

## EXTRACTION OF MAIN URBAN ROADS FROM HIGH RESOLUTION SATELLITE IMAGES BY MACHINE LEARNING

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### ABSTRACT

*The extraction of primary urban road networks from high-resolution satellite imagery plays a vital role in urban planning, traffic management, and autonomous navigation systems. Conventional approaches, which depend on manual mapping and traditional image processing techniques, are often labor-intensive, time-consuming, and susceptible to inaccuracies. To address these limitations, this paper proposes a machine learning-based framework for the automated extraction of urban roads from satellite images. The proposed approach utilizes advanced deep learning architectures, including U-Net and DeepLabV3+, for semantic segmentation to accurately identify road structures. Preprocessing techniques such as contrast enhancement and data augmentation are applied to improve the robustness and generalization capability of the models. Furthermore, post-processing methods, including morphological operations and graph-based refinements, are employed to enhance the continuity and accuracy of the extracted road networks.*

*The performance of the proposed system is evaluated using benchmark datasets, demonstrating high accuracy and efficiency in road detection tasks.*

*Experimental results indicate that the proposed method significantly outperforms traditional techniques in terms of precision and reliability. The generated road maps can be effectively integrated into Geographic Information Systems (GIS), supporting real-world applications such as smart city development and intelligent transportation systems.*

**Keywords:** Urban Road Extraction, High-Resolution Satellite Imagery, Machine Learning, Deep Learning, Semantic Segmentation, U-Net, DeepLabV3+, Image Pre processing, Morphological Operations, Geographic Information Systems (GIS), Smart Cities, Intelligent Transportation Systems.

### INTRODUCTION

The automatic extraction of urban road networks from high-resolution satellite imagery has become increasingly significant in applications such as urban planning, traffic management, and autonomous navigation. Accurate and up-to-date road information is essential for developing efficient transportation systems and supporting smart city initiatives. However, traditional road extraction methods primarily rely on manual digitization and classical image processing techniques, which are labor-intensive,

time-consuming, and often prone to inaccuracies due to human intervention and environmental complexities.

To overcome these limitations, recent advancements in machine learning, particularly deep learning, have provided promising solutions for automated road extraction. In this context, the present work proposes a machine learning-based framework that leverages deep neural networks to accurately identify and segment main urban roads from high-resolution satellite images. By utilizing advanced models, the system aims to significantly reduce manual effort while improving the precision and efficiency of urban mapping processes.

One of the major challenges in satellite image analysis is the presence of variations in illumination, shadows, noise, and occlusions caused by buildings, vegetation, and other urban structures. These factors can adversely affect the performance of learning models. To address these issues, the proposed approach incorporates robust preprocessing techniques, including contrast enhancement, data augmentation, and noise reduction, which enhance the quality of input data and improve model generalization across diverse environmental conditions.

Furthermore, although deep learning models are effective in segmenting road regions, their outputs may contain discontinuities, gaps, or misclassifications. To refine the extracted road networks, post-processing techniques such as morphological operations, skeletonization, and graph-based optimization are integrated into the system. These methods

improve the structural continuity and topological correctness of the road networks, making them more suitable for practical applications.

The resulting road maps can be effectively utilized in Geographic Information Systems (GIS) for applications including traffic analysis, route optimization, and infrastructure planning. By providing an automated, scalable, and accurate solution for road extraction, this work contributes to improved decision-making in urban development and supports the advancement of intelligent transportation systems.

## OBJECTIVE

The primary objective of this project is to develop an efficient and automated system for extracting main urban road networks from high-resolution satellite images using machine learning techniques. The specific objectives are as follows:

- To design and implement a deep learning-based framework for accurate detection and segmentation of urban roads from satellite imagery.
- To minimize human intervention by replacing traditional manual digitization methods with an automated and scalable solution.
- To enhance the quality of input data through preprocessing techniques such as contrast enhancement, data augmentation, and noise reduction.
- To improve the robustness of the model in handling challenges such as shadows, occlusions, and varying illumination conditions.

- To refine the extracted road networks using post-processing techniques including morphological operations, skeletonization, and graph-based optimization.
- To ensure high accuracy, continuity, and topological correctness of the extracted road structures.
- To enable integration of the generated road maps into Geographic Information Systems (GIS) for real-world applications such as urban planning, traffic analysis, and route optimization.
- To contribute to the development of intelligent transportation systems and smart city infrastructure through reliable and scalable road extraction methods.

## NEED FOR STUDY

The rapid growth of urbanization and the increasing demand for efficient transportation systems have created a critical need for accurate and up-to-date road network information. High-resolution satellite imagery provides a valuable data source for mapping and monitoring urban infrastructure; however, extracting meaningful road information from such data remains a challenging task. Traditional methods, which rely on manual digitization and heuristic-based image processing, are inefficient, time-consuming, and often fail to deliver consistent results in complex urban environments.

With the expansion of smart cities and intelligent transportation systems, there is a growing requirement for automated,

scalable, and high-precision solutions for road extraction. Existing approaches struggle to handle challenges such as occlusions caused by buildings and trees, variations in lighting conditions, and the presence of noise in satellite images. These limitations highlight the necessity for more advanced techniques that can ensure robustness and reliability across diverse scenarios.

The integration of machine learning, particularly deep learning, offers significant potential to address these challenges by enabling accurate feature learning and automated road detection. However, further improvements are required to enhance road continuity, reduce segmentation errors, and generate topologically correct road networks suitable for real-world applications.

Therefore, this study is essential to develop an efficient and intelligent system that leverages deep learning and advanced preprocessing and post-processing techniques to improve the accuracy, automation, and usability of urban road extraction. The outcomes of this study can significantly contribute to urban planning, traffic management, navigation systems, and the overall development of smart city infrastructure.

## EXISTING SYSTEM

The existing approaches for urban road extraction from satellite imagery can be broadly categorized into traditional image processing methods and early machine learning techniques. Traditional methods include edge detection algorithms such as Canny, mathematical morphology, active contour models (Snakes), and pattern-matching techniques. These approaches

rely on predefined heuristics based on road characteristics, such as linear geometry, parallel boundaries, and spectral consistency. Such methods typically depend on handcrafted features and often require manual intervention, including the selection of seed points and parameter tuning. Early machine learning techniques attempted to improve automation by using feature-based classification; however, their performance remained limited due to inadequate feature representation and poor generalization capabilities.

Although recent advancements in deep learning have improved road extraction performance, existing models still encounter challenges in handling complex urban environments, particularly in cases involving narrow roads, occlusions, and discontinuities in road structures.

## DISADVANTAGES

The limitations of the existing systems are summarized as follows:

- High dependency on manual intervention and parameter tuning, making the process time-consuming and less scalable.
- Sensitivity to noise, illumination variations, and image quality, leading to reduced accuracy.
- Poor performance in complex urban environments with shadows, vehicles, and building occlusions.
- Inability to maintain continuity of road networks, resulting in fragmented and incomplete road extraction.
- Limited capability in detecting narrow or less prominent roads.

## PROPOSES SYSTEM

The proposed system presents an advanced deep learning-based framework for the automatic extraction of main urban roads from high-resolution satellite imagery. The system employs a semantic segmentation model based on a modified U-Net architecture to achieve precise pixel-wise classification of road regions. To further enhance performance, the model incorporates specialized architectural components such as attention mechanisms and residual blocks, which improve feature representation and enable effective handling of challenges such as occlusions and spectral variations.

In addition to the segmentation process, the proposed system integrates a robust post-processing pipeline to refine the extracted road structures. The initial segmentation output, which may contain noise and discontinuities, is processed using geometric transformations and graph-based techniques. These methods convert the raster output into a structured, topologically consistent, and vectorized road network. This ensures improved connectivity and makes the extracted data suitable for direct integration into Geographic Information Systems (GIS) and other real-world applications.

## ADVANTAGES

The key advantages of the proposed system are summarized as follows:

- Provides a high level of automation, significantly reducing manual effort and improving processing efficiency.
- Achieves superior accuracy and robustness through the use of

advanced deep learning architectures.

- Effectively handles occlusions and complex urban scenarios, ensuring improved continuity of road networks.

feature extraction, model training, and testing.

- The system shall display outputs in real-time for better user interaction and analysis.

### Functional-Requirements

The functional requirements describe the core operations and capabilities of the proposed system for urban road extraction:

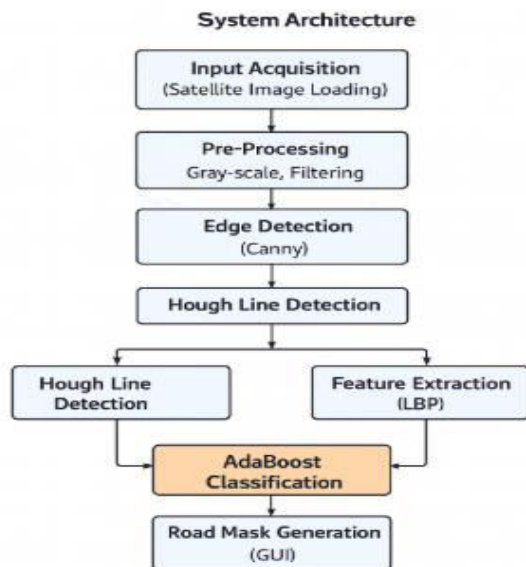
1. **Dataset Upload:**  
The system shall allow users to upload high-resolution satellite images in bulk for processing and analysis.
2. **Feature Extraction:**  
The system shall extract relevant features from input images using techniques such as Canny Edge Detection, Hough Line Transform, and Local Binary Patterns (LBP) for texture analysis.
3. **Model Training:**  
The system shall train a machine learning model using the AdaBoost algorithm on the extracted features to build an effective road detection model.
4. **Road Extraction:**
  - The system shall accept a test image as input.
  - The system shall apply the trained model to the input image.
  - The system shall generate and display the extracted road mask as output.
5. **User Interface:**
  - The system shall provide an interactive interface with options for dataset upload,

### Non-Functional Requirements

The non-functional requirements define the quality attributes and performance characteristics of the system:

1. **Scalability:**  
The system should be capable of handling large volumes of high-resolution satellite images efficiently and support future expansion without performance degradation.
2. **Reliability:**  
The system should provide consistent and dependable results under varying conditions such as noise, shadows, and occlusions, ensuring stable operation without frequent failures.
3. **Performance:**  
The system should process images efficiently and deliver results within a reasonable time frame through optimized algorithms and effective resource utilization.
4. **Accuracy:**  
The system should achieve high precision in detecting and segmenting road networks with minimal errors to ensure suitability for real-world applications.

## SYSTEM ARCHITECTURE



## SYSTEM REQUIREMENTS

### Software Requirements

Backend: Django

Frontend: HTML,CSS,JavaScript

Data base : SQLite

Editor: VisualStudioCode

### Hardware Requirements

Processor:Anyprocessor more than i3

RAM:8 GB

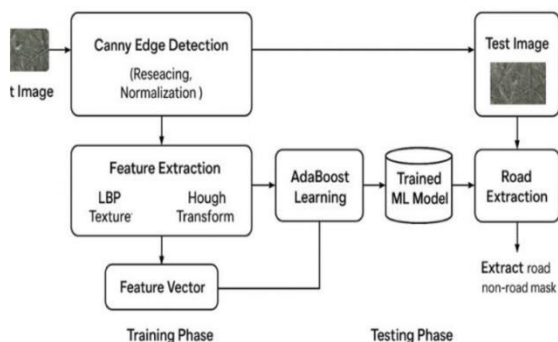
HardDisk:512GB

Web cam : For facial recognition

## MODULES

A module is an independent part of the system that performs a specific function. The proposed system consists of the following modules:

### Technical Architecture



#### 1. Input Acquisition Module:

This module is used to upload and collect high-resolution satellite images for processing.

#### 2. Pre-Processing Module:

This module improves image quality using techniques like contrast enhancement, noise reduction, and data normalization.

#### 3. Edge Detection Module:

This module detects road boundaries using edge detection techniques such as Canny edge detection.

#### 4. Feature Extraction Module:

This module extracts important features from images using methods like Hough Transform and LBP to identify road patterns.

#### 5. Classification Module:

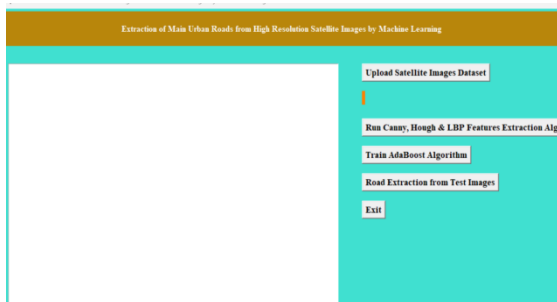
This module uses machine learning/deep learning models to

classify pixels and detect road regions in the image.

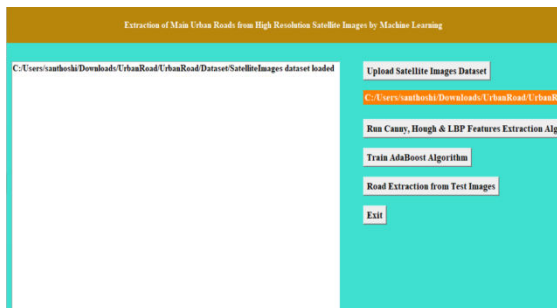
### 6. Road Mask Generation & Output Module:

This module generates the final road mask and displays the extracted road network for further use in GIS applications.

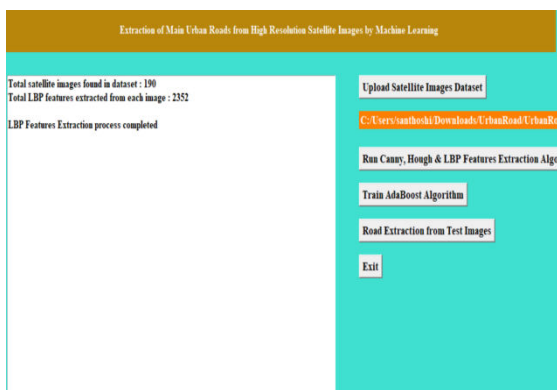
### SCREEN SHOTS



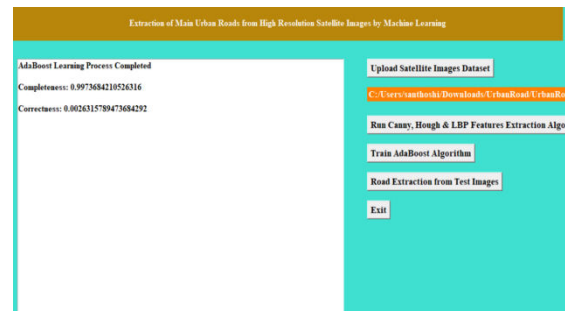
### Uploading Dataset



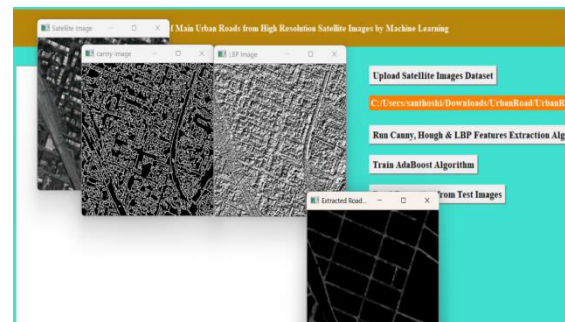
### Uploaded Dataset



### Feature Extraction



### Train Algorithm



### Extraction Images

### Conclusion

The proposed system demonstrates an effective and automated approach for extracting urban road networks from high-resolution satellite images using machine learning techniques. By integrating deep learning with preprocessing and post-processing methods, the system achieves improved accuracy, robustness, and continuity of road structures. The generated outputs are suitable for real-world applications such as urban planning, traffic management, and GIS-based analysis, contributing to the development of smart city infrastructure.

## FUTURE ENHANCEMENT

- Integration of advanced deep learning models such as Transformer-based architectures for improved accuracy.
- Use of multi-source data (e.g., LiDAR, GIS layers) to enhance road detection.
- Real-time road extraction and updating using streaming satellite data.
- Improved handling of occlusions and complex urban scenarios.
- Development of lightweight models for faster processing and deployment on edge devices.
- Enhanced GIS integration with dynamic mapping and visualization features

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