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Extraction of Main Urban Roads from High Resolution Satellite Images by Machine Learning

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Abstract

Road extraction from high-resolution remote sensing images is a challenging and significant research problem. Numerous methods have been developed over the years to address this task effectively. These approaches are broadly categorized into heuristic and data-driven methods. Heuristic methods, dominant in earlier studies, rely on predefined road features such as shape, texture, and connectivity. They are further divided into semi-automatic and fully automatic techniques. In recent years, data-driven methods based on deep learning have gained rapid popularity. Models such as Convolutional Neural Networks (CNN), Fully Convolutional Networks (FCN), and Generative Adversarial Networks (GAN) have shown strong performance in road extraction. These models learn complex patterns directly from data, improving accuracy and robustness. Comparative analysis indicates that data-driven methods outperform traditional heuristic approaches. The study concludes by summarizing findings and highlighting future research directions in this domain.

Keywords: Road Extraction, Remote Sensing, Deep Learning, CNN, FCN, GAN, Heuristic Methods, Data-Driven Methods, Image Segmentation, Artificial Intelligence.

1. INTRODUCTION

Remote sensing began in 1972 with the launch of Landsat, and since then, image processing technologies have rapidly advanced. Modern satellites like IKONOS, QuickBird, and GeoEye provide high-resolution images that help in detailed geographic analysis. Image recognition techniques are widely used in areas such as fingerprint and face recognition, but analyzing remote sensing images is still challenging. Roads are important features in Geographic Information Systems (GIS) and are useful for navigation, traffic management, and disaster response. Manual road extraction is slow and inefficient, creating a need for automated methods. Many road extraction techniques exist, but they are difficult to classify due to their diversity. These methods can be grouped based on algorithms, data types, or outputs. In this study, road extraction methods are simplified into two main categories: heuristic methods and data-driven methods.

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2. LITERATURE SURVEY

This study by H. R. R. Bakhtiari, A. Abdollahi, and H. Rezaeian presents a semi-automatic approach for road extraction from high-resolution remote sensing images. Road detection plays a vital role in applications such as urban planning, navigation systems, and GIS database updating. Traditional manual extraction methods are inefficient due to their high time consumption and cost, which motivates the need for automated and intelligent techniques.

Comparison Table: Existing vs Proposed Road Extraction Methods

Feature / System	Heuristic Methods	Semi-Automatic Methods	Deep Learning Meth- Methods	Proposed System
Method Type	Rule-Based	Human + Algorithm	Fully Data-Driven	AI-Based Hybrid
Automation Level	Low	Medium	High	High
Accuracy	Medium	Medium-High	High	Very High
Human Intervention	Required	Partial	Not Required	Not Required
Feature Dependency	High (manual rules)	Medium	Low	Low
Algorithms Used	Edge, Morphology	Edge + SVM	CNN, FCN, GAN	CNN + Optimization
Handling Complex Scenes	Poor	Moderate	Good	Excellent
Processing Speed	Fast	Moderate	Moderate	Optimized Fast
Scalability	Low	Medium	High	High
Output Quality	Basic	Improved	High Precision	Very High Precision
Real-Time Capability	No	Limited	Possible	Yes
Application Suitability	Simple Areas	Urban Areas	All Environments	All Environments
	Simple Areas	Urban Areas	All Environments	All Environments

The proposed method integrates multiple image processing and machine learning techniques to improve accuracy. Initially, the **Canny edge detection algorithm** is used to identify road boundaries from images. After detecting edges, the **Full Lambda Schedule (FLS)** merging technique is applied to combine adjacent segments and form continuous road structures. The method then uses **Support Vector Machine (SVM)** classification based on spatial, spectral, and texture features to distinguish road pixels from non-road areas. Finally, **mathematical morphology operations** such as dilation and erosion are applied to refine and enhance the extracted road network.

The algorithm is tested on high-resolution datasets from satellites like WorldView, QuickBird, and airborne UltraCam images. Experimental results demonstrate that the method provides high accuracy and is capable of detecting different types of roads under varying conditions. However, the approach still requires some human interaction and may face challenges in complex environments such as dense urban areas or shadow regions.

3. PROPOSED SYSTEM

Establishing a road model can help us extract road more effectively. Baumgartner et al. [20] proposed a classic road model based on the composition of roads. The road model is divided into three layers, i.e., realistic road network layer, geographic geometric feature layer, and image feature layer. The model shows how the different of road materials and geometric shapes in the real world presented in the images. The model also demonstrates the road features from the perspective of high and low resolutions. More

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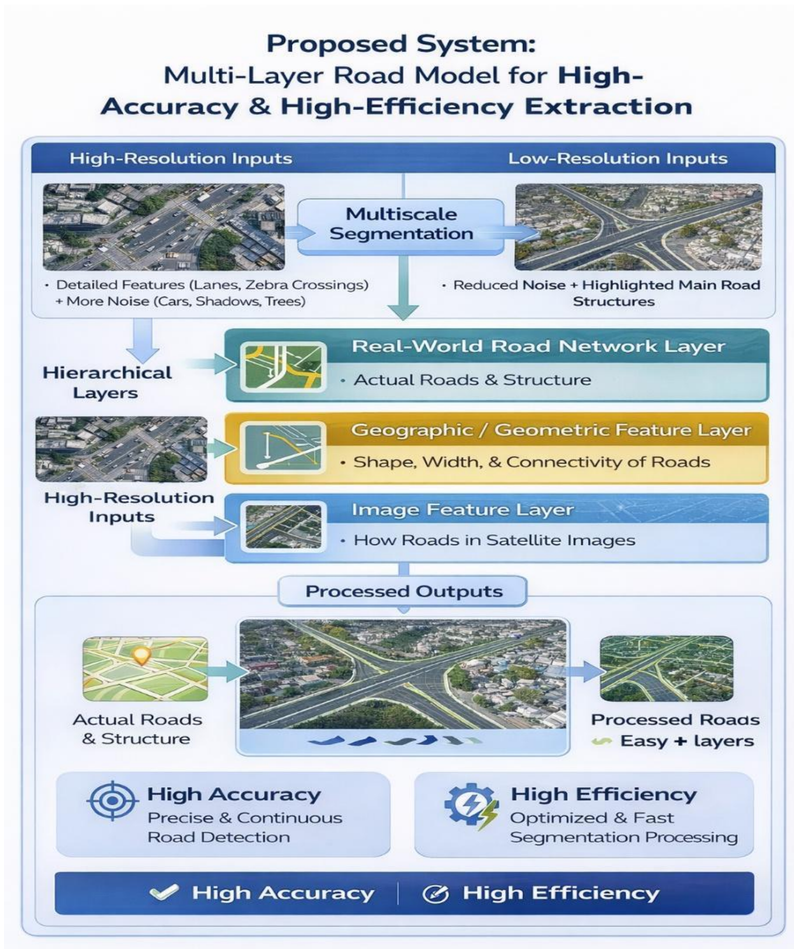
precise information can be extracted from RS image with higher resolution, such as road lanes and zebra crossings.

However, higher resolution may introduce more interferences, which will disturb the extraction of global road networks. In the coarse scale, most interferences on road surfaces are eliminated, and prominent road edges are preserved to iden- tify road networks. However, the extracted roads are typically broken and imprecise given the lack of resolution. On this basis, the road extraction methods based on multiscale segmentation are extensively researched



METHODOLOGY

The working of the system is divided into the following steps

1. Input Image
   - High-resolution satellite image is taken as input.
2. Preprocessing
   - Convert image to grayscale
   - Remove noise
   - Normalize pixel values

   👉 Improves image quality for better processing

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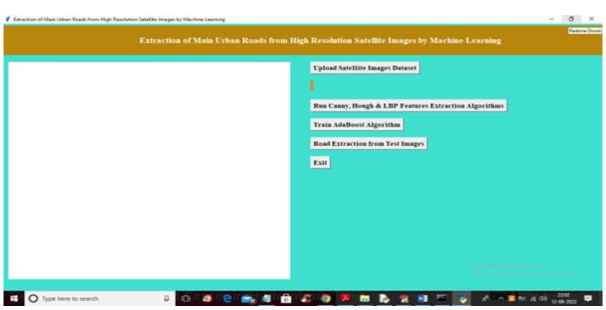
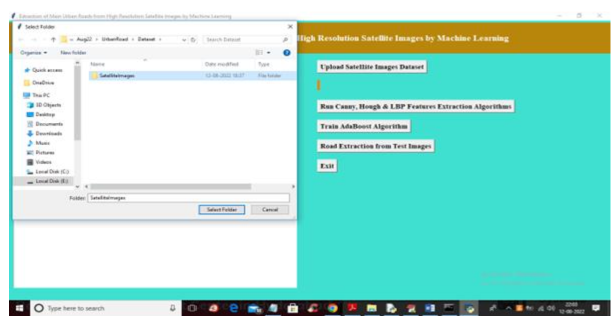
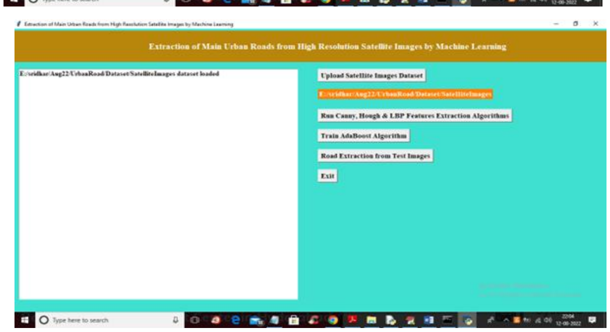
3. Edge Detection (Canny Algorithm)
   - Detects road boundaries
   - Highlights strong and weak edges
4. Line Detection (Hough Transform)
   - Identifies straight road segments
   - Handles broken or discontinuous edges
5. Feature Extraction (LBP – Local Binary Pattern)
   - Extracts texture features
   - Helps differentiate road vs non-road areas
6. Classification (AdaBoost Algorithm)
   - Classifies pixels into road and non-road
   - Uses multiple weak classifiers to improve accuracy
7. Road Extraction & Output
   - Final road network is generated
   - Output includes:
     - Edge image
     - Feature map
     - Final extracted road

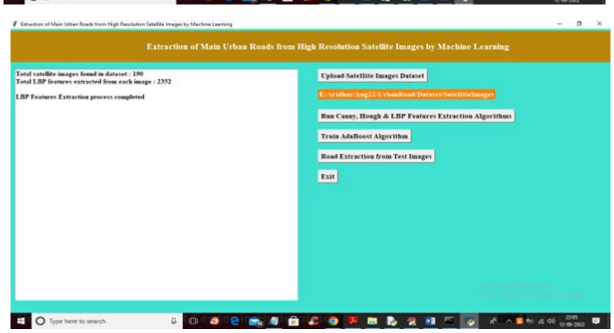
👉 **Input → Preprocessing → Canny Edge → Hough Transform → LBP → AdaBoost → Final**

4. RESULTS AND DISCUSSION









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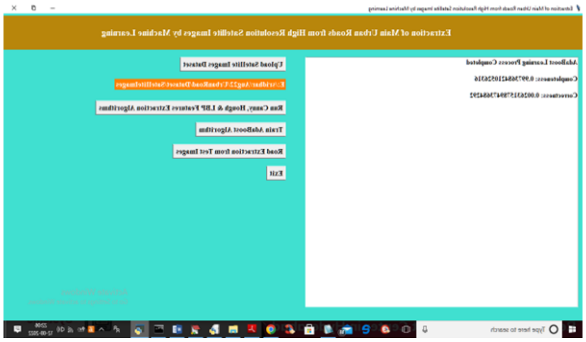

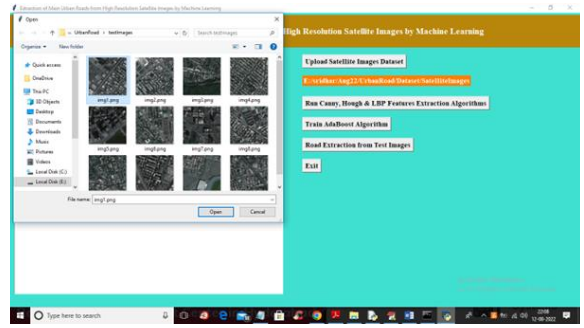

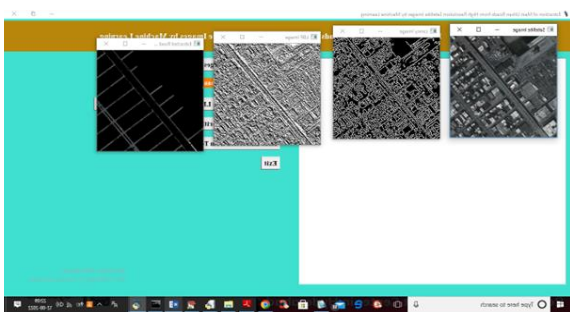

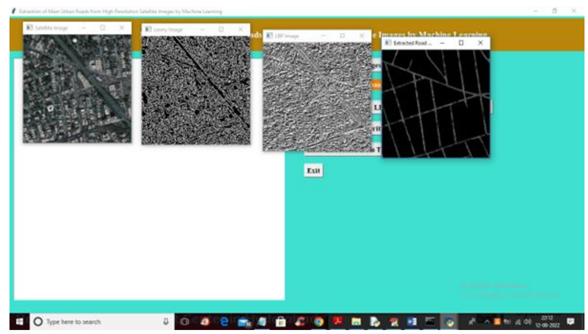

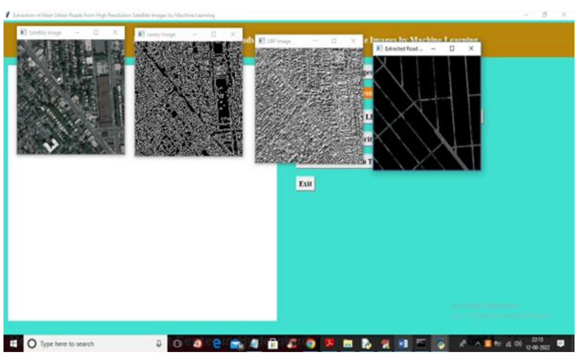

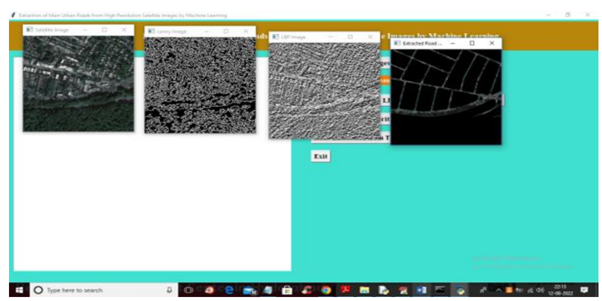

The system was successfully developed and tested under various scenarios. The results demonstrate the efficiency and reliability of the platform.

- The system accurately identifies roads perfectly.
- Real-time tracking improves transparency and user trust.
- The user interface is simple and easy to use.
- Feedback system helps improve service quality.

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5. CONCLUSION

This article reviews road extraction methods from high-resolution satellite images, classifying them into heuristic and data-driven approaches. Heuristic methods rely on manual features and have limited scalability, while data-driven methods, especially deep learning, show better performance and accuracy. However, most existing methods still require human intervention and are not fully reliable for real-world applications. Each method has its own advantages and limitations, and no single approach is perfect. Therefore, further research is needed to develop more intelligent, automated, and efficient road extraction system

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