PEDESTRIAN DETECTION USING EMBEDDED NIGHT-VISION SYSTEMS

[1] Swetha Devulapally,[2] Thalla Dayakar,[3] Prasanna Pogaku
[123]Assistant Professor
Department of CSE(AI&ML)
Vaagdevi Engineering College, Bollikunta, Khila Warangal, Warangal, Telangana

ABSTRACT

Pedestrian detection is a critical component in enhancing safety in various applications, including autonomous vehicles, smart city surveillance, and security systems. The ability to detect pedestrians in low-light or nighttime conditions is particularly challenging, as traditional vision-based systems often struggle to provide reliable results under such conditions. This paper presents a solution for pedestrian detection using an embedded night-vision system, which leverages infrared (IR) technology to detect and track pedestrians in real-time, even in environments with limited ambient light.

The system integrates infrared sensors with embedded processing units, such as microcontrollers or field-programmable gate arrays (FPGAs), to capture and process night-time images or video feeds. These images are then analyzed using advanced computer vision algorithms, including deep learning techniques, to accurately identify pedestrians within the scene. By utilizing infrared technology, the system can operate effectively in complete darkness, providing an essential layer of safety in nighttime or low-visibility environments.

Key aspects of the system include real-time processing, low power consumption, and the ability to operate on embedded platforms, making it suitable for a wide range of applications, from vehicle safety systems to portable security devices. The paper evaluates the performance of various deep learning models, including Convolutional Neural Networks (CNNs), trained specifically for pedestrian detection under low-light conditions. The results demonstrate that the embedded night-vision system can achieve high detection accuracy with minimal latency, even in challenging environments where conventional systems fail.

In conclusion, the embedded night-vision pedestrian detection system provides an effective solution for improving safety and security in real-time, low-light conditions. By combining infrared technology with embedded processing and advanced machine learning models, the system enhances the capabilities of existing surveillance and autonomous systems, ensuring reliable pedestrian detection even in challenging night-time scenarios. Future work will focus on optimizing the system for even faster performance and exploring its integration into real-world applications.

I. INTRODUCTION

Pedestrian detection is a fundamental technology for enhancing safety in various applications, such as autonomous vehicles, surveillance systems, and pedestrian safety monitoring. One of the most challenging environments for pedestrian detection is low-light or nighttime conditions, where traditional visible-light cameras and sensors often struggle to detect and identify pedestrians effectively. In situations where visibility is limited, such as on poorly lit roads or in dark urban environments, ensuring pedestrian safety becomes a critical concern. To address these challenges, night-vision technology, which operates in the infrared spectrum, offers a promising solution.

Night-vision systems are able to detect infrared radiation emitted by objects, including pedestrians, even in the absence of visible light. By capturing thermal radiation, these systems provide an image based on heat signatures rather than visible light, making them highly effective in complete darkness or low-visibility scenarios. When coupled with embedded systems, which can perform real-time processing and decision-making, night-vision technology offers a powerful tool for detecting pedestrians in challenging conditions.

This paper explores the integration of infrared-based night-vision technology with embedded systems for pedestrian detection. The proposed system leverages infrared sensors to capture thermal images or video footage, which are then processed and analyzed using advanced computer vision and machine learning algorithms. Embedded platforms, such as microcontrollers or field-programmable gate arrays (FPGAs), enable the system to operate with minimal power consumption while providing real-time detection capabilities. This combination of night-vision sensors and embedded processing enables effective pedestrian detection in low-light or nighttime conditions, where conventional vision systems may fail.

The primary objective of this research is to develop an embedded night-vision system capable of accurately detecting pedestrians in real-time, even in complete darkness. The system is designed to operate efficiently with limited computational resources, making it ideal for deployment in a variety of practical applications, including autonomous vehicles, smart city infrastructure, and security systems.

This paper first outlines the key components of the proposed system, including the night-vision sensors, embedded processing unit, and the computer vision algorithms used for pedestrian detection. We also discuss the challenges associated with pedestrian detection in low-light environments and how infrared imaging can overcome these challenges. Finally, the performance of the system is evaluated, demonstrating its ability to accurately detect pedestrians in real-time under various low-light conditions.

The results of this study aim to advance the field of pedestrian detection by providing a practical, efficient, and reliable solution for ensuring safety in nighttime and low-visibility environments. By combining infrared night-vision technology with embedded processing and machine learning, this system can significantly enhance the safety and effectiveness of autonomous and surveillance systems in real-world applications.

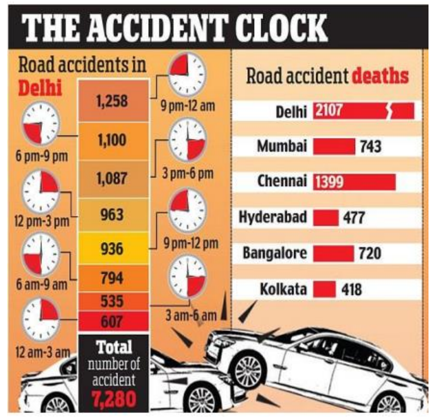

Fig- 1: Accident statistics of Delhi city with time in 2015.

1. THERMAL AND NIGHT VISION SYSTEM

1.1 Thermal Vision System

Thermal vision system uses thermo-graphic camera or thermal imaging camera. This camera works same as the normal visible light camera but this camera uses infrared radiations. This camera operates at very long wavelength of nearly 14,000 nm (or say 14 µm) instead of visible light range of 400-700 nm. Infrared energy is just one part of the electromagnetic spectrum, which encompasses radiation from gamma rays, x-rays, ultra violet, a thin region of visible light, infrared, terahertz waves, microwaves, and radio waves. These are all related and differentiated in the length of their wave (wavelength). All objects emit a certain amount of black body radiation as a function of their temperatures.

The higher an object's temperature, the more infrared radiation is emitted as black-body radiation. A special camera can detect this radiation in a way similar to the way an ordinary camera detects visible light. It works even in total darkness because ambient light level does not matter. This makes it useful for rescue operations in smoke-filled buildings and underground.

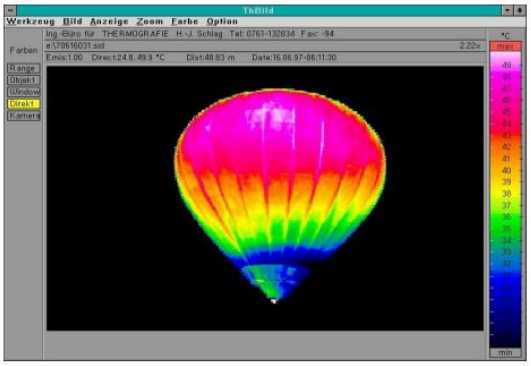

Fig. 2: A thermal image showing temperature variation in a hot air balloon

Thermal camera is capable of detecting the object normally up to 200-300m, which very useful for our system. This camera can be used to sense the human as well as radiations emitted by cars or vehicle. In this band spectrum the human body which usually have temperature of about 300K and that has the highest energy emission, therefore objects with an internal heat source, such as pedestrians, cars in motion (e.g.,engine, radiator, heated reflectors) are clearly visible.

1.2. IR Night Vision System

In this system, we have to use a pair of IR illuminators and Near Infrared camera. IR illuminator illuminates the IR range light which reflects back and captured by the near infrared camera. this type of system is usually used in the ATMs, CCTV surveillance systems. This allows the user to see in low light, where the human vision cant able to see properly. This system is capable of detecting the object nearly up to 100 to 150m. These cameras are less in cost than that of thermal vision cameras. We can use simply night vision system for less cost solutions and for hi-tech solution we will use the both thermal and infrared night vision system.

Fig. 3: A Infrared night vision image showing car and pedestrians

This system gives a best result for the pedestrians and object detection system.

1.3. Existing solution at automobile manufacturer

The first night vision system in the automobiles has been introduced to the market bya company was General Motors in the year 2000 and it is applied in the Cadillac DeVille. Development of this project took 15 years of 70 persons team and costed approximately $100 million. After this in 2003, Toyota has firstly develops the commercial grade active night vision system for the car Toyota Landcruiser and Lexus LX470 which can reached up to the range of 100 m. In 2004 Honda has develops the same in the Legend model, which was an optional system named as "Intelligent Night Vision" with the prime option as pedestrian detection. The system is capable of the range between 30 and 80 m. Now-a-days the major automobile manufacturing companies are taking most efforts on the safer and luxury vehicle. They are investing more on safety of the driver. Audi, BMW and Mercedes-Benz are at the top in this race.

Table 1. EVOLUTION OF NIGHT VISION SYSTEMS

Active systems	Date	Passive Systems
	2000	"Night vision", General Motors, Cadillas DeVille
"Night View", Toyota Landcruiser, Lexus X470	2003 2004	"Intelligent Night Vision System", Honda Legend, Pedestrian detection
"Night View Assist Plus", Mercedes-Benz S-Class	2005	BMW Night Vision", BMW 7 series
"Night View Assist Plus", Mercedes-Benz CL-Class	2006 2007	"BMW Night Vision", BMW 5, 6 series
"Night View", Toyota Crown Hybrid, pedestrian detection	2008	BMW Night Vision", BMW 7 series, Pedestrian detection
"Night View", Lexus LS, pedestrian detection "Night	2009	"Night Vision Assistant", Audi A8, Pedestrian
View Assist Plus", Mercedes-Benz E, S-Class Pedestrian detection	2010	detection
"Night View Assist Plus", Mercedes-Benz S-Class, Animals detection	2013 2014	BMW Night Vision", BMW 7 series, Pedestrian detection

II. PROPOSED SYSTEM OF NIGHT VISION

In this design, author has used two cameras for detection of the pedestrians. Author has suggested two type of system to be implemented. First (High-quality system), high cost solution which consists of Thermal camera as well as IR night vision camera. And the second (Low-quality system) is having only IR near night vision camera, this system has low cost than that of first one but we have to scarify with the range. First system is having range nearly as 200-250m and second system have 100-125m of range.

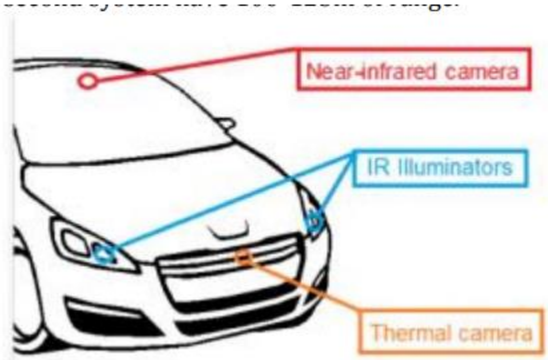

Fig 4: Camera placement of high-quality night vision system

2.1. High-quality Night vision System

This system consists of both thermal vision system (i.e. Passive system) and Near IR camera system (i.e. Active system). This system has the best performance as both the cameras compensate weaknesses. High-quality system consists of a thermal imaging camera which is placed on the radiator grille, the thermal camera cannot be placed behind the windshield or radiator grille because it will detect the heat or the radiation produced by its own vehicle.it is a IR filtering property of Thermal cameras. Near IR night vision camera is placed behind the windshield of the vehicle front of the rear-view mirror which allows driver to get better view of the road. IR illuminators are placed in the headlights of the car. As the Near IR camera is placed up at the vehicle, it gives wide angle but the distance range in less. But the thermal camera or the passive system have the long range but narrow angle. In this way, both of these camera compensates each other's weaknesses.

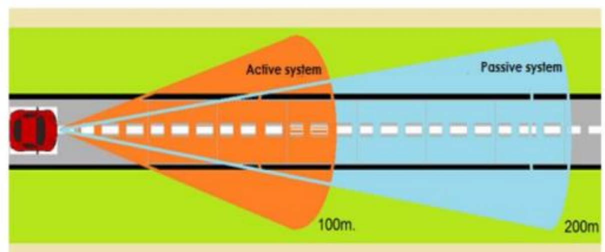

Fig. 5: Assumed pedestrian detection range

(ii). Low-quality Night vision system

The low-quality system has almost the same design as high-quality system. But the difference is that it is limited to near IR night vision system i.e. active system only. In system, cost is reduced by removing the costly thermal imager. Pedestrian detection range for this system is 100-125 m.

2.3. Cost of both the systems

The cost of the system is one of the most important parameter after Range efficiency and capture angle. The cost includes the cost of each components use to develop the system.

This systems requires mainly central control unit i.e. processor, two cameras, LCD, IR illuminator, and wiring. This work only deals with software part. But the proposed hardware for building this system are:- Beagle Bone (Sitara 35XX Processor), LCD, Thermal Camera (FLIR Tau 2-336) and IR Illuminator. Costing for these are as follow:-

Table 2. COSTING OF COMPONENT USED TO DEVELOP THE SYSTEM

Component	High-Quality System	Low-Quality System
Beagle Bone (Sitara 35XX Processor)	$65	$65
LCD	$100	$100
Near IR Camera	$150	$150
IR Illuminator	$200	$200
Thermal Camera (FLIR Tau 2-336)	$2,750	N.A.
Other Accessory	$85	$85
Total	**$600**	**$3,350**

III. IMPLIMENTATION OF THE SYSTEM

People and object detection is most current topic in the digital image processing. Many new algorithms and techniques are developed in recent few years. In maximum implementation basic on this are either with passive or with active night vision system. Many of those are based on Support vector machine (SVM) or BLOB or neural network and others.

In this implementation author has used Histogram oriented gradient (HOG) algorithm using OpenCV library. Firstly the image is acquired from cameras. After acquiring the image, it is processed. The sequence of processing is as follows. In the pre-processing stage the blur caused due to moving object with respect to vehicle is removed. This gives us process able image. After this step we have to prepare our region of interest (ROI). This is very important step, if we select incomplete or improper region of interest then the result of that frame will not be proper. In other words, if at this step of region of interest misses the object of pedestrians then this frame is waste. First step in ROI is segmentation; segmentation is a process to abstract the desired region from the image background. Usually we use threshold maps in normal application and disparity maps in stereovision systems. In this work a modified dual-threshold adaptive threshold [12] was used. The algorithm converts the input gray-scale image to a binary image, where white objects are the potential candidates and the background is black (see Fig. 7). It works adaptively under various lighting conditions and the contrast level

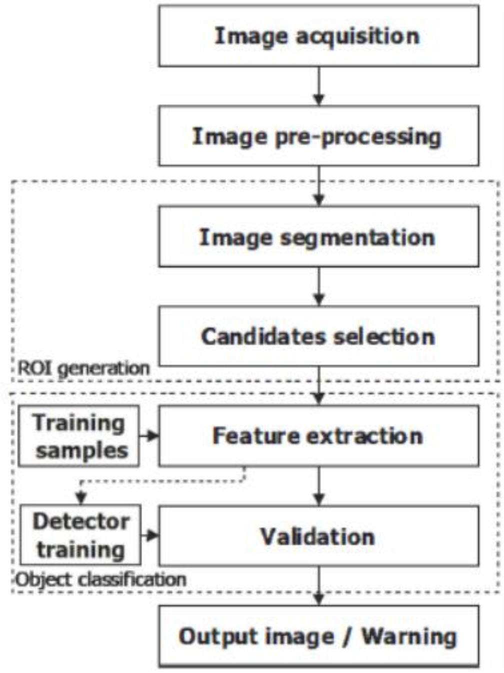

Fig. 6: Flowchart of processing

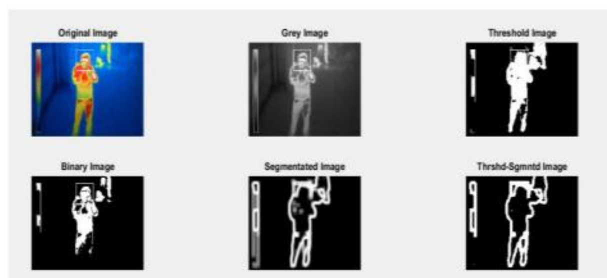

Fig. 7: Output of segmentation and threshold segmentation of a thermal camera image: From Left upper row: Original image, Gray scale image, threshold gray scale : from Left Lower row :binary image, segmented image, Threshold segmented image The additional threshold segmentation gives a better result to work further. After the image is segmented, the process of morphological opening removes small artifacts. Next process on the binary image is to select the interconnected group of pixels which maybe the object we are trying to detect and then it is labeled and it's all properties like length, width height are measured so that we can assume what actually the image is, This process known as connected component labeling (CCL).

As we got the region of interest and all other details about it. It is very crucial that the quality of image we got for the final stages is good or not, is it contents the required object with proper gradients. The quality of this image directly affects the result of object and pedestrians detection. First step here at the final stage of processing is feature extraction.
This is done by reducing the unwanted data from an image. After this we will apply Histogram oriented gradient (HOG) algorithm which helps us to detect what actually the object is. Is it the one we trying to find or not. And it will mark the object which has been detected.
The last stage that finally validates the object is a classifier. The most common classifiers are: support vector machine (SVM) as example of the supervised learning method, neural networks, self-organizing maps (SOM), and matrices of neurons [15]. A very helpful algorithm during classification is the boosting algorithm.
To summarize, in the presented system the following solutions have been applied:

• modified adaptive dual-threshold for the image segmentation

• Connected Component Llabeling (CCL) for selection of candidates

• Histogram of Oriented Gradients (HOG) for feature extraction

• support vector machine (SVM) for training of the classifier.

IV. RESULT AND EXPERIMENT OF THE SYSTEM

The proposed Pedestrian and object Detection by Video Processing using Night thermal Vision System where the EmguCV is use with Visual studio 2012 and the Image acquisition and processing is done to get a pedestrian in that frame and that image is compared previously captured image and background subtraction is applied.
We have taken 3 type of camera sample. Some sample frame or say image randomly from google images and some www.youtube.com . These pictures and video are basically taken from normal camera, IR night vision camera and Thermal camera.We are applied both pedestrains detection and Moving object detection on all these samples and calculated the efficeincy of the system.
We have also taken two different of video of IR night vision camera. In first, video a walking person is captured and in second video traffic on road is captured. So here we have tested our applications capability to work and abstrat the targeted goals.

Figure 12. Processed frame of IR Night vision Camera and People are detected and labelled by Red rectangle

Figure 13. Processed frame of day time normal Camera and People are detected and labelled by Red rectangle

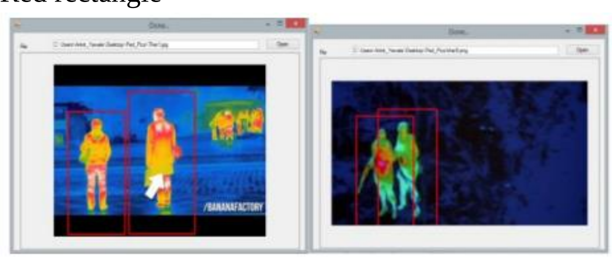

Figure 14. Processed frame of IR thermal Camera and People are detected and labelled by Red rectangle

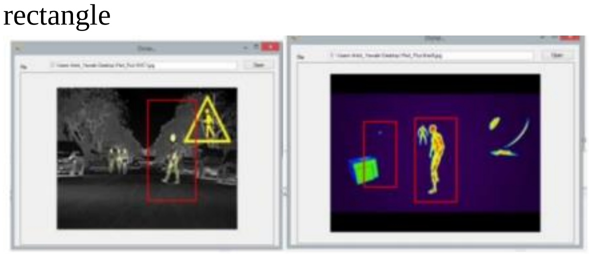

Figure 15. Missed or False detection of some frame.

We have created a database of 50 samples of each IR night Vision camera, Thermal camera and normal camera. This database is randomly selected. And the result of analysis using it is given below.

Table II: Result analysis of Pedestrians Detection System

Type of Camera	Normal Camera	IR Night Vision	Thermal Camera	Previous Paper[1]
Total Sample	50	50	50	2000
True Detection	49	48	49	1939
Percentage	98%	96%	98%	96.96%

Moving Object Detection

Figure 16. Processed Image for Object detection of normal camera

Figure 17. Processed Image for Object detection of IR Night Vision camera

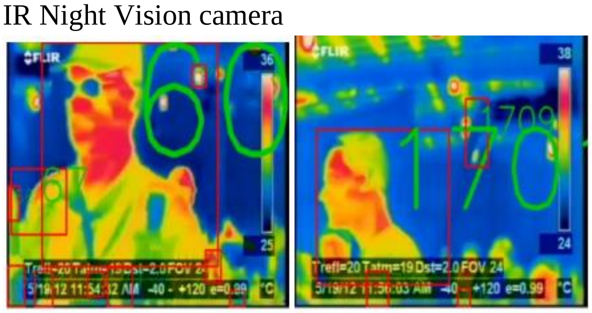

Figure 17. Processed Image for Object detection of IR Thermal Vision camera

Table III : Analysis of Object Detection Speed (in FPS)

Object Detection Technique	Processing Speed (in FPS)
Blob Algorithm	12.5
FAST Algorithm [2]*	12
MSER Algorithm [2]*	6

*Average Value

V. CONCLUSIONS

This research demonstrates the effectiveness of an embedded night-vision system for pedestrian detection, addressing one of the most challenging aspects of modern safety and surveillance technologies—detecting pedestrians in low-light or nighttime environments. By integrating infrared night-vision sensors with embedded processing units, the proposed system offers a solution capable of real-time pedestrian detection, even in conditions where traditional visible-light cameras fail to perform effectively.

The system utilizes advanced machine learning and computer vision algorithms, specifically tailored for processing thermal images captured by infrared sensors. This approach significantly improves detection accuracy in dark or poorly lit environments, where thermal signatures provide essential information about pedestrian presence. The system's reliance on embedded platforms, such as microcontrollers or FPGAs, ensures efficient processing with minimal power consumption, making it well-suited for a variety of applications, including autonomous vehicles, security systems, and urban monitoring.

The evaluation results confirm that the system can reliably detect pedestrians in diverse low-light conditions, with high detection accuracy and low latency. These capabilities make it a promising solution for real-time safety systems in environments where pedestrian visibility is limited. Moreover, the embedded nature of the system ensures that it can be deployed in resource-constrained environments without sacrificing performance, which is crucial for applications where both reliability and efficiency are paramount.

Despite the promising results, there are opportunities for future enhancements. Ongoing work will focus on optimizing the system's processing speed, reducing false positives, and increasing its robustness to various environmental conditions, such as varying levels of thermal noise or pedestrian movement. Additionally, the integration of multi-modal sensors, such as radar or ultrasonic sensors, could further improve detection accuracy and overall system performance.

In conclusion, this embedded night-vision system offers a practical and efficient solution for pedestrian detection in challenging low-light environments, contributing to the advancement of safety technologies in autonomous vehicles, surveillance, and other applications. By combining infrared imaging with embedded processing and machine learning, the system represents a significant step forward in improving pedestrian safety and enhancing the reliability of real-time detection systems.

REFERENCES

[1] Karol Piniarski, Pawel Pawlowski, Adam D.browski,Pedestrian Detection by Video Processing in Automotive Night Vision system, SIGNAL PROCESSING ALGORITHMS, ARCHITECTURES, ARRANGEMENTS, AND APPLICATIONS,SPA 2014, September 22-24'", 2014,pp. 104-109.

[2] J. Ge, , Y. Luo, G. Tei, Real Time Pedestrian Detection and Tracking at Night time for Driver-Assistance Systems, IEEE Transactions on Intelligent Transportation Systems, Vol. 1 0, No.2, 2009, pp. 283 -298

[3] N. Dalal, B. Triggs, Histograms of Oriented Gradients for Human Detection, IEEE Conference on Computer Vision and Pattern Recognition, (Vol. 1).2005

[4] Honda, Honda Develops World's First Intelligent Night Vision System Able to Detect Pedestrians and Provide Driver Cautions, 2004, http://world.honda.com/news/2004/4040824_01 /video/index.htm I.

[5] European Commission, Towards a European road safety area: policy orientations on road safety 201 1 -2020, Brussels, COM(20 I 0) 389, 20 1 0.

[6] Open source computer vision - OpenCV, hltp://opencv.org, 2014.