Real-Time Pedestrian Recognition in Low-Light Conditions for Enhanced Surveillance

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Abstract — Pedestrian recognition plays a crucial role in modern surveillance systems, particularly in applications related to public safety and security monitoring. However, recognizing pedestrians in low-light or night-time conditions remains a significant challenge due to poor illumination, noise, and low contrast. Traditional surveillance systems often fail to provide reliable results under such conditions. This paper presents a real-time pedestrian recognition framework specifically designed for lowlight environments. The proposed system integrates low-light image enhancement techniques with deep learning-based pedestrian detection models to improve recognition accuracy. Contrast enhancement and noise reduction are applied as preprocessing steps, followed by a real-time object detection model to identify pedestrians efficiently. Experimental observations indicate that the proposed approach improves detection accuracy while maintaining real-time performance, making it suitable for enhanced surveillance applications.

Keywords: Pedestrian Recognition, Low-Light Vision, Surveillance System, Image Enhancement, Deep Learning, Real-Time Detection

I. Introduction

Surveillance systems have become an essential component of modern security infrastructure, particularly in urban environments, transportation hubs, and restricted areas. Among various surveillance tasks, pedestrian recognition is of significant importance, as human presence often indicates potential security events or abnormal activities.

Despite advancements in computer vision, pedestrian recognition in low-light conditions remains challenging. Poor illumination leads to low contrast, loss of texture information, and increased noise, which significantly degrade detection performance. Conventional surveillance systems relying on manual monitoring or basic motion detection are ineffective during night-time conditions.

To overcome these challenges, this paper proposes a realtime pedestrian recognition system tailored for low-light environments. By combining image enhancement techniques with deep learning-based detection models, the proposed system enhances visibility and improves detection accuracy, thereby strengthening surveillance effectiveness.

II. Literature Survey

Early pedestrian detection approaches relied on handcrafted features such as Histogram of Oriented Gradients (HOG) combined with classifiers like Support Vector Machines (SVM). Although effective under good lighting conditions, these methods performed poorly in low-light environments.

With the introduction of deep learning, convolutional neural networks (CNNs) have significantly improved object detection accuracy. Models such as Faster R-CNN, SSD, and YOLO have demonstrated strong performance in pedestrian detection tasks. However, their effectiveness is highly dependent on image quality.

Several studies have explored low-light image enhancement techniques such as histogram equalization, CLAHE, and Retinex-based methods to improve detection performance. Recent research combines enhancement techniques with deep learning-based detectors, showing improved accuracy. However, many systems lack real-time capability, highlighting the need for efficient and lightweight solutions.

III. System Architecture

The proposed system architecture consists of multiple interconnected modules designed to process low-light video streams efficiently.

A. Video Acquisition

Live video is captured using surveillance cameras or recorded night-time footage. The video stream is divided into individual frames for processing.

B. Low-Light Image Enhancement

Each frame undergoes preprocessing using contrast enhancement and noise reduction techniques. CLAHE is applied to improve visibility and highlight pedestrian features.

C. Pedestrian Detection

Enhanced frames are passed to a deep learning-based object detection model. A YOLO-based detector is used due to its high speed and real-time performance. The model generates bounding boxes around detected pedestrians.

D. Output Module

Post-processing techniques such as non-maximum suppression remove duplicate detections. The final output displays detected pedestrians with bounding boxes and can trigger alerts if required.

IV. Dataset

A. Dataset Collection

The dataset includes low-light and night-time pedestrian images collected from publicly available surveillance datasets. The data contains annotated images captured under varying illumination conditions.

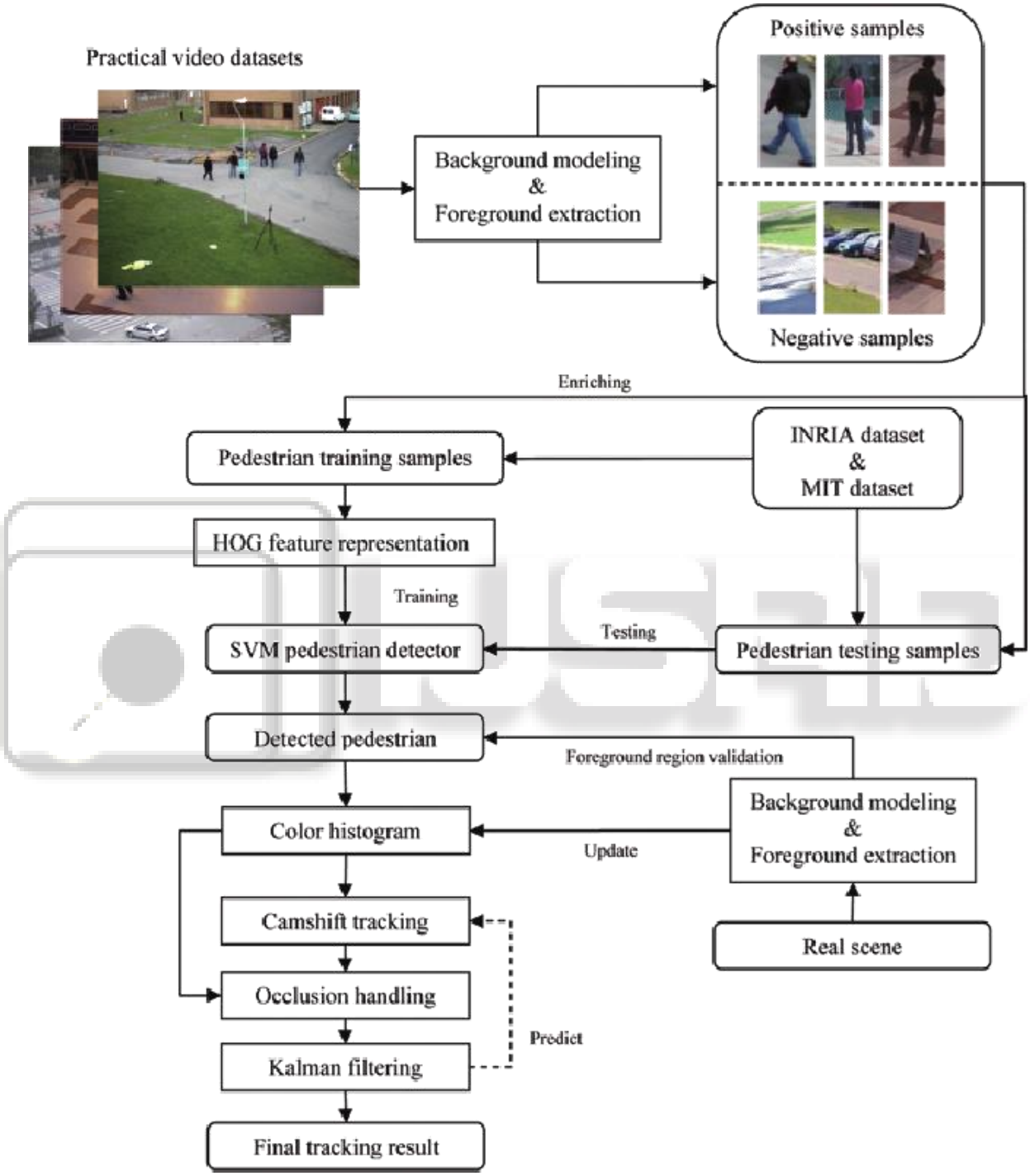
B. Preprocessing

Dataset preprocessing involves resizing images, normalizing pixel values, and applying synthetic low-light augmentation techniques to improve robustness.

C. Significance

A diverse dataset enables the model to learn robust pedestrian features, improving detection accuracy in real-world lowlight surveillance scenarios.

D. Figures and Tables



V. Methodology

The system follows a sequential pipeline starting from video capture to pedestrian recognition. Low-light enhancement improves image quality, which directly enhances feature extraction by the detection model. The use of a real-time detection algorithm ensures suitability for live surveillance applications.

VI. Advantages

Effective detection in low-light conditions
Real-time processing capability
Improved surveillance accuracy
Reduced manual monitoring
Scalable and adaptable system

VII. CONCLUSION

This paper presents a real-time pedestrian recognition system designed for low-light surveillance environments. By integrating image enhancement techniques with deep learning-based detection models, the proposed system effectively addresses the challenges posed by poor illumination. The system demonstrates improved detection accuracy while maintaining real-time performance, making it suitable for practical surveillance applications. Future work may include thermal imaging integration and behaviour analysis for enhanced security.

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