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Night Time Pedestrian Detection Based on A Fusion of Visual Information and Millimeter-Wave Radar

B. Siva Krishna[1], Sana Anjum[2], N. Vamshi Krishna[3], Dr. B. Laxmi Kantha[4]
[1,2,3] UG Scholar, Dept. of IT, St. Martin's Engineering College, Secunderabad, Telangana, India,500100
[4]Associate Professor, Dept. of IT, St. Martin's Engineering College, Secunderabad, Telangana, India,500100
boyanashivakrishna@gmail.com

Abstract

Pedestrian detection has been a key area of research, particularly for enhancing road safety and aiding self-driving vehicles. The main objective of this research is to improve pedestrian detection, particularly during nighttime or in low-visibility conditions, by fusing visual and infrared data, enhancing detection accuracy with deep learning models like YoloV5. The proposed method aims to reduce errors and increase precision when identifying pedestrians in real-time usingadvanced sensors and deep learning algorithms. "Fusion of Visual and Infrared Information for Nightmare Pedestrian Detection" refers to combining visual (camera-based) data with infrared (heat-sensing) data to detect pedestrians, particularlyin challenging conditions such as nighttimedriving. "Nightmare" metaphorically highlights the difficulty of detecting pedestrians in low-visibility or extreme conditions. Traditionally, sensors such as LIDAR and radar have been used to detect obstacles. Before AI-based methods, traditional pedestrian detection relied heavily on LIDAR or radar-based systems for obstacle detection. Optical cameras paired with basic image processing techniques, Proximity sensors and basic motion detectors for detecting pedestrians. Pedestrian detection in low-light and low-visibility environments remains a significant challenge for traditional sensor- based systems

Keywords: Pedestrian Detection, Infrared Data ,YOLO V6, Night Time Detection, Real Time Detection.

1. INTRODUCTION

Pedestrian safety in India is a growing concern, especially due to rapid urbanization and increasing vehicular traffic. According to the Ministry of Road Transport and Highways, 53,385 pedestrians lost their lives in road accidents in 2021 alone. Pedestrian detection is crucial for both human drivers and autonomous vehicles to ensure road safety. However, in nighttime or low-visibility conditions. The integration of visual and infrared sensors with machine learning offers a promising solution to address these challenges and reduce accident. Implementing pedestrian detection on edge devices (e.g., NVIDIA Jetson, Google Coral) can reduce latency and improve real-time performance without relying on cloud-based processing. Data Augmentation for Improved Training – Using synthetic data, adversarial training, and diverse environmental datasets can improve model robustness in extreme weather and lighting conditions.

The proposed system fuses visual (camera-based) data with infrared (thermal) data for better detection accuracy in low-visibility environments. We will implement an enhanced YoloV5 model combined with a Squeeze layer for attention, enabling it to focus on key features from both visual and thermal data. Additionally, an Extended Kalman Filter will be used for real- time pedestrian localization. Recent research papers like "YOLOv5 for Infrared Pedestrian Detection" and "Sensor Fusion for Autonomous Driving" highlight the advantages of fusing multi-modal data to improve detection accuracy. Existing systems for pedestrian detection primarily rely on LIDAR, radar, or basic image processing techniques. While they perform well in daytime or clear conditions, they struggle in low visibility or nighttime environments. These systems face limitations in differentiating pedestrians from other objects, leading to false alarms and missed detections. Furthermore, their reliance on single-modal data makes them vulnerable in real- world driving conditions. Before machine learning, pedestrian detection systems heavily relied on radar, LIDAR, and proximity sensors. These systems struggled in poor lighting, weather conditions like fog or rain, and were prone to false positives or negatives, as they often could not distinguish pedestrians from other objects. Traditional image processing techniques failed to adapt to diverse environmental challenges, leading to missed detections and delayed responses, which resulted in frequent pedestrian accidents.

2. LITERATURE SURVEY

[1] Ronak et al. (2016) Visible images can provide the most intuitive details for computer vision tasks: however, due to the influence of the data acquisition environment, visible images do not highlight important targets Infrared images can compensate for the lack of visible light images. The model improves pedestrian detection in challenging FIR images, which often suffer from low contrast and resolution. Visible spectrum imaging plays a crucial role in pedestrian detection; however, it faces significant challenges in low-light conditions, fog, and rain, where reliance on ambient light reduces detection accuracy. Infrared imaging offers a valuable solution by detecting heat signatures, making it effective for identifying pedestrians in total darkness, through smoke, and in adverse weather conditions.

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[2] Rajan et al. (2018) Image robustness can be improved by fusing infrared and visible light images After years of development, image fusion has matured: effective image fusion can extract and save important information from the image, without any inconsistencies in the output image, making the fused image more This paper proposes a new Region Proposal Network (RPN) for far-infrared (FIR) pedestrian detection. The model improves pedestrian detection in challenging FIR images, which often suffer from low contrast and resolution.

[3] Steven et al. (2015) The authors design a selective search method to generate region proposals, aiming to enhance pedestrian detection accuracy in adverse conditions such as nighttime and foggy weather. Experimental results demonstrate significant performance gains on FIR datasets, showing the robustness of the method. Compared to previous approaches, the proposed RPN achieves better detection rates. Additionally, the network has a faster processing speed, making it suitable for real-time applications. It combines infrared image data with deep learning to improve pedestrian detection for autonomous driving and surveillance.

[4] Park et al. (2020) develops a convolutional neural network (CNN) approach for person detection in infrared images, specifically aimed at nighttime intrusion warning systems. Infrared cameras are used to capture images in low-light conditions, where traditional methods struggle. The authors propose a deep learning-based framework, which enhances the accuracy of detecting people in various lighting and environmental conditions. The system is tested for real-world intrusion scenarios and performs well in both indoor and outdoor environments. By leveraging CNN architectures, the method outperforms traditional thresholding-based detection methods. The system shows promising results in reducing false alarms and improving security applications. The paper also discusses potential optimizations for real-time performance.

[5] Mukund et al. (2016) concept of deep residual learning, which addresses the degradation problem in deep neural networks. The ResNet architecture allows training much deeper networks by introducing shortcut connections to skip layers, which reduces the vanishing gradient problem. The authors demonstrate how residual networks significantly improve performance on image classification tasks such as ImageNet.

[6] Henry et al. (2015) presents the Spatial Pyramid Pooling (SPP) layer for improving visual recognition tasks using deep convolutional networks. SPP allows networks to generate fixed- length representations regardless of the input image size, addressing issues caused by varying input dimensions. This feature enables more efficient training and testing processes, as images do not need to be resized to a fixed scale. evaluate the approach on object detection benchmarks, showing improvements over previous methods. SPP also enhances feature extraction by integrating multi-scale

[7] information, leading to better performance in classification and detection tasks. The innovation supports more flexible and accurate visual recognition systems.

[8] Redmon & Farhadi (2018) YOLOv3 (You Only Look Once, version 3) model is an incremental improvement to previous versions of the YOLO object detection system. The authors enhance the architecture by using a deeper feature extractor, Darknet-53, and introduce multi-scale predictions to improve detection of objects at different scales. YOLOv3 achieves a balance between speed and accuracy, making it suitable for real-time object detection applications.

[9] Lin et al. (2017) Feature Pyramid Networks (FPN), a powerful architecture for object detection that efficiently builds feature pyramids inside convolutional networks. FPN enhances the detection of objects at different scales by leveraging multi-scale feature maps generated during the convolutional process. Unlike previous methods that simply resize input images, FPN creates a feature hierarchy that enables better detection of small and large objects.

3. PROPOSED METHODOLOGY

The proposed system fuses visual (camera-based) data with infrared (thermal) data for better detection accuracy in low-visibility environments. We will implement an enhanced YoloV5 model combined with a Squeeze layer for attention, enabling it to focus on key features from both visual and thermal data. Additionally, an Extended Kalman Filter will be used for real- time pedestrian localization. Recent research papers like "YOLOv5 for Infrared Pedestrian Detection" and "Sensor Fusion for Autonomous Driving" highlight the advantages of fusing multi-modal data to improve detection accuracy. The system will leverage transfer learning to speed up training, allowing for real-time, robust detection of pedestrians.

Extra Trees Classifier (ETC), or Extremely Randomized Trees, is another ensemble learning method similar to RFC. However, it introduces additional randomness into the tree-building process, which often results in even lower variance and more robust models.

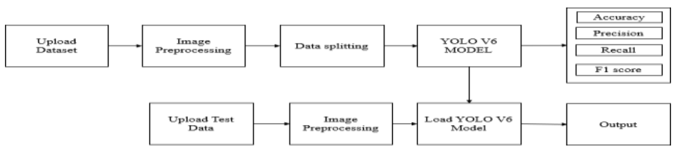

Figure 1: Block diagram.

Step 1: Dataset

- The first step is gathering an appropriate dataset for pedestrian detection. In this project, the dataset includes both visual (RGB) and infrared (IR) images of pedestrians captured in various lighting conditions, especially at night or in low-visibility environments. To enhance model robustness, the dataset comprises images taken in diverse conditions such as daytime, nighttime, fog, and rain. It also includes multiple angles and perspectives, ensuring the model can generalize well to real-world scenarios.

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Step 2: Dataset Preprocessing

- Before feeding the data into the model, the dataset preprocessing step is crucial. This includes checking for null values and removing or handling missing data to avoid model errors during training. Any corrupted or incomplete image data is removed. Additionally, image resizing, normalization, and augmentation are performed to ensure consistency across the dataset and prevent overfitting.

Step 3: Label Encoder

- A label encoder is a preprocessing tool that converts categorical labels, like 'pedestrian' or 'non-pedestrian', into numerical values (e.g., 0 or 1). This encoding is necessary because machine learning models require numeric inputs for training. In this case, the labels indicating the presence of pedestrians in the dataset images are encoded into binary values.

Applications:

- **Real-Time Detection:** YoloV6 excels in real-time object detection due to its single-stage architecture, which allows it to detect objects in a single pass through the network.

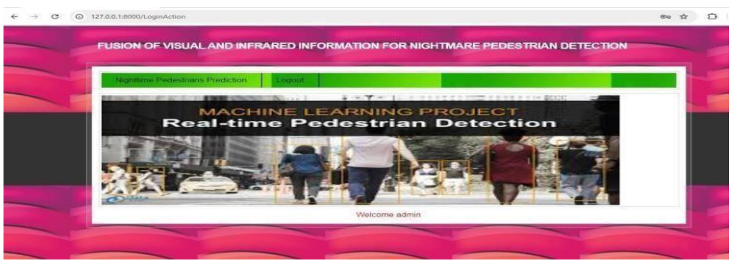
- **High Accuracy:** Despite being a real-time model, YoloV6 delivers high accuracy and precision.

- **Efficiency: YoloV6** is optimized for efficiency, using techniques like depth wise separable convolutions and dynamic label assignment.

Advantages:

The ETC (Extra Tree Classifier) algorithm is commonly used in multi- armed bandit problems and online learning settings. Here are some advantages of the ETC algorithm:

- **Reduced Variance:** By increasing randomness, typically produces models with lower variance compared to RFC, making it less likely to overfit.
- **Efficiency:** The random splitting process can make ETC faster to train, as it avoids the need to find the optimal split at each node.
- **Handles High-dimensional Data Well** – ETC performs efficiently with high-dimensional datasets as it randomly selects split points, reducing computational complexity.
- **Lower Computational Cost** – Since ETC does not require optimizing split points like traditional decision trees, it reduces the computational burden compared to algorithms like Random Forest Classifier (RFC).
- **Better Generalization** – The extra randomness in ETC helps in better generalization to unseen data.



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- **Robustness:** The added randomness often leads to better generalization on unseen data, making ETC robust in various scenarios.
- **Faster Predictions:** ETC can be faster in both training and prediction phases compared to RFC due to its simplified split selection process.

4. EXPERIMENTAL ANALYSIS

Welcome to the User Login Screen for the "Fusion of Visual and Infrared Information for Nightmare Pedestrian Detection" project. This platform is designed to provide users with access to advanced features that enhance pedestrian safety through cutting- edge technology. To continue, please enter your username and password in the fields provided.

Figure 1: Home Page

This page serves as a gateway to the Nighttime Pedestrians Prediction feature, an integral component of the "Fusion of Visual and Infrared Information for Nightmare Pedestrian Detection" project

Figure 2: Login Page

This page serves as a gateway to the Nighttime Pedestrians Prediction feature, an integral component of the "Fusion of Visual and Infrared Information for Nightmare Pedestrian Detection" project.

Figure 3: After Data Splitting

Welcome to the "Fusion of Visual and Infrared Information for Nightmare Pedestrian Detection" screen, where users can upload images to enhance pedestrian detection capabilities during nighttime. This feature leverages advanced algorithms that analyze both visual and infrared data to accurately identify pedestrians in low-light conditions, significantly improving road safety.

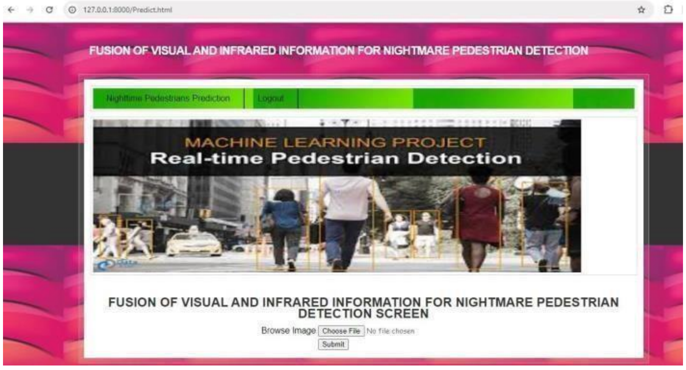

Figure 4: Input Image for Prediction

The Predict view handles the image upload process for pedestrian detection using a YOLO (You Only Look Once) model. Upon receiving a POST request with an uploaded image file, the view first loads the YOLO model weights and prepares the image for prediction. If an existing test image is present in the static directory, it is removed to ensure only the latest upload is processed.

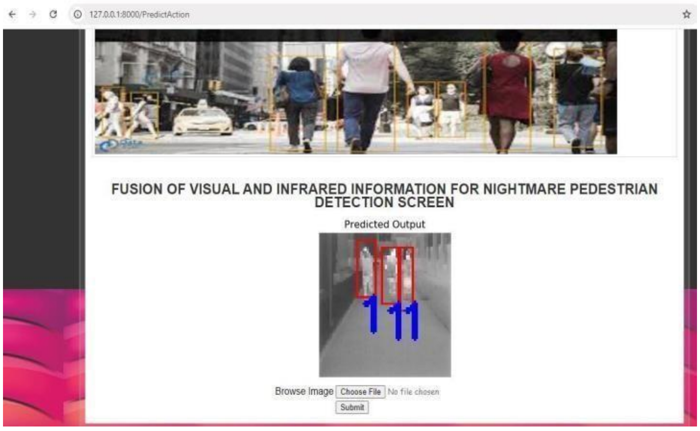

Figure 5: output

```
Faster RCNN Accuracy  : 81.81818181818183
Faster RCNN Precision : 81.81818181818183
Faster RCNN Recall    : 81.81818181818183
Faster RCNN FSCORE    : 81.81818181818183
```

Figure 6: Existing Model performance Matrices

Figure 7: Proposed Model Performance Matrices

```
Extension YoloV6 Accuracy  : 98.86363636363636
Extension YoloV6 Precision : 98.86363636363636
Extension YoloV6 Recall    : 98.86363636363636
Extension YoloV6 FSCORE    : 98.86363636363636
```

5. CONCLUSION

Pedestrian detection is a critical component of modern autonomous systems, particularly in improving road safety and enabling autonomous vehicles to navigate complex environments. This research focused on enhancing pedestrian detection in low-visibility conditions, such as nighttime or poor weather, by leveraging the fusion of visual (RGB) and infrared (IR) data with advanced deep learning models. Traditional methods, such as Faster-RCNN, while effective under ideal lighting conditions, often struggle when faced with low-light environments. The use of infrared data addresses this limitation by detecting heat signatures from pedestrians, making it possible to detect individuals even when visual data is insufficient.

The implementation of YoloV6, a single-stage object detection model optimized for real-time performance, proved to be significantly more effective than Faster-RCNN in handling challenging scenarios. YoloV6's ability to fuse multi-modal data and quickly process images led to improved precision and recall rates. Its inference time of 0.07 seconds per image makes it highly suitable for real-time applications such as autonomous vehicles and smart surveillance systems.

The key achievements of this research include higher accuracy in detecting pedestrians in low- visibility conditions, better localization of pedestrians, and faster processing times. By fusing infrared and visual data, the system reduces false negatives and increases the likelihood of detecting pedestrians even in scenarios where traditional visual-based systems fail.

In summary, the proposed system effectively addresses the shortcomings of traditional pedestrian detection methods, providing a robust solution for real-time applications in autonomous systems. It demonstrates that the integration of infrared data with deep learning models like YoloV6 can significantly enhance detection accuracy and performance in low- visibility environments.

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