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A study on An Image-Based Changed Detection Framework for Unauthorized Construction Monitoring in Smart Cities

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Abstract: **Rapid growth has made it difficult for city authorities to monitor and control unauthorized construction activities. Traditional methods that rely on manual inspections are slow, costly and not practical for large cities. This study presents an automated system that helps to detect illegal construction using different types of remote sensing data. The system integrates satellite images, drone photographs and official building approval records to improve accuracy. It analyses images of the same location taken at different times to identify changes using techniques such as image comparison filtering and segmentation. The results are displayed on an interactive web platform that shows visual comparison, highlights new construction areas and provides useful statistics for decision makers. The system also includes separate dashboards for government officials to support real time monitoring and action. Since the framework is modular and scalable, it can be easily upgraded in the future with more advanced technologies making it a practical solution for smart city management.**

Keywords: Smart City Monitoring, Remote sensing, Unauthorized construction, Image processing, Satellite Imagery, Drone imaging.

I. INTRODUCTION

Rapid urban development and infrastructure expansion have significantly increased the complexity of monitoring construction activities, particularly in identifying unauthorized structures. Municipal authorities and urban planners traditionally rely on manual inspections and field surveys, which are often labor-intensive, time-consuming, and inefficient for large-scale urban environments. The growing availability of high-resolution satellite imagery and geospatial visualization tools has created new opportunities for automated monitoring systems [1].

Recent advancements in image processing and computer vision techniques have enabled the detection of structural and environmental changes using temporal image analysis. Change detection methods, which analyze differences between images captured at different time intervals, have proven effective in applications such as land-use monitoring, disaster assessment, and urban development analysis. However, many existing approaches emphasize either complex deep learning architectures requiring large labeled datasets or standalone detection mechanisms lacking practical usability [2].

This research presents a Java-based framework for unauthorized construction detection using classical image processing techniques. The proposed system leverages before and after images acquired from Google Earth Pro to identify structural variations associated with construction activities. Unlike deep learning–based approaches that demand extensive training data and computational resources, the presented framework employs computationally efficient techniques including image differencing, grayscale conversion, thresholding, and segmentation [3].

The primary motivation behind this work is to develop a scalable, accessible, and cost-effective solution suitable for preliminary construction monitoring. By integrating automated change detection with visual result interpretation, the system assists users in identifying potential construction activities without requiring complex training procedures. Furthermore, the Java-based implementation ensures platform independence, ease of deployment, and compatibility with widely used image processing libraries such as OpenCV [4].

This paper presents a Java-based framework for detecting unauthorized construction through image change analysis. It applies classical image processing techniques to identify structural variations between temporal images and visually highlights detected construction regions. The proposed approach is computationally efficient, scalable, and suitable

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for continuous urban monitoring to support sustainable planning and regulatory compliance.

II. RELETED WORK

Unauthorized construction detection and urban change monitoring have attracted significant attention in recent years due to rapid urbanization and increasing pressure on urban planning authorities. Various techniques ranging from traditional image processing to advanced deep learning models have been explored for structural change analysis.

Early research in change detection primarily relied on classical image processing methods. Image differencing techniques, which compute pixel-wise variations between temporal images, have been widely adopted due to their simplicity and computational efficiency. These methods often combine grayscale conversion, thresholding, and morphological operations to highlight significant structural changes. Despite their effectiveness, such approaches are sensitive to illumination variations, noise, and misalignment between images.

Threshold-based segmentation techniques have also been extensively investigated. Fixed and adaptive thresholding methods enable separation of foreground changes from background information. Otsu's thresholding, in particular, has been recognized for its ability to automatically determine optimal thresholds. However, thresholding-based methods may produce false detections in scenarios involving shadows, vegetation changes, or seasonal variations.

With advancements in machine learning, researchers began employing supervised classification techniques. Support Vector Machines (SVM), Random Forests, and clustering algorithms have been used for urban change detection using spectral and textural features. While these approaches improve detection accuracy, they require labeled datasets and feature engineering, which may limit scalability [5].

Recent studies emphasize deep learning–based change detection models, including Convolutional Neural Networks (CNNs), Siamese Networks, and U-Net architectures. These models demonstrate superior performance in complex environments by automatically learning hierarchical feature representations. However, deep learning approaches require large annotated datasets, high computational resources, and extensive training procedures, making them less suitable for lightweight and cost-effective monitoring systems [6, 7].

In the context of practical deployment, several frameworks integrate remote sensing imagery with Geographic Information Systems (GIS) for urban analysis. Such systems provide valuable visualization and mapping capabilities but often rely on complex data pipelines and infrastructure [8]. Compared to existing approaches, the proposed framework adopts a classical image processing strategy implemented in Java. This design choice prioritizes computational efficiency, ease of implementation, and reduced dependency on large labeled datasets. By leveraging temporal images from Google Earth Pro, the system offers an accessible and scalable solution for preliminary unauthorized construction detection [9, 10].

III. METHODOLOGY

The proposed system adopts a classical image processing–based approach to detect unauthorized construction activities through temporal image analysis. The methodology focuses on identifying structural variations between reference (before) and current (after) images acquired from Google Earth Pro [11]. Fig. 1 shows, the overall workflow consists of image acquisition, preprocessing, change detection, segmentation, and visualization.

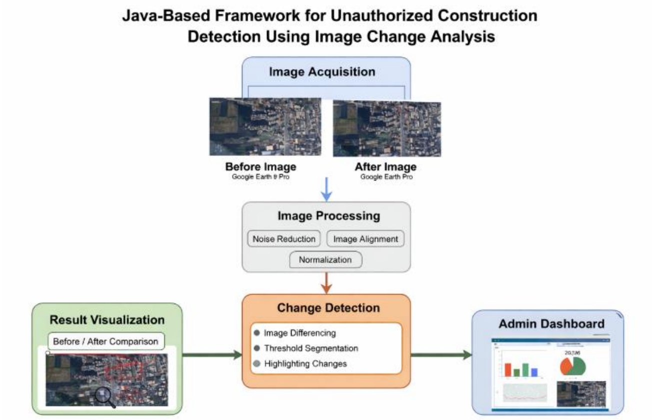

Fig. 1. Proposed System Architecture

A. Image Acquisition

The system utilizes high-resolution satellite images obtained from Google Earth Pro. Two images representing the same geographical region at different time intervals are selected:

- Reference Image (Before Image) – Baseline representation
- Current Image (After Image) – Updated scene representation

Care is taken to ensure similar scale, orientation, and viewpoint to minimize geometric inconsistencies.

B. Image Preprocessing

Preprocessing is performed to improve detection accuracy and reduce noise-related artifacts.

- Grayscale Conversion
  Since color information is not essential for structural change detection, the RGB images are converted into

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grayscale representations. This step reduces computational complexity while preserving intensity variations [12].

Igray=0.299R+0.587G+0.114B

- Noise Reduction
  Filtering techniques are applied to suppress minor variations caused by illumination changes and sensor noise. Gaussian smoothing is commonly employed to stabilize pixel intensity values.

C. Change Detection

Change detection is the core stage of the system.

- Image Differencing

  Pixel-wise subtraction is performed between the grayscale images:

  $$D(x,y) = \mid I_{after}(x,y) - I_{before}(x,y) \mid$$

  Where:

  • $I_{before}(x,y) \rightarrow$ Reference image

  • $I_{after}(x,y) \rightarrow$ Current image

  • $D(x,y) \rightarrow$ Difference image

  Significant pixel variations indicate potential construction changes.

- Thresholding

  Thresholding separates meaningful structural changes from background variations.

  $$B(x,y) = \begin{cases} 1, & D(x,y) > T \\ 0, & D(x,y) \leq T \end{cases}$$

  Where Trepresents the threshold value.
  This step produces a binary change map
  highlighting altered regions.

D. Segmentation

Segmentation isolates detected construction areas.
Morphological operations such as dilation and erosion are applied to:

- Remove noise
- Fill gaps
- Enhance detected structures

Connected component analysis is used to identify contiguous change regions.

E. Visualization of Results

Detected construction regions are highlighted for intuitive interpretation. The system overlays detected areas on the original image, typically using bounding contours or color-coded regions.

This visual representation enables:

- Easy identification of changes
- Improved decision-making
- Enhanced usability for non-technical users

F. System Implementation

The framework is implemented using the Java programming language, ensuring platform independence and scalability. Image processing operations are performed using OpenCV integrated with Java bindings. The modular design allows independent execution of preprocessing, detection, and visualization stages [13].

IV. RESULTS

This section presents the evaluation of the proposed Java-based unauthorized construction detection framework using temporal satellite imagery obtained from Google Earth Pro. The system performance is analyzed through qualitative visual assessment of detected construction changes [3, 14].

A. Visual Analysis of Construction Changes

To validate the effectiveness of the proposed framework, before and after images representing the same geographical region were analyzed. Fig 2 and Fig. 3, illustrates the baseline condition of the selected area, while the current image captures recent structural developments.

Fig. 2. Reference Image (Before Construction)

Fig. 3. Current Image (After Construction)

Visual comparison of the images indicates noticeable structural variations associated with construction activities. Newly developed regions, building expansions, and infrastructure modifications are observable in the current image.

B. Change Detection Output

The proposed image processing pipeline computes pixel-wise intensity differences to identify structural variations. The thresholding and segmentation stages isolate significant changes, while morphological refinements enhance region continuity.

Fig. 4. Detection Output (Highlighted Construction Changes)

Fig. 4, detection output clearly highlights construction-related changes. The framework effectively distinguishes modified regions from unchanged background areas, enabling intuitive interpretation.

C. System Performance Evaluation

Experimental observations demonstrate that the proposed system successfully detects major structural variations corresponding to construction activities. The image differencing technique captures pixel-level intensity deviations, while threshold segmentation isolates meaningful changes.

The preprocessing stages, including grayscale conversion and noise reduction, contribute to stabilizing illumination-related variations. Morphological operations improve detection reliability by reducing fragmented regions.

D. Robustness and Limitations

The system exhibits reliable performance when images maintain consistent scale, alignment, and viewpoint. Significant construction changes are accurately detected across evaluated image pairs.

However, minor intensity variations caused by:

- Illumination differences
- Shadows
- Seasonal texture variations

may introduce low-intensity noise regions. Despite these challenges, segmentation refinements minimize false detections.

V. DISCUSSION

The experimental results confirm that classical image processing techniques provide a computationally efficient solution for preliminary unauthorized construction detection. Unlike deep learning approaches requiring large labeled datasets and high computational resources, the proposed framework achieves effective detection using lightweight operations.

The Java-based implementation further enhances portability, scalability, and ease of deployment. The system is particularly suitable for rapid monitoring applications and decision-support scenarios. Future enhancements incorporating adaptive thresholding, illumination normalization, and hybrid AI integration may further improve detection accuracy.

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