for data analytic. Entrepreneurs can offer air quality improvement services, create carbon offset programs, and invest in real estate projects benefiting from improved air quality and green spaces. These opportunities align with the project's aim to enhance air quality in Lahore through green-blue space optimization while fostering economic growth and sustainability.

2.9 Conclusion

In this chapter we have briefly described the project vision of Urban Blue Green Areas Segmentation to Improve AQI, elaborated the scope, goals and objectives. Furthermore, the constraints, business opportunity and Sustainable Development Goal has been discussed.

Chapter 3 Literature Review / Related Work

This chapter covers the related works ,studies and research materials that are studied carefully and critically analysed regarding their usefulness in achieving the goals and objectives of the project. The research materials are grouped together based on technology or scope and divided into sections for ease of understanding.

3.1 Definitions, Acronyms, and Abbreviations

Following are listed definitions, acronyms, and abbreviations that are used in the project.

3.1.1 Definitions

Basic definitions that have been used accross this chapter are listed down below.

Convolutional Neural Networks: A Convolutional Neural Network is a deep learning model designed for image and video analysis, using convolutional and pooling layers to automatically extract and process visual features for tasks like image classification and object detection.

ResNet-34: ResNet-34 is a deep convolutional neural network with 34 layers, used for image classification and feature extraction.

ResNet-50: ResNet-50 is a deep convolutional neural network with 50 layers, used for image classification and feature extraction.

Root Mean Square Error: Root Mean Square Error measures the average of the squared differences between predicted and actual values, and then takes the square root of this average. It quantifies the typical magnitude of errors and gives more weight to larger errors.

Mean Absolute Error: Mean Absolute Error measures the average of the absolute differences between predicted and actual values. It provides a straightforward way to understand the average magnitude of errors without considering their direction.

Mean Absolute Percentage Error: Mean Absolute Percentage Error calculates the average percentage difference between predicted and actual values. It expresses errors as a percentage of the actual values, making it useful for understanding the relative error magnitude.

Normalized Difference Vegetation Index: Normalized Difference Vegetation Index) is a vegetation health indicator calculated from satellite imagery, providing information about the density and health of vegetation by measuring the difference between near-infrared and red light reflection. Higher NDVI values indicate healthier vegetation.

Normalized Difference Water Index: Normalized Difference Water Index is a remote sensing index that helps detect and analyze the presence of surface water in satellite or aerial imagery by measuring the difference in reflectance between Near-Infrared and Shortwave Infrared bands. Higher NDWI values indicate a higher likelihood of water.

Enhanced Vegetation Index 2: Enhanced Vegetation Index 2 is an advanced vegetation index used in remote sensing to assess the health and density of vegetation by taking into account adjustments for atmospheric and background conditions, making it more accurate for monitoring changes in vegetation over time.

Red, Green, Blue : It refers to the color model used in electronic displays and digital imaging. In this model, colors are represented using varying intensities of red, green, and blue light. The combination of these primary colors allows for the creation of a wide array of colors in images and displays.

Graphics Processing Unit : This is a specialized electronic circuit designed to accelerate the processing of graphical and visual data in computers and other devices. The GPU is responsible for rendering images, videos, and graphical elements, and it plays a crucial role in enhancing overall system performance, especially in applications requiring intense graphical computations.

Normalized Difference Vegetation Index with Red and Near-Infrared bands : This is a composite vegetation index that integrates the Normalized Difference Vegetation Index (NDVI) with the Red and Near-Infrared bands of the electromagnetic spectrum. This composite index improves the assessment of vegetation health and density by leveraging specific spectral bands.

Enhanced Vegetation Index 2, Normalized Difference Water Index, and Near-Infrared bands composite index : This is a composite vegetation index that integrates the Enhanced Vegetation Index 2 (EVI2), Normalized Difference Water Index (NDWI), and Near-Infrared bands of the electromagnetic spectrum. This composite index offers a comprehensive assessment of both vegetation and water content, aiding in various environmental analyses.

3.1.2 Acronyms and Abbreviations

Basic acronyms and abbreviations that are used acrossed this chapter have been listed down below.

CNN : Convoluted Neural Network

UGS : Urban Green Spaces

NDVI : Normalized Difference Vegetation Index

EVI2 : Enhanced Vegetation Index 2

NDWI : Normalized Difference Water Index

NDVI–red–NIR : Normalized Difference Vegetation Index with Red and Near-Infrared bands

EVI2–NDWI–NIR : Enhanced Vegetation Index 2, Normalized Difference Water Index, and Near-Infrared bands composite index

RGB : Red, Green, Blue

LSTM : Long Short-Term Memory

PM 2.5 : Particulate Matter 2.5

RNN : Recurrent Neural Network

VHR : Very High Resolution

DBN : Deep Belief Network

UHI : Urban Heat Island

GPU : Graphics Processing Unit

UGS: Urban Green Spaces

PM: Particulate Matter

ResNet: Residual Network

AI: Artificial Intelligence

RMSE: Root Mean Square Error

MAE: Mean Absolute Error

MAPE: Mean Absolute Percentage Error

GA: Genetic Algorithm

3.2 Detailed Literature Review

Urban blue-green areas, including greenery and water bodies, are integral components of an urban ecosystem, fostering environmental sustainability and healthy well-being. Recent advancements in the fields of remote sensing and artificial intelligence (AI) have revolutionized the determination and analysis of these components. This comprehensive literature review focuses on research efforts made globally for implementing urban blue-green spaces segmentation using AI techniques. Each study is examined carefully, including the methodology, data set, model selection rationale, implementation details, test metrics and the results obtained.

3.3 Urban Green Infrastructure Mapping

This section lists downs various research papers and their findings relevant to urban green infrastructure mapping.

3.3.1 Mapping Urban Green Infrastructure Using Sentinel-2 Images and Deep Learning

Urban blue-green spaces play a critical role in enhancing the sustainability and well-being of urban areas. Authors recognized the need of accurately mapping urban blue-green infrastructure to efficiently plan and manage blue-green spaces. Their thoughtful approach involved a two-step process, the first of

which was data preparation. The data set, obtained from Kaggle, comprised multi-spectral Sentinel-2 imagery. The data set provided spectral information, capturing various aspects of urban land cover.
To ensure the quality and relevance of the data set, many pre-processing techniques were applied. Techniques like Radiometric calibration, Masking and Filtering were used to refine and enhance the dataset features. These preprocessing techniques significantly improved the quality of the data, setting a strong base for the subsequent deep learning phase.
In the second step, the authors employed a Convolutional Neural Network (CNN), a deep learning architecture known for its succuess in the feature extraction from image data. The CNN was carefully trained on the pre-processed dataset, optimizing its weights and parameters. The model achieved impressive accuracy of 92%, and an F1 score of 0.91. These results underlined the effectiveness of the CNN in accurately mapping blue-green spaces. The selection of a CNN was supported by its capacity to learn intricate spatial features from the multi-spectral imagery, making it suitable choice for the segmentation task.

3.3.2 Mapping Urban Green Spaces at the Metropolitan Level Using Very High Resolution Satellite Imagery and Deep Learning Techniques for Semantic Segmentation

This research paper focuses the significance of UGS (Urban Green Spaces) and its impact on the environment and public health. It emphasizes on sustainable UGS system to optimize urban spaces, creating safe, resilient, and sustainable urban atmosphere. The objective is to perform semantic segmentation of UGS using two proposed deep learning models.
The research outlines the materials and methods employed, including data collection using nine worldview-2 satellites for very high-resolution imagery. Data preprocessing involves categorizing input data into various classes based on polygon shapes. Three equations—NDVI, EVI2, and NDWI—are used for preprocessing. The study evaluates the models using several metrics, including Accuracy Score, Dice Coefficient, Intersection over Union, Recall analysis, and Kappa Coefficient.
The results indicate optimal performance of ResNet-34 with the “NDVI–red–NIR” band and remarkable results of ResNet50 with the “red–green–blue” band. However, the composition of EVI2–NDWI–NIR demonstrated lower results for both encoders. The research concludes that both models display exceptional potential for the semantic segmentation of UGS and can detect patterns in all types of UGS. This suggests the accuracy and proficiency of the methodology in updating UGS databases at the metropolitan level, essential for measuring progress toward SDG 11.7 concerning green spaces.

3.4 Deep Learning for Blue-Green Space Analysis

This section lists downs various research papers and their findings relevant to Deep Learning for Blue-Green Space Analysis.

3.4.1 Segmenting Green Spaces Using Deep Learning Algorithms: A Case Study of Karachi City

Segmenting urban green spaces within a city is vital for effective urban planning and sustainable development. Authors recognized this and focused their research on a case study in Karachi City, where urban growth necessitated a better understanding of green spaces. The study progresses with the acquisition of the high-resolution satellite imagery, encompassing both RGB and near-infrared bands. This type of multispectral dataset provided a useful feature information, including vital vegetation indices present in the near-infrared band.

To optimize the training on dataset for accurate segmentation, pre-processing techniques were critical. Spectral and spatial features were carefully extracted, creating a dataset relevant to the segmentation task. Convolutional Neural Networks (CNNs), known for their capacity to learn hierarchical features from raw data, were selected for segmentation task. The CNN model underwent rigorous training, optimizing its architecture to achieve accurate segmentation results for blue-green spaces. The choice of CNNs was supported by their proven ability to capture complex spatial patterns and feature present in the satellite imagery. The model demonstrated an impressive accuracy of 88%, highlighting the effectiveness of CNNs in precise detection and outlining of blue-green areas within the city.

3.4.2 Urban Green Spaces Segmentation and Classification Based on Deep Learning Techniques

Urban green spaces are crucial components of the cities, providing a range of environmental and social benefits to the urban community. Authors focused on developing a robust methodology for the segmentation and classification of urban blue-green areas using deep learning algorithms. The dataset used in the research included high-resolution multi-spectral imagery, capturing the diverse nature of urban landcover. However, the challenge lies in achieving a generalized model that can accurately segment and classify the blue-green areas across diverse urban environments.

To enhance the model's ability to generalize, data augmentation technique was used during the pre-processing step. This augmentation process significantly improved the dataset quality and relevance, providing a broader set of samples for training and validation phases. The authors recognized the potential of deep neural networks in learning intricate features from the complex data. A Convolutional

Neural Network (CNN) architecture, or a deep learning model, was utilized and thoughtfully trained on the augmented data set. CNN's ability to capture complex patterns within the data made it good choice for accurate classification results. The resulting model achieved an impressive overall classification accuracy near 90%, supporting the appropriateness of employing deep neural networks in the segmentation and classification tasks for urban blue-green spaces.

3.4.3 Artificial Intelligence and Urban Green Space Facilities Optimization Using the LSTM Model: Evidence from China

This research focuses the escalating air pollution issue, particularly the rise in PM 2.5 concentration in air due to increased urbanization. It emphasizes the crucial role of Urban Green Spaces (UGS) planning in mitigating the PM 2.5 pollution and evaluates machine learning models, specifically LSTM and RNN, for the accurate monitoring and prediction of PM 2.5 levels in city.

RNN and LSTM models are crucial for effective UGS planning to combat air pollution. The implementation necessitates a substantial dataset encompassing three urban road configurations. Python is chosen for model development and data preprocessing. The research compares the results of four machine learning models and illustrates that the proposed model outperforms others with an accuracy of 82.6%, effectively monitoring PM 2.5 concentration. However, the model exhibits a significant margin of error in regions with low PM 2.5 concentration. The research emphasizes the need for further improvement despite the model's impressive accuracy.

3.4.4 Deep Learning for Remote Sensing and Hyperspectral Data

This section lists downs various research papers and their findings relevant to Deep Learning for Remote Sensing and Hyperspectral Data.

3.4.4.1 Green Area Detection from VHR Remote Sensing Images Using a Fusion Deep Learning Method

Very high-resolution (VHR) remote sensing imagery provides a useful and relevant data for detecting and mapping blue-green spaces within an urban land cover .Authors leveraged the potential of fusion deep learning methods in effectively utilizing such type of data. The dataset used in this research contained VHR remote sensing images ,spectral and spatial information. However, effectively utilizing the data for green spaces detection required careful pre-processing and strategic approach.

The dataset underwent pre-processing to enhance the features relevant to the green area identification. This step was crucial in transforming the data set and making it useful for accurate detection. What sets this research apart from other, is the application of a fusion deep learning method. Fusion strategies integrate the strengths of multiple deep learning models, most commonly Convolutional Neural Networks (CNNs). This fusion approach integrated information from different models, resulting in an outstanding accuracy of 94% for blue-green spaces. The authors' choice to adopt a fusion approach was strategic, aiming to improve segmentation accuracy by combining the diverse features learned by individual models. The fusion technique showed remarkable improvement in accuracy compared to using models in the isolation.

3.4.4.2 Deep Learning for Classification of Hyperspectral Data: A Review

Hyperspectral data, with high-dimensional nature, presents unique challenges in classification tasks. Authors recognized this issue and presented a detailed review focusing on deep learning methods for classification of hyper-spectral data. Hyper-spectral data consist of a multitude of narrow and contiguous spectral bands, demanding specialized approaches for effective classification using it.

The review covered a diversity of deep learning approaches, including Convolutional Neural Networks (CNNs), recurrent neural networks (RNNs), and deep belief networks (DBNs). Each of these approaches offered unique advantages in dealing with the challenges posed by hyper-spectral data classification task. Furthermore, the authors outlined several publicly available hyper-spectral data-sets used for training and testing deep learning models, providing valuable insights into the diversity of data available for experimentations and validations.

This comprehensive review served as a base, illustrating versatility and the applicability of various deep learning models in the complex field of hyper-spectral data analysis. While not presenting a specific type of implementation, the review provided useful insights into the rationale for chosing diverse deep learning approaches and datasets to address the challenges associated with hyperspectral data classification. The comprehensiveness of the review made it a significant reference for researchers and practitioners in this field, guiding the exploration of efficient and effective deep learning methodologies for hyperspectral data classification.

3.5 Urban Green Space Prioritization and Optimization

This section lists downs various research papers and their findings relevant to Urban Green Space Prioritization and Optimization.

3.5.1 Urban Green Space Prioritization to Mitigate Air Pollution and the Urban Heat Island Effect in Kathmandu Metropolitan City, Nepal

In response to the pressing air pollution concerns and the adverse effects of Urban Heat Islands (UHIs), this study thoroughly addresses the prioritization and optimization of Urban Green Spaces (UGS) within Kathmandu Metropolitan City, Nepal. The authors focus on the vital role of the strategically planned UGS in mitigating these environmental challenges. Urbanization has deteriorated air pollution, making the targeted UGS planning and allocation critical to cope with these issues.
The study's main focus area, Kathmandu Metropolitan City, Nepal, holds significant relevance due to its air pollution challenges born from rapid urbanization. The methodology for UGS prioritization involves a complete analysis of air pollution statistics, land surface temperatures, and vegetation indices .This data driven approach supports the credibility of the research. The thorough analysis outlines areas within the city needing immediate UGS prioritization for effective air pollution mitigation and UHI improvement. The research provides actionable insights, identifying the areas demanding urgent UGS attention to cope with air pollution issues and counter the Urban Heat Island effect. Furthermore, it delivers a strategic plan for optimizing UGS distribution, vital for enhancing healthy well-being in rapidly urbanizing areas like Kathmandu Metropolitan City.

3.6 Literature Review Summary Table

Table 3.2 provides a comparative overview of the research material discussed in above literature reviews highlighting their research methodology or approach, data set nature and availability details, pre-processing techniques used, algorithm or sophisticated model used and their results or conclusions.

3.6.1 Related Works and Applications

Our exploration of the existing literature revealed a multitude of related works and applications pertinent to the research objectives. These works serve as crucial building blocks for our understanding of the landscape surrounding land segmentation and its critical role in mitigating air pollution.
Through an in-depth analysis of related works and applications as in Table 3.1, we recognize a pressing need for a dedicated application specifically tailored to address air pollution concerns through efficient land segmentation. The research underscores the urgency of such an application, which can significantly contribute to environmental sustainability and public health.

Table 3.1: Relevant Applications and works

This summary Table compares existing applications or works relevant to the project's scope

Application Title	**Model/Framework used**	**Goals/Objectives of the application**	**Publisher Name**
Segmentation of water bodies	CNN based on the U-Net architecture.	Segment bodies of water in satellite images.	**Wct432 (Willem)**
Predict air quality index using python	XGBoost	Webapp to predict the Air Quality Index of a region given climate conditions.	**Vinit Neogi**
Segmentation of green areas	Color transform models to generate CSI	Color Image Segmentation Accomplished by an Adaptive Similarity Measure	**Rodolfo Alvarado-Cervantes , Edgardo Manuel Felipe Riverón**

3.7 Conclusion

Given the objective of improving air quality through effective segmentation of urban blue and green spaces and after overview of results of various studies as in table 3.2, a fusion of techniques is recommended. Leveraging CNN-based segmentation techniques, particularly with high-resolution satellite imagery such as Sentinel-2 [6], can provide a solid foundation for precise mapping of green spaces. Additionally, the utilization of LSTM models [12], as demonstrated in air quality monitoring, holds promise for effectively integrating air quality data within the segmented urban green spaces.

Incorporating a fusion approach that integrates CNN-based segmentation for green space mapping and LSTM for air quality monitoring within the same urban areas can provide a comprehensive understanding of the correlation between urban greenery and air quality. This integrated approach can significantly contribute to your project's aim of enhancing air quality (AQI improvement) through a comprehensive understanding of urban blue and green spaces.

Table 3.2: Summary of Literature Review

This summary Table summarizes important aspects and findings of the research content discussed in chapter 3

Study Title	Methodology & Approach	Dataset Details	Preprocessing Steps	Model/Algorithm Used	Results & Model Accuracy
Mapping Urban Green Infrastructure Using Sentinel-2 Images [6]	Deep Learning (CNN)	Multi spectral Sentinel-2 imagery, downloaded from Kaggle	Radiometric calibration, Masking and Filtering	Convolutional Neural Network (CNN)	Accuracy: 92%, F1 Score: 0.91
Segmenting Green Spaces Using Deep Learning Algorithms: A Case Study of Karachi City [7]	Deep Learning (CNN)	High-resolution satellite imagery with RGB and near-infrared bands	Feature extraction, Spectral and spatial analysis	Convolutional Neural Network (CNN)	Accuracy: 88%
Urban Green Spaces Segmentation and Classification Based on Deep Learning Techniques [8]	Deep Learning (CNN)	High-resolution multi spectral imagery representing urban scenes	Data augmentation	Convolutional Neural Network (CNN)	Overall Classification Accuracy: 90%
Green Area Detection from VHR Remote Sensing Images Using a Fusion Deep Learning Method [9]	Fusion of Deep Learning Models	Very high-resolution (VHR) remote sensing images	Feature enhancement, Data augmentation	Fusion of Deep Learning Models (e.g., CNNs)	Detection Accuracy: 94%
Deep Learning for Classification of Hyper spectral Data: A Review [10]	Review	Publicly available hyper spectral data sets	Data Augmentation	Various Deep Learning Approaches (CNNs, RNNs, DBNs)	Comprehensive review of deep learning methods for hyper-spectral data classification
Urban Green Space Prioritization to Mitigate Air Pollution and the Urban Heat Island Effect in Kathmandu Metropolitan City, Nepal [11]	Geospatial analysis.	Multispectral Landsat images	LST, Pt, GA equations are used	Geospatial analysis	NDVI equation scores for wards range from 28.36% to 39.28%
Urban Green Spaces optimization using LSTM [12]	Green belts/ spaces were chosen for the experiment test points.	Dataset of North road, south road, and east road.	Tensorflow framework with hardware Intel (R) Core (TM) i7-6900K CPU, NVIDIA GeForce GTX 1080 GPU	Sensitivity-based self-organizing LSTM	Accuracy of 89.24% and RMSE, MAE, and MAPE of 1.75, 1.12, and 6.06.
Mapping Urban Green Spaces at the Metropolitan Level [13]	Data is collected using world-view satellites, classified based on bands using Two CNN models	Collected using nine world-view2 satellites.	Data is divided based on polygon shapes and then two clippers are used to produce ortho-mosaic images.	ResNet-34 and ResNet50 Encoder models are used.	Dice coefficient :0.5748 and accuracy :0.9503 by ResNet-34. Dice coefficient :0.4378 and accuracy :0.9839 by ResNet-50.

Chapter 4 Software Requirement Specifications

This section will describe all modules of system requirements and design along with the necessary diagram and figures. It will describe functional requirements, design constraints, and other factors necessary to provide a complete and comprehensive description of the software.

4.1 List of Features

The following features will be available in the system.

- Run pre-trained segmentation models on satellite images.
- Select among different post processing options to get urban planning insights.
- Save Segmented images and Statistics.

4.2 Functional Requirements

The following functional requirements shall be available in the system.

4.2.1 User Perspective

- The user shall be able to search for locations using a search bar or by dragging and scrolling the map.
- The user shall be able to zoom in and out of the map to view the desired area at different scales.
- The user shall be able to view cropped satellite images of the desired area.
- The user shall be able to perform land cover segmentation on cropped satellite images.
- The user shall be able to view the results of land cover segmentation, with blue and green areas segmented and highlighted.
- The user shall be able to calculate the percentage of blue, green, and white areas in the image.
- The user shall be able to select any of the three parameters (blue, green, or others) as an analysis parameter.
- The user shall be able to adjust the percentage change of the selected analysis parameter using a slider.
- The user shall be able to view the impact of changing the analysis parameter on the AQI (Air Quality Index).

- The user shall be able to upload multiple satellite images in chronological order and analyse deforestation or afforestation trends.
- The user shall be able to view a graph showing the percentage of blue, green, and white areas over time.
- The user shall be able to save the segmented image or segmentation results to their disk or upload them to the cloud.

4.2.2 System Perspective

- The system shall provide a user-friendly interface for searching for locations and zooming in and out of maps.
- The system shall display cropped satellite images of the desired area.
- The system shall perform land cover segmentation on cropped satellite images using a pre-trained model.
- The system shall display the resultant image with segmented blue and green areas and others in the image.
- The system shall calculate the percentage of blue, green, and white areas in images and display them all percentages.
- The system shall allow users to select any of the three parameters (blue, green, or others) to set it as an analysis parameter.
- The system shall display a slider initially set to the current calculated percentage of the parameter selected and an AQI initially set to the current AQI in the area.
- The system shall display the percentage changed due to the movement of the slider and the relevant change in AQI due to that change.
- The system shall allow users to upload multiple satellite images in chronological order and analyse deforestation or afforestation trends.
- The system shall perform segmentation on all the images and process them to find blue, green, and other areas percentage for each1.
- The system shall allow users to save the segmented image or segmentation results on their disk or upload them to the cloud.

4.3 Quality Attributes

To guarantee the avoidance of application faults, the project aims to include the following core quality criteria. Every attribute will be utilized to assess the performance and quality of the application when it is in use.

4.3.1 Reliability

Ensuring the segmentation process accurately identifies blue-green areas in Lahore consistently and reliably, regardless of variations in environmental conditions or data inputs. The identification of these areas should be consistent and accurate to contribute to improving the AQI.

4.3.2 Maintainability

Implementing state-of-the-art techniques for segmentation and analysis, with a focus on allowing future updates or improvements in the algorithms used for segmentation. The system should be adaptable to new technologies or improved methods as they develop.

4.3.3 Usability

Developing an easily accessible and user-friendly system that allows stakeholders and the public to comprehend and utilise the insights gained from the blue-green area segmentation. It should facilitate easy interaction and interpretation of the data insights for both technical and non-technical users.

4.3.4 Correctness

Ensuring the accuracy of the segmentation model to avoid false positives or misinterpretation of blue-green areas. The system should strictly comply with functional requirements and incorporate empirical metrics for further improvement.

4.3.5 Efficiency

Optimizing the process to efficiently analyze and quantify blue-green areas within Lahore. The system should minimize computational resources while ensuring timely delivery of insights and predictions to support decision-making.

4.3.6 Flexibility

Providing the ability for researchers and users to adapt and potentially enhance the segmentation model or techniques. Enable the system to be modified or fine-tuned to suit various needs, allowing the inclusion of new algorithms or customization options.

4.4 Non-Functional Requirements

The following non-functional requirements will be included in the system to operate effectively.

4.4.1 Re-usability

Developing a modular system that allows components to be reused in other projects. Ensure the correct functioning of the system regardless of the structural changes in future adaptations or reuse.

4.4.2 Reliability

Ensuring the system consistently produces accurate segmentation results irrespective of environmental factors or hardware limitations. It should also provide means for users to assess and validate the results using established metrics.

4.4.3 Performance

Employing cloud computing to accelerate the segmentation process and generate accurate results swiftly. Additionally, allow users the option to utilize offline resources for processing if available.

4.4.4 Robustness

Enabling the system to handle large volumes of data without compromising critical information or system functionality. It should retain progress made even in the event of connection dropouts or hardware failures.

4.4.5 Extensibility

Adhering to standard development practices to facilitate extensibility for future researchers. Allow potential contributors to extend the project by integrating new algorithms or improved architectures.

4.5 Assumptions

Following list down all the assumptions made for the specification.

- Users shall know the basic English to use the system as the language of the system is English.
- Users have sound knowledge of the project's purpose and utility as well as of technology to use the system.

- Users have basic knowledge to use the Google Maps features.

4.6 Use Cases

In this section, all core use cases have been listed for better understanding of different workflows of the project.

4.6.1 Upload Satellite Image for Segmentation from Disk

<table>
<tr><td>Name</td><td colspan="3">Upload Satellite Image for Segmentation from Disk</td></tr>
<tr><td>Actors</td><td colspan="3">User</td></tr>
<tr><td>Summary</td><td colspan="3">The user clicks on the upload image button to upload the image located on the disk and the image will be loaded into the system.</td></tr>
<tr><td>Pre-Conditions</td><td colspan="3">Network connectivity.
The data set has to be pre-processed and segmentation has to be applied.</td></tr>
<tr><td>Post-Conditions</td><td colspan="3">Post processing model will be
applied on the image and segmented image will be displayed as a result.</td></tr>
<tr><td>Special Requirements</td><td colspan="3">None</td></tr>
<tr><td colspan="4">Basic Flow</td></tr>
<tr><td colspan="2">Actor Action</td><td colspan="2">System Response</td></tr>
<tr><td>1</td><td>User selects the upload button.</td><td>2</td><td>The system asks for storage access to upload from disk.</td></tr>
<tr><td>2</td><td>User provides Storage access.</td><td>4</td><td>System displays the successfully uploaded image.</td></tr>
<tr><td colspan="4">Alternative Flow</td></tr>
<tr><td>3</td><td>User does not provide Storage access</td><td>4-A</td><td>System displays the upload fail error message.</td></tr>
</table>

4.6.2 Select Area on Google Maps for Segmentation

Name	Select Area on Google Maps for Segmentation
Actors	User
Summary	The user searches for an area on a Google Maps screen displayed on the system and selects that area to obtain its satellite view. The system crops the selected area, converts it into an image, and presents it to the user for segmentation.

<table>
<tr><td>Pre-Conditions</td><td colspan="3">Network connectivity.
Google Maps integration with the system.
Image cropping and conversion capabilities.</td></tr>
<tr><td>Post-Conditions</td><td colspan="3">The cropped and converted satellite image of the selected area is displayed to the user.
The image is ready for segmentation processing.</td></tr>
<tr><td>Special Requirements</td><td colspan="3">None</td></tr>
<tr><td colspan="4">Basic Flow</td></tr>
<tr><td colspan="2">Actor Action</td><td colspan="2">System Response</td></tr>
<tr><td>1</td><td>User searches for the desired location and selects the area using the provided selection tool in required format.</td><td>2</td><td>System crops the selected area.</td></tr>
<tr><td></td><td></td><td>3</td><td>System converts the cropped area into an image</td></tr>
<tr><td></td><td></td><td>4</td><td>System displays the converted image to the user.</td></tr>
<tr><td colspan="4">Alternative Flow</td></tr>
<tr><td>1-A</td><td>User selects an area that is too small or too large for processing.</td><td>2-A</td><td>System displays an error message indicating that the selected area is not suitable for processing.
It suggests the user to select an area within the appropriate size range.</td></tr>
</table>

4.6.3 Land Cover Segmentation

Name	Land Cover Segmentation
Actors	User
Summary	The user can run a pre-trained segmented model on the provided image of an area.
Pre-Conditions	Network connectivity. Downloaded Pre-Trained Model. Image has been provided by the user.
Post-Conditions	The segmentation results will be displayed. Percentage of Blue Green Area and Urban area will be displayed.
Special Requirements	None

Basic Flow			
Actor Action		**System Response**	
1	The user clicks the "Segment" button.	2	The system hits the inference API and Displays the segmented Image to the user.
Alternative Flow			
1	There is an error communicating to the API	2-A	The system will display the error message "Segmentation Request Failed".
1	There is an error in segmentation	2-A	The system will display an error message "Segmentation error".

4.6.4 Download Segmentation Results

Name	Download Segmentation Results		
Actors	User		
Summary	The user shall be able to download the segmentation results generated by pre-defined model.		
Pre-Conditions	Network connectivity. Download permissions granted.		
Post-Conditions	The Segementation results shall be downloaded on the user disk.		
Special Requirements	None		
Basic Flow			
Actor Action		**System Response**	
1	The user clicks "Save" button.	2	The system starts the download process.
Alternative Flow			
1	The download fails.	2-A	The system will display the error message :"Download failed."

4.6.5 Performing Analysis on AQI and Blue Green area relationship.

Name	Performing Analysis on AQI and Blue Green area relationship.
Actors	User
Summary	The user performs analysis on the relationship of AQI with the Blue Green area and uses insights for Urban Planning.

Pre-Conditions	Network connectivity. The segmented data and AQI record has been fetched.		
Post-Conditions	Effect of the change in blue green area will be displayed on AQI and vice versa in stats form.		
Special Requirements	None		
Basic Flow			
Actor Action		**System Response**	
1	The user selects from the Analysis parameters (Blue, Green or Urban area) to analyze the image.	2	The system displays the selected analysis parameters and analysis tab containing a slider.
		3	The system displays and sets the slider to the current percentage area of the specified parameter.
4	The user varies the percentage area of selected parameters through the slider.	5	The system displays the percentage change in area specified by the user.
		6	The System will display the impact of user provided change in area of selected parameter, on AQI level.
Alternative Flow			
4-A	The user varies the current AQI level to the desired one.	5-A	The system displays the percentage change required in the area selected by the user to achieve that AQI level

4.6.6 Visualize Trends

Name	Visualize Trends
Actors	User
Summary	The system generates a graph showing the trends of blue, green, and urban areas over time.

Pre-Conditions	Network connectivity. The dataset has to be pre-processed. The image has already been segmented. Storage access has been granted.		
Post-Conditions	Post processing model will provide meaningful stats about the segmented images.		
Special Requirements	None		
Basic Flow			
Actor Action		**System Response**	
1	The user uploads more than one image for comparison.	2	The system displays the uploaded images.
3	The user click on button "Visualize Trends".	4	The system will show a bar graph showing comparative trends of blue, green and urban areas existing among the images uploaded.
		5	The system shows afforestation, deforestation and urbanization percentage by comparing uploaded images segmentation results.
Alternative Flow			
1	Upload fails.	2-A	The system show error message "Unable to load images".
1	Only one or no image has been uploaded.	4-A	The system show an alert "Upload sufficient number of images for comparison".

4.6.7 Download Trends among different images

Name	Download Trends among different images
Actors	User
Summary	The user shall be able to download the trends that exist among images generated by the predefined model.
Pre-Conditions	Network connectivity. Download permissions granted.
Post-Conditions	The comparative trends results shall be downloaded on the user disk.

<table>
<tr><td>Special Requirements</td><td colspan="3">None</td></tr>
<tr><td colspan="4">Basic Flow</td></tr>
<tr><td colspan="2">Actor Action</td><td colspan="2">System Response</td></tr>
<tr><td>1</td><td>The user clicks “Download” button.</td><td>2</td><td>The system starts the download process.</td></tr>
<tr><td colspan="4">Alternative Flow</td></tr>
<tr><td>1</td><td>The download fails.</td><td>2-A</td><td>The system will display the error message :“Download failed.”</td></tr>
</table>

4.7 Hardware and Software Requirements

For its operations, the project makes use of hardware and software services. The following software and hardware prerequisites must be met in order to develop this project.

4.7.1 Hardware Requirements

The following are the hardware requirements required for the operation of the system:

4.7.1.1 Computer Workstations

High-performance workstations for data processing, machine learning model training, and software development will be required for seamless and un-interupted development environment.

4.7.1.2 Storage Infrastructure

Sufficient storage space to store and manage large data sets, high resolution satellite imagery, and project files will be required.

4.7.1.3 Graphics Processing Units (GPUs)

Powerful GPUs for accelerating machine learning model training and data processing tasks will be required for saving time to focus on bussiness logic.

4.7.1.4 Server or Cloud Resources

Depending on data processing needs, cloud computing resources like AWS, Google Cloud, or Microsoft Azure may be required.

4.7.2 Software Requirements

The following are the software requirements that may be required for the operation of the system:

4.7.2.1 Operating System

Typically, the project can be carried out on Windows, macOS, or Linux operating systems.

4.7.2.2 Machine Learning and Data Analysis

- Python programming language.
- Jupyter Notebook , Google Collab or similar integrated development environments for data analysis.
- Machine learning libraries like TensorFlow, PyTorch, scikit-learn, and Keras for model development and training.
- Data analysis libraries like NumPy, Pandas, and Matplotlib for data manipulation and visualization.

4.7.3 Web Development

- Web development tools such as HTML, CSS, JavaScript and React for front-end development.
- Web application frameworks like Django or Flask if we are using Python for back-end development.
- Database management systems like MongoDB or MySQL for storing data.
- Web hosting and server environments for deploying the web application.

4.7.3.1 Version Control

Git and platforms like GitHub for collaboration and version control will be used. Project will be stored in the form of set of repositories.

4.7.3.2 Communication Tools

Collaboration and communication tools like Microsoft Teams and Google Workspace for team coordination and updates will be used.

4.7.3.3 Documentation

Tools for creating project documentation, such as Microsoft Word or LaTeX for reports and project proposals will be used as they provide easy collaboration environment specifically for development purposes.

4.7.3.4 Internet Connectivity

A stable and high-speed internet connection for data download, updates, and collaboration.

4.8 Graphical User Interface

This section provides an overview of how the system GUI will look like. It covers the major elements involved in general workflow of the system. Following Figure 4.1 shows the main screen graphical user interface for performing segmentation on sattelite images.

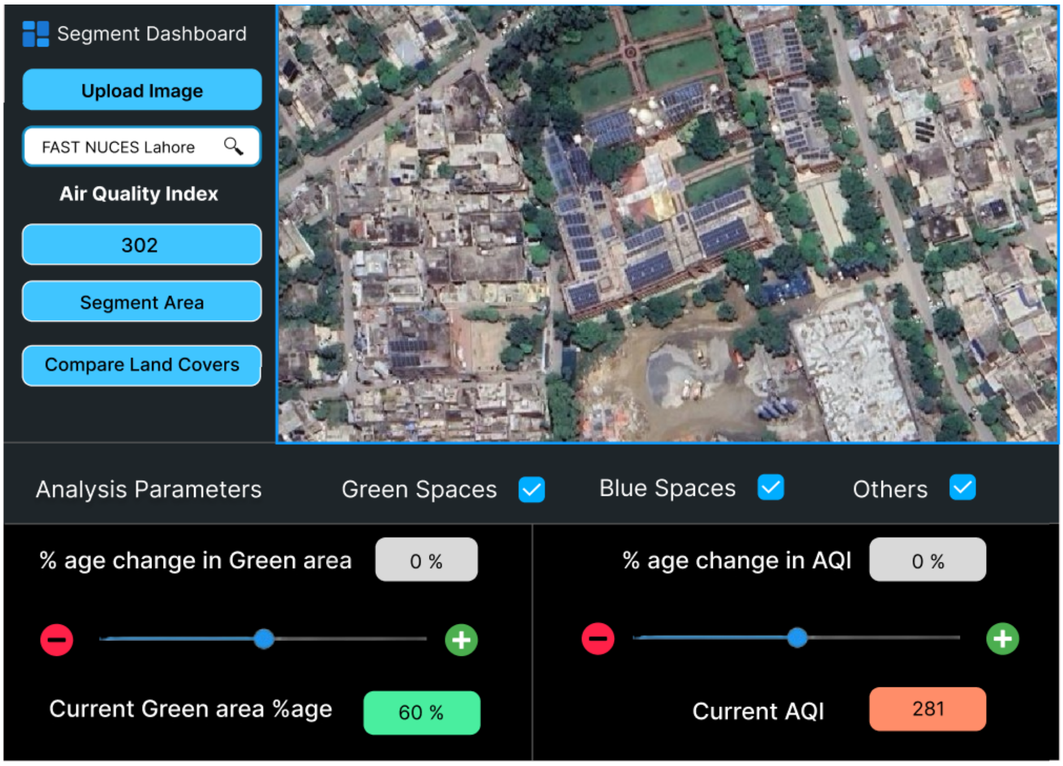

Figure 4.1: Main Screen - Segmentation Dashboard

The figure represents the main screen GUI that will allow user to perform segmentation task or navigate to the the next screen (Land Cover Comparison)

Following Figure 4.2 shows the Land Cover Comparison screen graphical user interface for visualizing and exporting trends among uploaded images.

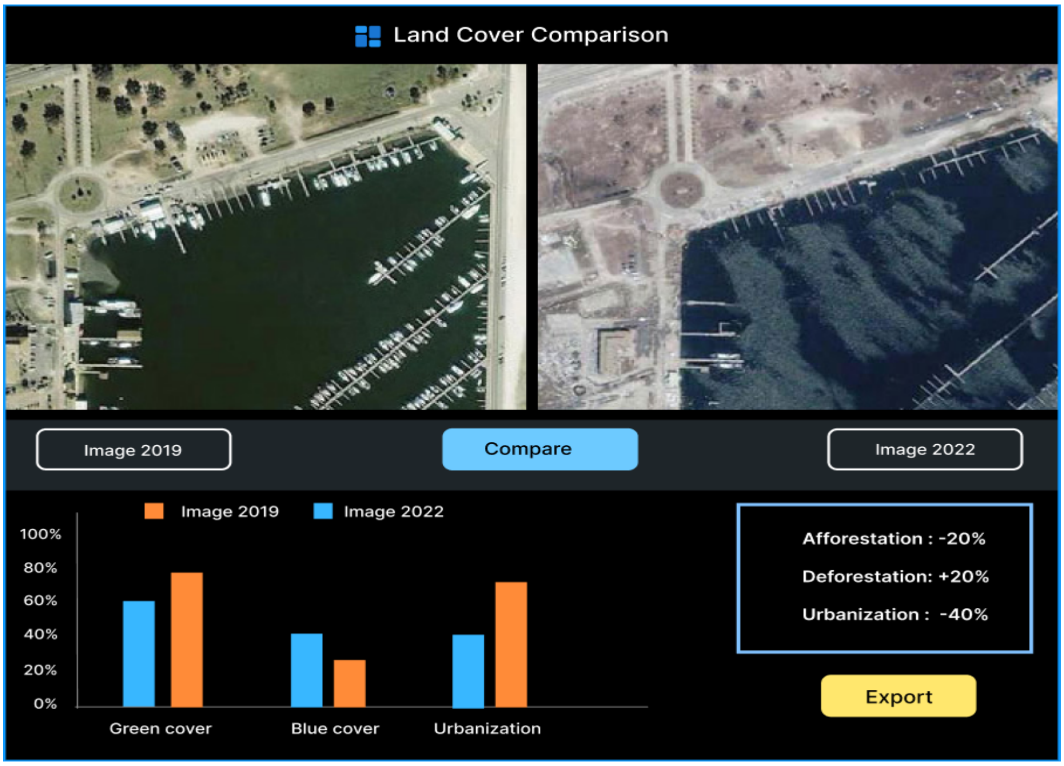

Figure 4.2: Second Screen - Land Cover Comparison

The figure represents the second screen GUI that visualizes trends existing among images

4.9 Risk Analysis

According to the study that was done, there are potential dangers that the project will face as it develops. The risks have been noted and are further described below.

4.9.1 Technical Analysis

Obtaining real-time and accurate Air Quality Index (AQI) data for the project is challenging due to the inconsistent and outdated nature of existing sources. Data fusion, real-time monitoring sensors, and data validation will be considered to address this issue. Additionally, collaboration with local authorities for reliable data and exploring predictive modelling to estimate AQI in areas with data gaps will be performed. These strategies will help ensure the availability of reliable AQI data for the project.

Obtaining accurate and updated remote imagery data for the project is challenging, as many sources do not regularly update their data. To mitigate this issue,leveraging data fusion from multiple sources, and exploring methods to enhance the accuracy of outdated imagery through image processing techniques and historical data analysis will be considered.

4.9.2 Performance Analysis

The project will be built on a python framework with the aid of popular libraries like tensor flow. However, due to the dynamic nature of python, the performance will not be able to meet all the benchmarks. Furthermore, the performance will be affected if the model is deployed on different platforms like mobile app, web framework and desktop app.

4.10 Conclusion

In conclusion, this section has provided a comprehensive overview of the software by describing all modules of system requirements and design, supported by necessary diagrams and figures. It has outlined the functional requirements, design constraints, and other factors essential for a thorough understanding of the software.

Chapter 5 Proposed Approach and Methodology

This chapter explains the proposed approach and methodology to implement accurate land cover segmentation. It includes description of pre-processing augmentation, segmentation and post-processing steps.

5.1 Pre-Processing

Since pre-processing of the images greatly impacts model training and accuracy, our project will be adopting the most beneficial pre-processing techniques, specific to the land cover segmentation task and data set.

5.1.1 One Hot Encoding

One-hot encoding will be used to represent the segmentation masks as the masks in our data set have more than one class like blue ,green or urban area. For each pixel in the mask, a one-hot encoded vector based on the class of that pixel, will be assigned. Figure 5.1 shows an example mask image containing more than one color classes.

Figure 5.1: Example Mask Image

The figure represents an instance of mask image from data set showing more than one color classes.

This representation will allow us to use standard categorical cross-entropy loss during the training of a neural network for image segmentation. It will help the network learn to predict the probability of each class for each pixel as each channel in one-hot encoded vector corresponds to a different class.

5.1.2 Random Cropping and Padding

For our segmentation task, padding will be used to address issues related to convolutional operations ensuring that spatial information is not lost at the edges of the image during convolution and pooling operations. Figure 5.2 shows an instance of padding applied to both original and mask images.

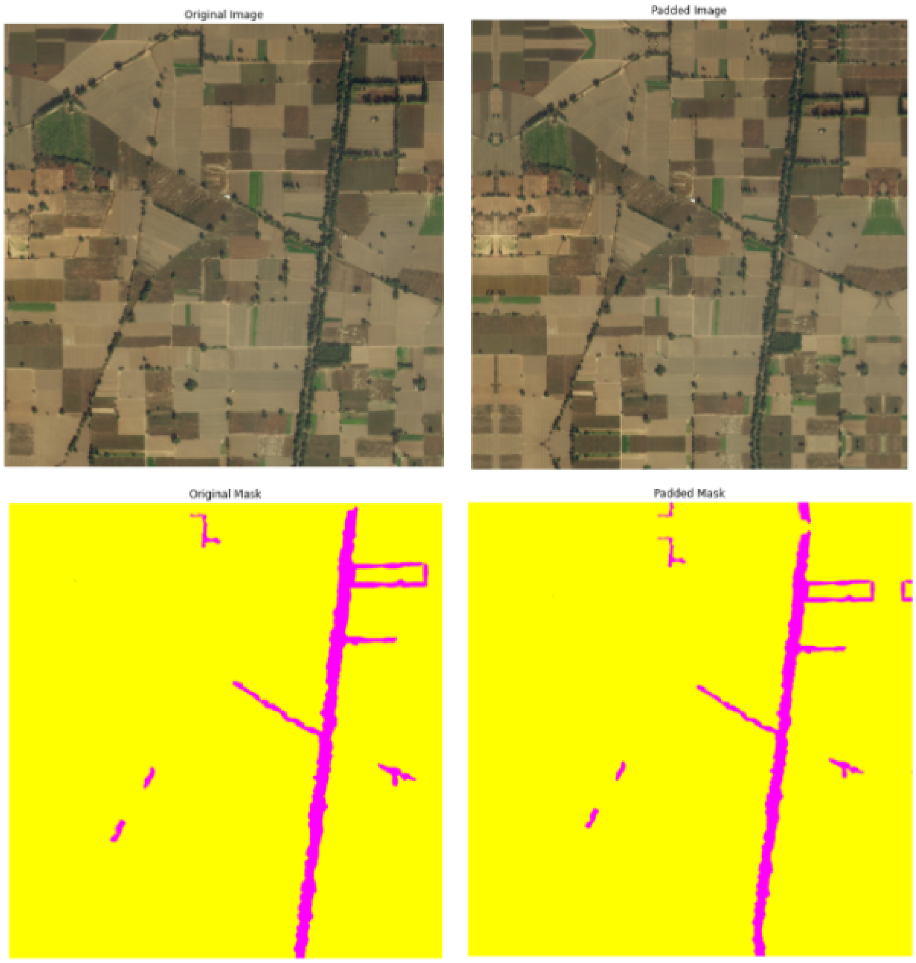

Figure 5.2: Example Padded Images

The figure represents an instance of padding applied on original and mask images

5.2 Augmentation

Since the limited size of the data set is one of the major limitations to our project, the system shall be adopting augmentation technique.The augmentation techniques will be carefully selected to keep the images as close to the real-life data as possible to avoid potential over-fitting issues.

Through experimentation and specifically for our data set, the following augmentations show positive results:

- For improving edges and details: CLAHE, Sharpen, and Emboss.

- For generalization on images that are poorly processed: Contrast and Brightness.
- For generalization on image positioning: Random Scaling, Rotation, and Flipping.

5.3 Segmentation

The model relies on the accurate selection of regions by detector. Through experimentation and research, it is found that UNet-based architectures have an excellent performance for such segmentation tasks. Our system will also be using UNeT-based architecture as backbone. The overall segmentation pipeline is shown in Figure 5.3.

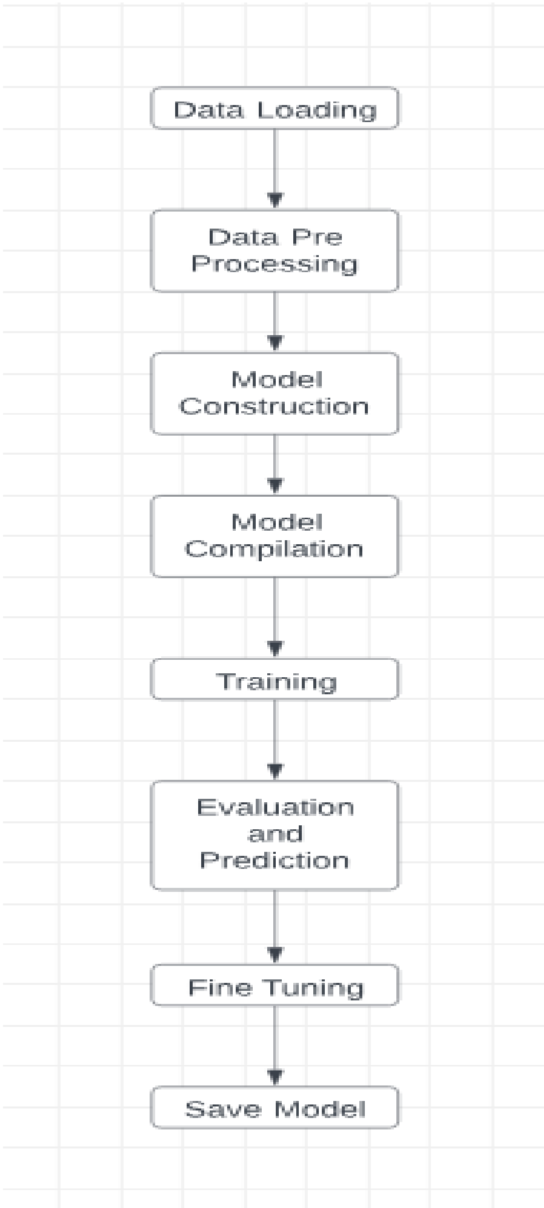

Figure 5.3: Overall Segmentation Pipeline

The figure depicts the pipeline adopted for the segmentation process.

5.4 Post Processing

After evaluating the model, various scores and accuracy parameters will be carefully reviewed to decide whether post processing is needed or not. Fine tuning may be done to reduce the noise in the results and improve the overall generalization.

5.5 Conclusion

This chapter outlined the proposed methodology for achieving precise land cover segmentation. The approach encompasses a detailed description of the pre-processing augmentation, segmentation, and post-processing steps. In particular, the methodology involves leveraging a pre-trained model for its learned features, followed by a fine-tuning process tailored to the specific task of accurately segmenting blue-green areas in satellite images.

Chapter 6 High-Level and Low-Level Design

This chapter discusses the high-level and low-level designs of the project. It includes the system overview, the design considerations, system architecture, architectural strategies, class diagram, sequence diagrams and the policies and tactics related to the project.

6.1 System Overview

The application will effectively record and study the effects of green blue spaces/bodies on air pollution. Furthermore, it will also lay down a roadmap for the UGS planning in the metropolitan area as there exists a correlation between the AQI and Blue-Green areas.
Our webpage will be a simple interface created using ReactJS as frontend and python with Django to implement the backend. Once the user provides the satellite image of an area, our frontend using an API, will provide the current AQI in that area and provide a comprehensive analysis environment to assess impact of percentage change in blue, green or urban area on AQI. Also the System will provide a comparative analysis interface for more than one image to study the trend of afforestation, deforestation or urbanization.

6.2 Design Considerations

This section describes the design considerations for the system. It includes the assumptions and dependencies of the system, the general constraints, the goals and guidelines, and the development methods.

6.2.1 Assumptions and Dependencies

The project makes use of the following assumptions and dependencies:

6.2.1.1 Data Source Dependencies

The project is dependent on the continuous availability and timely updates of data from satellite imagery, AQI monitoring stations, and other relevant sources.

6.2.1.2 Weather Conditions

The accuracy of air quality assessments and the impact of green cover may be influenced by weather conditions, making the project dependent on relatively stable weather patterns.

6.2.1.3 Internet Connectivity

A stable and constant internet connection is required for this tool as it is web based.

6.2.1.4 Data Accuracy

The project assumes that the data obtained from various sources, including satellite imagery, AQI data, land cover data, and weather data, is accurate and reliable.

6.2.2 General Constraints

Following are listed the general constraints related to the web application we are building for the segmentation and analysis tasks.

6.2.2.1 Availability or Volatility of Requirements

A high-speed internet connection will always be necessary for the application to function properly as well as timely.

6.2.2.2 Data Repository and Distribution Requirements

Constraints relevant to data management include issues related to the use of MongoDB as the database management system.It was chosen for ensuring the simplicity and ease of the integration with the MERN stack.

6.2.2.3 Security Requirements

The project is constrained by the necessity for robust security measures, encompassing secure data transmission, access control, and protection against potential vulnerabilities.

6.2.2.4 Language Constraint

This web application will be available in English language.

6.2.2.5 End-User Environment

To operate this online application, the end-user will need a web browser installed on their system.

6.2.3 Goals and Guidelines

Following goals, guidelines, principles, and priorities are a part of this project:

- User friendliness of the system.
- Emphasis on general accessibility.
- The KISS principle ("Keep it simple stupid!") because we do not want to over complicate things that need to be simple.
- Emphasis on accuracy rather than resource consumption.

6.2.4 Development Methods

For the development of this project, the chosen methodology is Scrum, an agile framework that prioritizes collaboration and incremental progress. The choice of using Scrum is based on its ability to adapt to constantly changing requirements and its focus on breaking down the tasks into easily manageable sprints. These sprints allow team to focus on specific project components, such as data integration, machine learning models, and web application features, ensuring uninterrupted and timely delivery of tangible results.

The iterative nature of Scrum aligns well with dynamic aspects of project, enabling quick response to feedback. Regular reviews with the Scrum Master facilitate constructive feedback, contributing to ongoing enhancements and the overall success of the project.

6.3 System Architecture

The system provides users an easy to use interface for assesing the relation of AQI and blue-green spaces. The process begins by demonstrating the user a comprehensive test in order to access them to be eligible for using the system. Afterwards, they are navigated to the main dashboard where they can use Google Maps to select areas and segment green blue spaces from them along with AQI labels on them.

The software application offers a publicly accessible API that enables authorized clients to submit requests for the image segmentation tasks. The back-end module serves as a comprehensive framework, abstracting the implementation of various essential functions and processes outlined in the specifications section. These functions encompass executing inference on the satellite images and performing analysis on the segmented images.

In essence, the application serves as a versatile platform, allowing users to seamlessly integrate and utilize key functionalities for the image analysis, whether it involves running inferences on their images or performing post processing tasks.

Basic architecture diagram of the system has been shown in Figure 6.1 that shows all key components that are the part of the system.

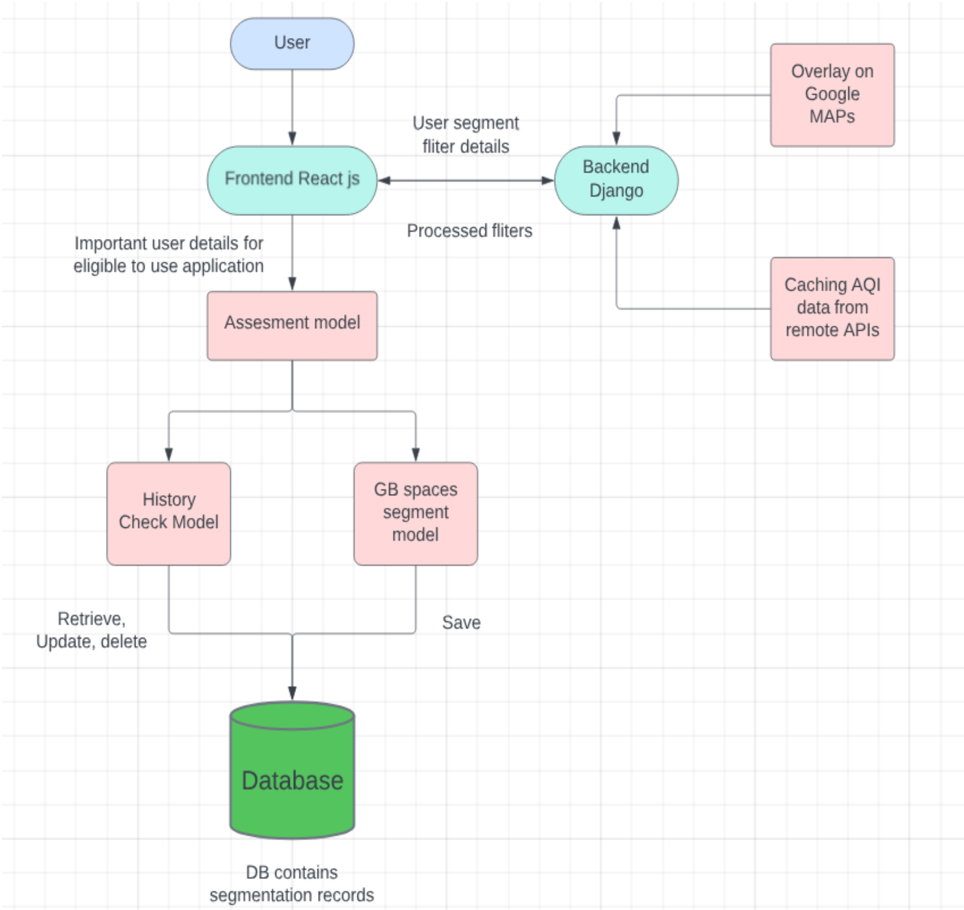

Figure 6.1: System Architecture Diagram

The Diagram for High Level Architecture

6.4 Architectural Strategies

The system's architectural approaches are based on industry standards, emphasizing the importance of system robustness, flexibility, and interoperability. Therefore, our focus will be directed towards implementing the following architectural strategies to bring the project to successful completion.

6.4.1 Technology Stack

Given that the project revolves around machine learning models and research, Python and Django stand out as the most fitting options for backend operations. On the frontend side, the application will be using the MERN stack for the development purpose. Moreover, the selected technology stack benefits from online resources and large user base to address any potential issues which may occur during the development.

6.4.2 Database Management

As we use the MERN stack, we use MongoDB as database management, due to its simplicity and ease of integration using Mongoose with the backend.

6.4.3 Frontend Paradigms

The frontend architecture for this project shall be developed using the MERN stack. The user interface will follow the principles of a Single Page Application (SPA), leveraging React as part of the MERN stack. The application will adopt a Component-Based Architecture, breaking down the UI into reusable components to enhance maintainability and code reusability. The integration with the backend will follow RESTful API principles, ensuring effective communication between the frontend and the Python-Django backend creating a modular, scalable, and performant frontend for the project.

6.4.4 Version Control System

We will use GitHub as a version control system.The application will be stored as a set of repositories on GitHub.The development team will submit pull requests, and the modifications will be implemented with the agreement of two other team members.

6.5 Class Diagram

The Basic class diagrams of the proposed system is shown in Figure 6.2

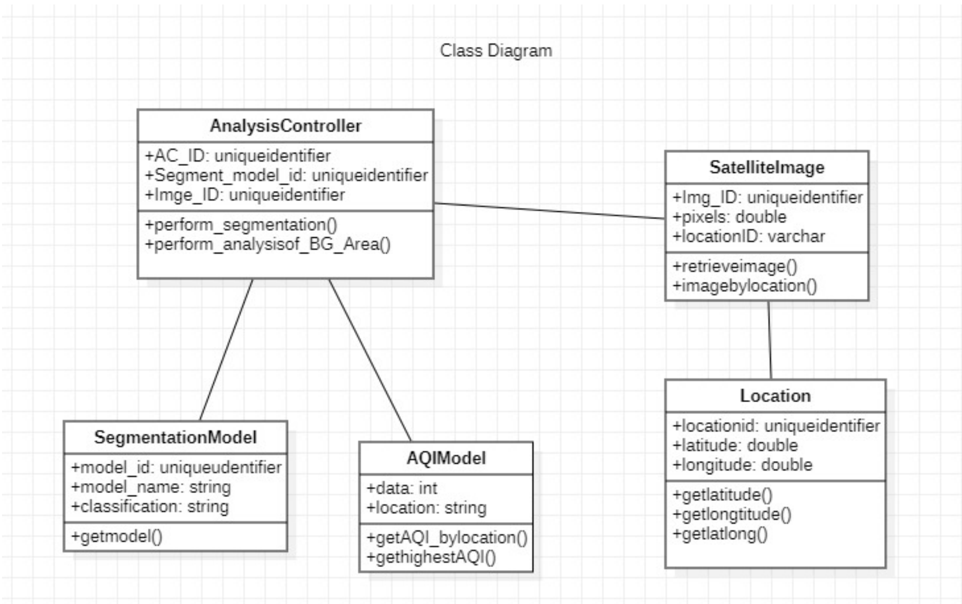

Figure 6.2: Class Diagram

The High Level Class Diagram proposed for the System

6.6 Sequence Diagrams

The sequence diagrams relevant to our web application are listed below in Figures 6.3 ,6.4 and 6.5.

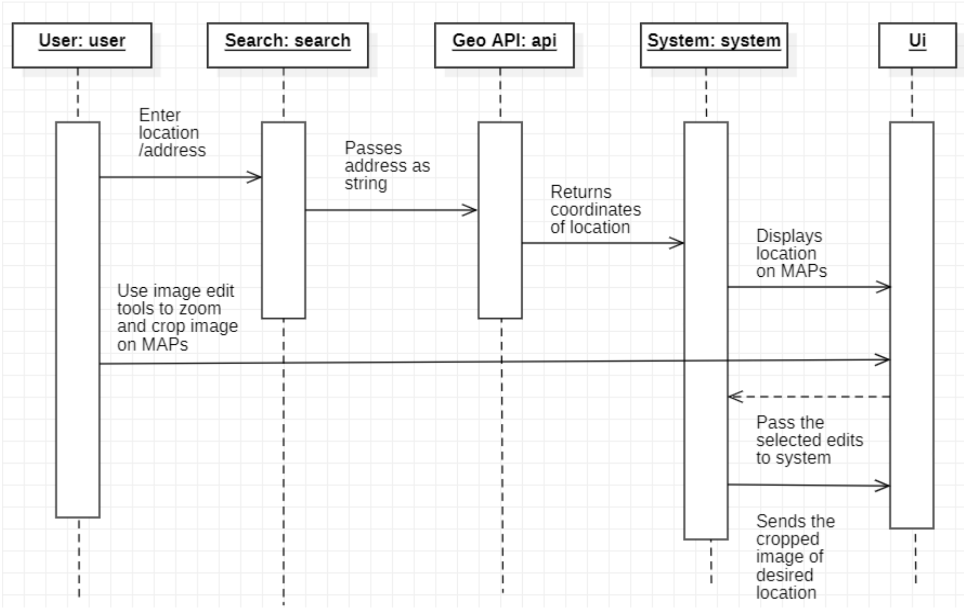

Figure 6.3: Sequence Diagram - Searching and Extracting Image of Desired Area for Segmentation

The figure displays the sequence of events involved in searching a desired area on google maps and then extracting its cropped image to be sent for segmentation.

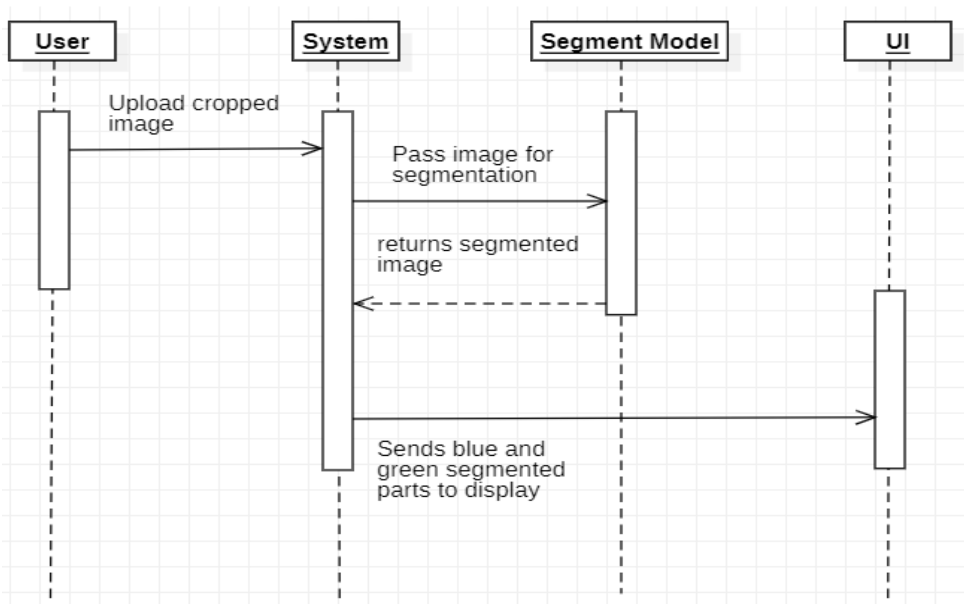

Figure 6.4: Sequence Diagram - Uploading Image and Getting Segmentation Results

The Figure displays the sequence of events involved in uploading an image into the system and sending it to API for fetching segmentation results.

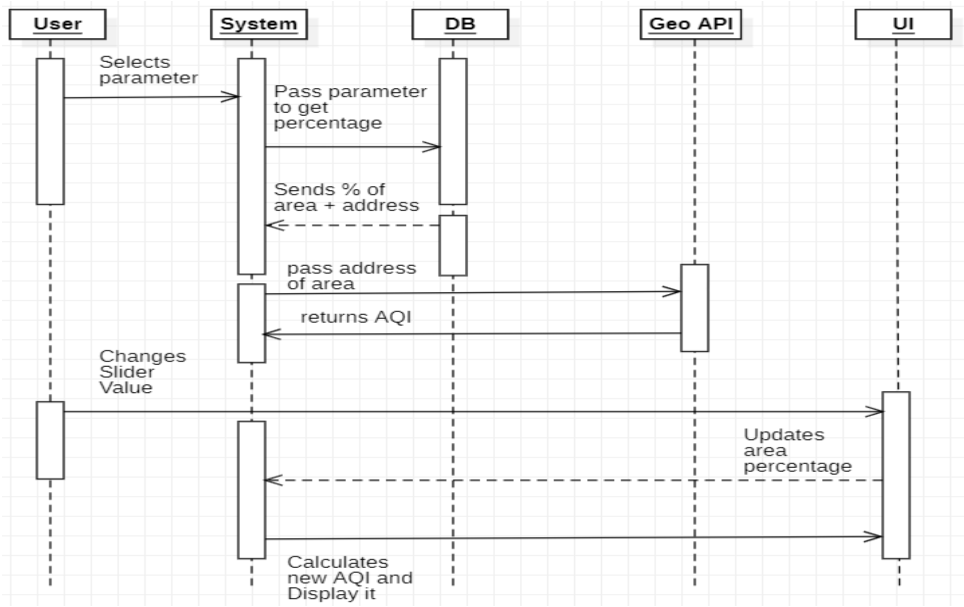

Figure 6.5: Sequence Diagram - Performing Analysis and Getting Trends among Land Covers

The Figure displays the sequence of events involved in performing Land Cover Comparison and Analysis.

6.7 Policies and Tactics

This section will go through the design policies and tactics that may not necessarily have any larger architectural implications, which means they will not have an enough impact on the organization of the system as a whole and high-level structures of it, but it will affect the details of the interface and the implementation of different aspects of the system greatly.

6.7.1 Conventions

Following are listed some conventions which will be followed in the development of the project.

6.7.1.1 Policy

Adherence to coding conventions and naming standards to ensure consistency and readability in the code base.

6.7.1.2 Tactics

- Utilize consistent naming conventions for variables, functions, and components across the front-end and back-end to enhance code clarity.
- Enforce a consistent code formatting style using tools like Prettier for the front-end and Black for the back-end.

6.7.2 Testing

Following are listed the testing strategies which will be adopted for the completion of the project.

6.7.2.1 Policy

Implement a comprehensive testing strategy to ensure the reliability and functionality of the system.

6.7.2.2 Tactics

- Emphasize unit testing for individual components and functions to validate their correctness.
- Conduct integration testing to verify the proper collaboration between different modules of the system.
- Engage in UAT (User Acceptance Testing) to validate the overall functionality and user experience.

6.7.3 End-User Interface

6.7.3.1 Policy

Prioritize a user-centric design and seamless user experience.

6.7.3.2 Tactics

- Implement a responsive design approach to ensure optimal user experience across various devices and screen sizes.
- Follow Material Design principles for the front-end to maintain consistency and provide a familiar interface.

6.8 Conclusion

In summary, this chapter covers both the high-level and low-level designs of the project. It encompasses the system overview, design considerations, system architecture, architectural strategies, class diagram, sequence diagrams, and project-related policies and tactics.

Chapter 7 Implementation and Test Cases

The following part includes an overview of the project's implementation so far, as well as technical specifics that were left out of the overall high-level design. The content is subject to change as the project progresses.

7.1 Implementation

This chapter details the actual implementation of how the land cover segmentation system was developed and the various considerations taken into account during implementation.

7.1.1 Environment settings

Following Environment settings were used for the Image Segmentation Model Training:

- Image size: 320x320 pixels
- Batch size: 8
- Number of periods: 20

7.1.1.1 Data preparation and Loading

The classes were loaded and their respective RGB values in the mask were extracted from comma separated file. Satelite and Mask Images were loaded and shuffled in the form of data frames using pandas library. The data set used was dsplit into a set for training, validation and test, and the ratio was about 60% for the training, 20% for the validation and 20% for the test data set.

7.1.1.2 Data Augmentation

To improve the generalization ability of the model and increasing the diversity of the training data set, techniques like data augmentations were used. Improvements include resizing, horizontal and vertical flipping, arbitrary brightness/contrast adjustments, Gaussian blur, elastic transformation and rotation.

7.1.2 Dataset Preparation

Different built-in python libraries were used to load images and masks, convert them to RGB format and optimize them according to the changes. Utility Functions were used to convert the RGB mask to a categorical mask using the RGB values-to-list map. Data was normalized and converted to PyTorch tensors.

7.1.3 Model Architecture

The segmentation model architecture used is U-Net++.The encoder is based on the RegNetY-120 model before training on ImageNet. The model uses the softmax activation function to output pixel-wise classes. Dice Loss is used as a loss in training.

7.1.4 Training

The ”LightningModule” class is subclassed to define training, validation and testing steps. The model is trained using an Adam optimizer with a 0.0001 learning rate. Training and validation measures including loss, IoU, accuracy, precision, recall, F1 score and F1 score is recorded during training. Sample checks are saved based on guaranteed F1 points and hired early to avoid overwork.

7.1.5 Model Evaluation

Measurements including loss, IoU, accuracy, accuracy, recovery and F1 score were recorded. GPU usage during testing was monitored. Matplotlib to visualize the training and validation process to identify performance patterns over time, was used. Metrics included loss, IoU, accuracy, precision, recovery and F1 score.

7.2 Test case Design

Following are the test cases identified in our project.

7.2.1 Fetching AQI Test Case

.

Fetching AQI			
1			
Test Case ID:	*1*	**QA Test Engineer:**	*Muhaamd Sohaib*
Test case Version:	*1.0*	**Reviewed By:**	*Hafiz Hamza Shahid*
Test Date:	*02-04-2024*	**Use Case Reference(s):**	*Select Area on Google Maps for Segmentation*
Revision History:	*None*		
Objective:	*To test AQI fetch properly for visualize trends*		
Product/Ver/ Module:	*AirQualify/1.0/Segmentation Module*		

Environment:	*Web Browser. Internet connection.*		
Assumptions:	*If API key is expired or Data is not available*		
Pre-Requisite:	*User Must Select a place to which system fetch an AQI*		
Step No.	**Execution description**	**Procedure result**	
1	*User click/Search any location on map.*	*AQI will displayed on screen.*	
Comments: Test Case Passed. Our system is working properly			
[Yes] Passed [] Failed [] Not Executed			

7.2.2 Save Image Test Case

.

Save Satelite Image			
2			
Test Case ID:	*2*	**QA Test Engineer:**	*Muhaamd Sohaib*
Test case Version:	*1.0*	**Reviewed By:**	*Taimoor Mukhtar*
Test Date:	*03-04-2024*	**Use Case Reference(s):**	*Select Area on Google Maps for Segmentation*
Revision History:	*None*		
Objective:	*Saved image can later be used for segmentation.*		
Product/Ver/ Module:	*AirQualify/1.0/Segmentation Module*		
Environment:	*Web Browser. Internet connection.*		
Assumptions:	*System is in running*		
Pre-Requisite:	*None*		
Step No.	**Execution description**	**Procedure result**	
1	*User click/Search any location on map.*	*Red dot displayed on that location in map*	
2	*Pressing the 'Save Location' button.*	*Save the image in our local device.*	
Comments: Test Case Passed. Our system is working properly			
[Yes] Passed [] Failed [] Not Executed			

7.2.3 Fetch Current Location Test Case

.

Current Location			
3			
Test Case ID:	*3*	**QA Test Engineer:**	*Muhaamd Sohaib*
Test case Version:	*1.0*	**Reviewed By:**	*Taimoor Mukhtar*
Test Date:	*03-04-2024*	**Use Case Reference(s):**	*Select Area on Google Maps for Segmentation*
Revision History:	*None*		
Objective:	*Enable quick map orientation.*		
Product/Ver/ Module:	*AirQualify/1.0/Segmentation Module*		
Environment:	*Web Browser. Internet connection.*		
Assumptions:	*None*		
Pre-Requisite:	*Google Map is shown on screen*		
Step No.	**Execution description**	**Procedure result**	
1	*User clicks 'Current Location' button*	*Current Location displayed on screen*	
Comments: Test Case Passed. Our system is working properly			
[Yes] Passed [] Failed [] Not Executed			

7.2.4 Segmentation Test Case

.

Segment			
4			
Test Case ID:	*4*	**QA Test Engineer:**	*Hafiz Hamza Shahid*
Test case Version:	*1.0*	**Reviewed By:**	*Taimoor Mukhtar*
Test Date:	*03-04-2024*	**Use Case Reference(s):**	*Land Cover Segmentation*
Revision History:	*None*		
Objective:	*To test segmentation results are displayed.*		
Product/Ver/ Module:	*AirQualify/1.0/Segmentation Module*		
Environment:	*Web Browser. Internet connection.*		
Assumptions:	*None*		

Pre-Requisite:	*User Must Select a place to which image is segmented*	
Step No.	**Execution description**	**Procedure result**
1	*User click/Search any location on map.*	*Red dot displayed on that location in map*
2	*The user clicks the 'Segment' button*	*The segmentation results are displayed.*
Comments: Test Case Passed. Our system is working properly		
[Yes] Passed [] Failed [] Not Executed		

7.2.5 Upload Image Test Case

.

Upload Image			
5			
Test Case ID:	*5*	**QA Test Engineer:**	*Hafiz Hamza Shahid*
Test case Version:	*1.0*	**Reviewed By:**	*Taimoor Mukhtar*
Test Date:	*12-04-2024*	**Use Case Reference(s):**	*Upload Satellite Image for Segmentation from Disk*
Revision History:	*None*		
Objective:	*To test if an image is uploaded correctly.*		
Product/Ver/ Module:	*AirQualify/1.0/Compare Module*		
Environment:	*Web Browser. Internet connection.*		
Assumptions:	*None*		
Pre-Requisite:	*None*		
Step No.	**Execution description**	**Procedure result**	
1	*The user clicks the 'Choose File' button and selects an image.*	*The image is shown on Screen*	
Comments: Test Case Passed. Our system is working properly			
[Yes] Passed [] Failed [] Not Executed			

7.2.6 Visualize Trends Test Case

.

Visualize Trends

6			
Test Case ID:	*6*	**QA Test Engineer:**	*Hafiz Hamza Shahid*
Test case Version:	*1.0*	**Reviewed By:**	*Muhammad Sohaib*
Test Date:	*15-04-2024*	**Use Case Reference(s):**	*Visualize Trends*
Revision History:	*None*		
Objective:	*To Visualize trends in environmental changes over different location.*		
Product/Ver/ Module:	*AirQualify/1.0/Compare Module*		
Environment:	*Web Browser. Internet connection.*		
Assumptions:	*None*		
Pre-Requisite:	*Userh ave two satellite Images*		
Step No.	**Execution description**	**Procedure result**	
1	*User upload two Images one by one*	*Images is shown along their segmented result.*	
2	*User clicks on 'Compare' button*	*Show a bar graph showing comparative trends of blue, green and urban areas among images uploaded.*	
Comments: Test Case Passed. Our system is working properly			
[Yes] Passed [] Failed [] Not Executed			

7.2.7 Download Segmented Result Test Case

.

Download Segmented Result			
7			
Test Case ID:	*7*	**QA Test Engineer:**	*Hafiz Hamza Shahid*
Test case Version:	*1.0*	**Reviewed By:**	*Taimoor Mukhtar*
Test Date:	*15-04-2024*	**Use Case Reference(s):**	*Download Segmentation Results*
Revision History:	*None*		
Objective:	*To test if segmented results are saved*		
Product/Ver/ Module:	*AirQualify/1.0/Segmentation Module*		
Environment:	*Web Browser. Internet connection.*		

Assumptions:	*None*	
Pre-Requisite:	*Images must be segmented*	
Step No.	**Execution description**	**Procedure result**
1	*The user clicks the 'Save' button.*	*The segmented results are downloaded.*
Comments: Test Case Passed. Our system is working properly		
[Yes] Passed [] Failed [] Not Executed		

7.2.8 Download Trends Test Case

.

Download Trends among different images			
8			
Test Case ID:	*8*	**QA Test Engineer:**	*Hafiz Hamza Shahid*
Test case Version:	*1.0*	**Reviewed By:**	*Taimoor Mukhtar*
Test Date:	*15-04-2024*	**Use Case Reference(s):**	*Download Trends among different images.*
Revision History:	*None*		
Objective:	*To test if trends results are saved*		
Product/Ver/ Module:	*AirQualify/1.0/Compare Module*		
Environment:	*Web Browser. Internet connection.*		
Assumptions:	*None*		
Pre-Requisite:	*Images must be segmented and trends are displayed*		
Step No.	**Execution description**	**Procedure result**	
1	*The user clicks the 'Save' button.*	*The trends results are downloaded.*	
Comments: Test Case Passed. Our system is working properly			
[Yes] Passed [] Failed [] Not Executed			

7.2.9 Analyze AQI and Blue Green area effect Test Case

.

Analyze AQI and Blue Green area effect
9

Test Case ID:	*9*	**QA Test Engineer:**	*Hafiz Hamza Shahid*
Test case Version:	*1.0*	**Reviewed By:**	*Taimoor Mukhtar*
Test Date:	*20-04-2024*	**Use Case Reference(s):**	*Performing Analysis on AQI and Blue-Green area relationship.*
Revision History:	*None*		
Objective:	*To Analyze AQI and Blue Green area relation.*		
Product/Ver/ Module:	*AirQualify/1.0/Analysis Module*		
Environment:	*Web Browser. Internet connection.*		
Assumptions:	*None*		
Pre-Requisite:	*Percentages of blue-green area and AQI are known.*		
Step No.	**Execution description**	**Procedure result**	
1	*The user varies the percentage area of green area.*	*The system displays the percentage change in AQI of that specified by the user.*	
Comments: Test Case Passed. Our system is working properly			
[Yes] Passed [] Failed [] Not Executed			

7.2.10 Reliability Test Case

.

Reliability			
10			
Test Case ID:	*10*	**QA Test Engineer:**	*Taimoor Mukhtar*
Test case Version:	*1.0*	**Reviewed By:**	*Muhammad Sohaib*
Test Date:	*20-04-2024*	**Use Case Reference(s):**	-
Revision History:	*None*		
Objective:	*To test if the system gives reliable and valid results.*		
Product/Ver/ Module:	*AirQualify/1.0/Segmentation Module*		
Environment:	*Web Browser. Internet connection.*		
Assumptions:	*None*		
Pre-Requisite:	*An image must be segmented.*		

Step No.	Execution description	Procedure result
1	*The user segments images.*	*The inference results are consistent and valid across all images.*
Comments: Test Case Passed. Our system is working properly		
[Yes] Passed [] Failed [] Not Executed		

7.2.11 Correctness Test Case

.

Correctness			
11			
Test Case ID:	*11*	**QA Test Engineer:**	*Taimoor Mukhtar*
Test case Version:	*1.0*	**Reviewed By:**	*Muhammad Sohaib*
Test Date:	*25-04-2024*	**Use Case Reference(s):**	-
Revision History:	*None*		
Objective:	*To test if the results are functionally correct and avoid the false positives on our system.*		
Product/Ver/ Module:	*AirQualify/1.0/Segmentation Module*		
Environment:	*Web Browser. Internet connection.*		
Assumptions:	*None*		
Pre-Requisite:	*An image must be segmented.*		
Step No.	**Execution description**	**Procedure result**	
1	*The user segments an images.*	*The results are accurate.*	
Comments: Test Case Passed. Our system is working properly			
[Yes] Passed [] Failed [] Not Executed			

7.2.12 Usability Test Case

.

Usability			
12			
Test Case ID:	*12*	**QA Test Engineer:**	*Taimoor Mukhtar*
Test case Version:	*1.0*	**Reviewed By:**	*Muhammad Sohaib*

Test Date:	*20-04-2024*	**Use Case Reference(s):**	-
Revision History:	*None*		
Objective:	*To test if system is easy to use.*		
Product/Ver/ Module:	*AirQualify/1.0/Segmentation Module*		
Environment:	*Web Browser. Internet connection.*		
Assumptions:	*None*		
Pre-Requisite:	-		
Step No.	**Execution description**	**Procedure result**	
1	*The user opens the application.*	*The interface is user friendly and the user is able to interact with ease.*	
Comments: Test Case Passed. Our system is working properly			
[Yes] Passed [] Failed [] Not Executed			

7.3 Test Metrics

Following are the test case metrices

7.3.1 Functional Test Metrics

Metric	**Purpose**
Number of Test Cases	9
Number of Test Cases Passed	9
Number of Test Cases Failed	0
Test Case Defect Density	0
Test Case Effectiveness	100
Traceability Matrix	The file is enclosed separately.

7.3.2 Non Functional Test Metrics

Metric	**Purpose**
Number of Test Cases	3
Number of Test Cases Passed	3
Number of Test Cases Failed	0
Test Case Defect Density	0
Test Case Effectiveness	100
Traceability Matrix	The file is enclosed separately.

7.4 Conclusion

The chapter outlined the implementation details for the project and test cases that are implemented in the project.

Chapter 8 User Manual

This manual provides a complete guidance on using the Urban Blue Green Areas Segmentation web application, including its installation, features, and workflow.

8.1 Installation and Setup

To use the Urban Blue Green Areas Segmentation application, no installation is required as it operates through a web interface. Simply access the application through your preferred web browser.

8.2 Features

The Urban Blue Green Areas Segmentation application offers the following key features:

8.2.1 Google Maps Interface

- The front end includes a Google Maps window allowing users to search for areas using the search bar or by manually navigating the map.
- Users can toggle satellite view on or off to better visualize the area.

8.2.2 Fetch AQI

Users can click on the ”Fetch AQI” button to retrieve the current Air Quality Index (AQI) of the selected location on the Google Maps interface.

8.2.3 Segment Landcover

- Users can click on the ”Segment Landcover” button to perform landcover segmentation on the cropped image of the selected location on the Google Maps interface.
- After segmentation, the blue area, green area, and other percentages will be displayed in the bottom half of the screen.

8.2.4 Sliders for Analysis and Prediction

Two sliders are available for analysis and prediction:

- Green Area: Adjust the percentage of green area in the segmented image.
- Carbon Emissions: Adjust the carbon emission percentage in the area.

Predict AQI: By setting the green area and carbon emission percentages using the sliders, users can predict the AQI for the specified values by clicking the ”Predict AQI” button.

8.2.5 Analyse Cover Change

- The ”Analyse Cover Change” button on the upper half of the screen takes users to a new page.
- On this page, users can upload two satellite images of landcovers and compare their green and blue areas side by side.
- A graph below the images displays the trend of green, blue, and other areas using a bar graph.

8.3 Application Workflow

Follow these steps to effectively use the Urban Blue Green Areas Segmentation application:

1. Navigate to the desired location using the Google Maps interface.
2. Optionally, click ”Fetch AQI” to retrieve the current AQI of the selected location.
3. Click ”Segment Landcover” to perform landcover segmentation on the selected area.
4. Adjust the green area and carbon emissions percentages using the sliders if necessary.
5. Click ”Predict AQI” to predict the AQI based on the specified percentages.
6. Optionally, click ”Analyse Cover Change” that lands you on a new page to compare two landcover images and view their area trends.

8.4 Conclusion

This chapter provided a detailed user manual that introduces the user with various functionalities and features of the web platform provided and guides through different workflows.

Chapter 9 Experimental Results and Discussion

This chapter presents the outcomes of the implemented land cover segmentation system. It provides an in-depth analysis of the experimental results, emphasizing key performance indicators and discussing the effectiveness of the developed system.

9.1 Initial Training and Validation Results

The system underwent training for multiple epochs, and the results at each epoch were carefully recorded. The progression of accuracy, loss values, and convergence trends during both training and validation phases was analyzed and visualized.The table 9.1 shows accuracy and loss values for validation and training using initial experimental approach.

Epoch	Training Loss	Validation Loss	Training Accuracy	Validation Accuracy
1	0.512	0.672	0.688	0.391
2	0.421	0.588	0.771	0.421
3	0.554	0.511	0.702	0.443
4	0.442	0.604	0.713	0.529
5	0.512	0.672	0.789	0.498
6	0.421	0.663	0.752	0.502
7	0.425	0.554	0.709	0.692
8	0.411	0.662	0.812	0.663
9	0.505	0.555	0.713	0.601
10	0.598	0.577	0.767	0.641

Table 9.1: Training and Validation Results

The table shows the training and validation accuracy and loss for the initial segmentation model training phase

Over all average training and validation accuracy is just satisfactory and is aimed to be improved in future developmental phases.

9.2 Evaluation Metrics

Comprehensive evaluation metrics relevant to segmentation task like accuracy, Precison, Recall, F1 score and IOU ,will be employed to assess the performance of the segmentation model and effect of different pre-processing techniques on the model's accuracy. So far the initial experimentations have been evaluated using accuracy metrics.

9.2.1 Final Trained Model Performance

After the final training of the model using best pre-processing steps and fine tuning the parameters to achieve maximum results, following results were achieved:

- test/Accuracy=0.983659267
- test/F1score=0.942806363
- test/IoU=0.91325742

9.3 Conclusion

The chapter depicted the initial experimentations and results for the land cover segmentation model which turn out to be average and needed to be improved in the upcoming developmental stages.

Chapter 10 Conclusions

Lahore's air quality faces severe deterioration due to rapid urbanization, traffic density and industrial growth. To address this critical issue, we proposed a strategic and innovative approach centered around Urban Blue-Green Areas Segmentation to improve AQI. We implemented a U-Net based segmentation pipeline to run inferences on satellite images and gain valuable urban planning insights. This further emphasized the project's commitment to leveraging cutting-edge technology for positive environmental impact.

We outlined a comprehensive plan and strategy to build a software solution to assist improving Air quality and urban well being. These blue-green areas, including parks, gardens, green rooftops, and water bodies, naturally purify air, provide shade and cooling, and improve community well-being. Hence, a complete decision support system for urban planners is the need of the hour. We employed advanced technologies like satellite imagery, GIS, and machine learning to segment blue-green areas. Various carefully picked pre processing techniques and dataset filtration were applied to improve training accuracy of the model. A satisfactory accuracy of segmentation has been achieved, hence marking the completion of our first main objective of the project.

Furthermore, we have extended this project to the second phase where we are post-processing the segmentation results for a particular area and investigating their relationship with the AQI in that area. Since one of the main target customers are urban planners or management authorities, we have made the UI more detailed while keeping it user friendly. Lastly, upon completion of all major milestones, deploying it on the web would be considered the last objective for the product development.

Through successful development of a highly responsive and accurate urban planning decision support system integrated with state of the art blue-green segmentation model and a predictive correlation model for AQI and Blue-Green areas , we not only aim to improve the Lahore Air breathable but also set an example for other cities to come forward and employ advanced technology for environment solutions.

This Chapter concluded the overall facts stated in detail in the above chapters and shed light on future goals and objectives for the project.

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