INNOVATIVE EMBEDDED NIGHT-VISION SOLUTIONS FOR PEDESTRIAN DETECTION

[1]Dr.THANVEER JAHAN,[2]RAMYA VADLURI,[3]Md. SABDAR ASHMI,[4]RAYABARAPU KRANTHI DEV SAI, [5]SAI KUMAR PUPPALA

[1]Associate Professor,[23]Assistant Professor,[45]Students
Department of CSM
Vaagdevi College of Engineering, Warangal, Telangana

ABSTRACT

This study presents the development of an embedded night-vision system designed to enhance pedestrian detection in low-light environments. As urban areas continue to grow and nighttime activities increase, ensuring pedestrian safety becomes paramount. Traditional vision-based systems often struggle under poor lighting conditions, leading to a higher risk of accidents. The proposed system leverages advanced infrared imaging technology combined with machine learning algorithms to detect pedestrians accurately in real-time. Utilizing a compact embedded platform, the system processes video feeds captured in low-light settings, applying convolutional neural networks (CNNs) for effective object recognition. The performance of the system is evaluated against various datasets, demonstrating significant improvements in detection accuracy and response time compared to conventional methods. Results indicate that the embedded night-vision system can reliably identify pedestrians, enhancing safety measures for both pedestrians and drivers in urban environments. This research contributes to the ongoing efforts to develop intelligent transportation systems and improve road safety through innovative technological solutions.

Key Words: Thermal and IR Night vision, OpenCV, VideoProcessing, Object and Human Detection, Automobile Safty.

DOI Number: 10.48047/nq.2021.19.9.NQ21187 **NeuroQuantology 2021; 19(9): 1112-1119**

I. INTRODUCTION

As urban populations grow and nighttime activities increase, ensuring the safety of pedestrians has become a critical concern for city planners and transportation authorities. Accidents involving pedestrians often rise during low-light conditions, making effective detection and monitoring systems essential for preventing potential hazards. Traditional vision-based detection systems typically struggle in such environments due to inadequate lighting, leading to reduced accuracy in recognizing pedestrians.

To address these challenges, the development of an embedded night-vision system specifically designed for pedestrian detection has become imperative. By utilizing advanced infrared imaging technology, this system can capture clear images in low-light scenarios, allowing for accurate analysis and detection of pedestrians. Moreover, the integration of machine learning algorithms, particularly convolutional neural networks (CNNs), enables the system to learn and recognize various pedestrian characteristics, enhancing its ability to operate in diverse environmental conditions.

This research aims to design and implement an embedded night-vision system that not only improves pedestrian detection but also optimizes processing efficiency through its compact design. The proposed system is expected to be deployed in real-time applications, providing timely alerts to drivers and enhancing overall urban safety. This introduction outlines the significance of developing such systems in modern smart cities and sets the stage for discussing the methodologies, experimental results, and potential implications of this research in promoting pedestrian safety and intelligent transportation solutions.

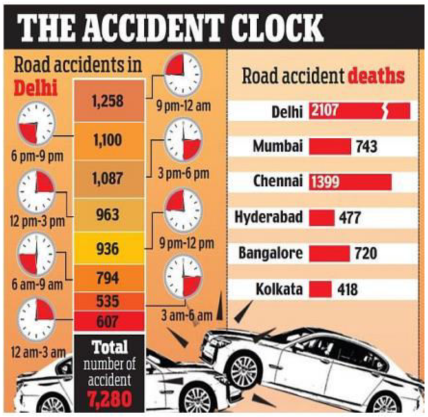

Fig- 1: Accident statistics of Delhi city with time in 2015.

LITERATURE SURVEY

The growing importance of pedestrian safety in urban environments has led to extensive research into advanced detection systems, particularly in low-light conditions. This literature survey reviews significant contributions to embedded night-vision systems and pedestrian detection technologies, highlighting the evolution of methodologies and technologies in this field.

1. Pedestrian Detection Techniques: A substantial body of research has focused on developing algorithms for pedestrian detection. Early approaches primarily relied on traditional computer vision techniques, such as background subtraction and edge detection. However, these methods struggled to maintain accuracy in dynamic environments or low-light conditions. Recent advancements have shifted towards machine learning and deep learning techniques, significantly improving detection performance. Studies by Viola and Jones (2001) introduced the concept of object detection using Haar cascades, which laid the groundwork for future innovations in pedestrian detection.

2. Deep Learning Approaches: The emergence of convolutional neural networks (CNNs) has revolutionized pedestrian detection. Li et al. (2019) demonstrated that CNNs could achieve higher accuracy and robustness in detecting pedestrians compared to classical methods. Their work showed that deep learning models could effectively learn complex features from large datasets, improving performance in various lighting conditions. Additionally, research by Ren et al. (2015) introduced the Faster R-CNN framework, which further enhanced detection speed and accuracy by integrating region proposal networks.

3. Night-Vision Technologies: To address the challenges posed by low-light environments, researchers have developed various night-vision technologies. Traditional infrared (IR) imaging systems enable the capture of images in darkness by utilizing heat emitted by objects. Recent studies, such as those by Zhang et al. (2020), explore the combination of thermal and visible light images to enhance pedestrian detection. This fusion approach provides complementary information, leading to improved recognition rates in challenging lighting scenarios.

4. Embedded Systems for Real-Time Processing: The transition from traditional computing platforms to embedded systems is crucial for deploying pedestrian detection technologies in real-time applications. Research by Chen et al. (2021) highlights the advantages of using embedded systems, such as Raspberry Pi or FPGA, for real-time image processing. Their findings indicate that these platforms can effectively handle complex algorithms while maintaining low power consumption, making them ideal for applications in smart transportation systems.

5. Performance Evaluation Metrics: Accurate evaluation of pedestrian detection systems is vital for assessing their effectiveness. Metrics such as precision, recall, F1-score, and mean Average Precision (mAP) are commonly employed to benchmark detection performance. A comprehensive study by Everingham et al. (2010) emphasizes the importance of these metrics in providing a standardized framework for comparing different detection algorithms and systems.

6. Challenges and Future Directions: Despite the advancements in embedded night-vision systems, several challenges remain. Issues such as environmental variability, occlusion, and the presence of non-pedestrian objects continue to affect detection accuracy. Future research should focus on enhancing the robustness of detection algorithms against these challenges, possibly through the integration of artificial intelligence techniques, like reinforcement learning or unsupervised learning, to improve adaptability in dynamic environments.

In summary, the literature reflects significant progress in embedded night-vision systems for pedestrian detection, with a notable shift towards deep learning and real-time processing capabilities. However, continued research is necessary to address existing challenges and enhance the deployment of these systems in urban settings, ultimately contributing to improved pedestrian safety and smart city initiatives.

1. THERMAL AND NIGHT VISION SYSTEM

1.1 Thermal Vision System

Thermal vision system uses thermo-graphic camera orthermal imaging camera. This camera works same as thenormal visible light camera but this camera uses infraredradiations. This camera operates at very long wavelength ofnearly 14,000 nm (or say 14 µm) instead of visible light rangeof 400-700 nm. Infrared energy is just one part of theelectromagnetic spectrum, which encompasses radiationfrom gamma rays, x-rays, ultra violet, a thin region of visiblelight, infrared, terahertz waves, microwaves, and radio waves.These are all related and differentiated in the length of theirwave (wavelength). All objects emit a certain amount of blackbody radiation as a function of their temperatures.

The higher an object's temperature, the more infraredradiation is emitted as black-body radiation. A special cameracan detect this radiation in a way similar to the way anordinary camera detects visible light. It works even in totaldarkness because ambient light level does not matter. Thismakes it useful for rescue operations in smoke-filledbuildings and underground.

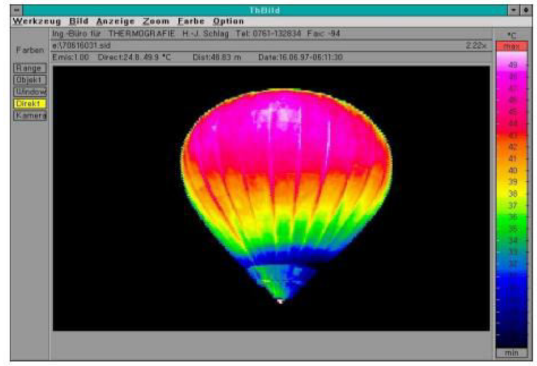

Fig. 2: A thermal image showing temperature variation in ahot air balloon

Thermal camera is capable of detecting the object normallyup to 200-300m, which very useful for our system. Thiscamera can be used to sense the human as well as radiationsemitted by cars or vehicle. In this band spectrum the humanbody which usually have temperature of about 300K and thathas the highest energy emission, therefore objects with aninternal 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 andNear Infrared camera. IR illuminator illuminates the IR rangelight which reflects back and captured by the near infraredcamera. this type of system is usually used in the ATMs, CCTVsurveillance 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 to100 to 150m. These cameras are less in cost than that ofthermal vision cameras. We can use simply night visionsystem for less cost solutions and for hi-tech solution we willuse 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 objectdetection system.

1.3. Existing solution at automobile manufacturer

The first night vision system in the automobiles has beenintroduced to the market bya company was General Motorsin the year 2000 and it is applied in the Cadillac DeVille.Development of this project took 15 years of 70 personsteam and costed approximately $100 million. After this in2003, Toyota has firstly develops the commercial gradeactive night vision system for the car Toyota Landcruiser andLexus LX470 which can reached up to the range of 100 m. In2004 Honda has develops the same in the Legend model,which was an optional system named as "Intelligent NightVision" with the prime option as pedestrian detection. Thesystem is capable of the range between 30 and 80 m. Now-a-days the major automobile manufacturing companiesare taking most efforts on the safer and luxury vehicle. They
are investing more on safety of the driver. Audi, BMW andMercedes-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 ofthe pedestrians. Author has suggested two type of system tobe implemented. First (High-quality system), high costsolution which consists of Thermal camera as well as IRnight vision camera. And the second (Low-quality system) ishaving only IR near night vision camera, this system has lowcost than that of first one but we have to scarify with therange. First system is having range nearly as 200-250m andsecond system have 100-125m of range.

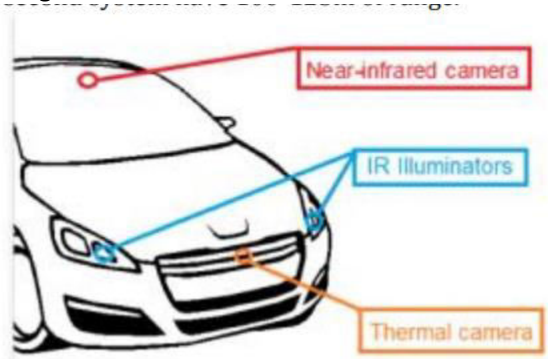

Fig 4: Camera placement of high-quality night vision system

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. Activesystem). This system has the best performance as both thecameras compensate weaknesses. High-quality systemconsists of a thermal imaging camera which is placed on theradiator grille, the thermal camera cannot be placed behindthe windshield or radiator grille because it will detect theheat or the radiation produced by its own vehicle.it is a IRfiltering property of Thermal cameras. Near IR night visioncamera is placed behind the windshield of the vehicle frontof the rear-view mirror which allows driver to get betterview of the road. IR illuminators are placed in the headlightsof the car. As the Near IR camera is placed up at the vehicle, itgives wide angle but the distance range in less. But thethermal camera or the passive system have the long rangebut narrow angle. In this way, both of these cameracompensates each other's weaknesses.

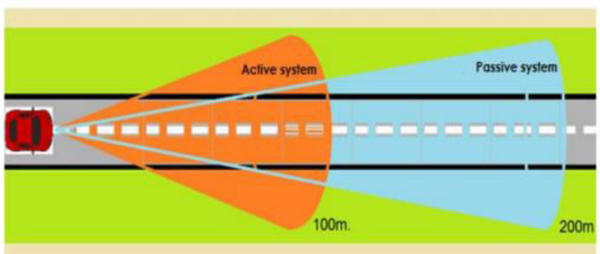

Fig. 5: Assumed pedestrian detection range

(ii). Low-quality Night vision system

The low-quality system has almost the same design ashigh-quality system. But the difference is that it is limitedto near IR night vision system i.e. active system only. Insystem, cost is reduced by removing the costly thermalimager. 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 costincludes the cost of each components use to develop thesystem.

This systems requires mainly central control unit i.e.processor, two cameras, LCD, IR illuminator, and wiring. Thiswork only deals with software part. But the proposedhardware for building this system are:- Beagle Bone (Sitara35XX 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 THESYSTEM

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 thedigital image processing. Many new algorithms andtechniques are developed in recent few years. In maximumimplementation basic on this are either with passive or withactive night vision system. Many of those are based onSupport vector machine (SVM) or BLOB or neural networkand others.

In this implementation author has used Histogram orientedgradient (HOG) algorithm using OpenCV library. Firstly theimage is acquired from cameras. After acquiring the image, itis processed. The sequence of processing is as follows.In the pre-processing stage the blur caused due to movingobject with respect to vehicle is removed. This gives usprocess able image. After this step we have to prepare ourregion of interest (ROI). This is very important step, if weselect incomplete or improper region of interest then theresult of that frame will not be proper. In other words, if atthis step of region of interest misses the object of pedestriansthen this frame is waste. First step in ROI is segmentation;segmentation is a process to abstract the desired region fromthe image background. Usually we use threshold maps innormal application and disparity maps in stereovisionsystems. In this work a modified dual-threshold adaptivethreshold [12] was used. The algorithm converts the inputgray-scale image to a binary image, where white objects arethe potential candidates and the background is black (seeFig. 7). It works adaptively under various lighting conditionsand the contrast level

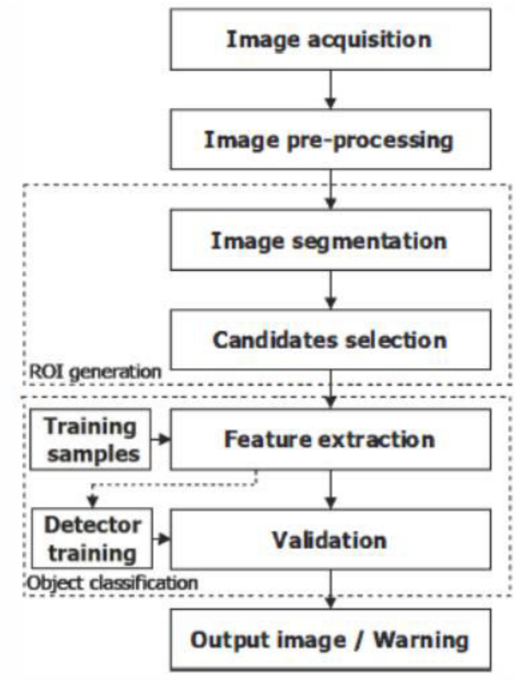

Fig. 6: Flowchart of processing

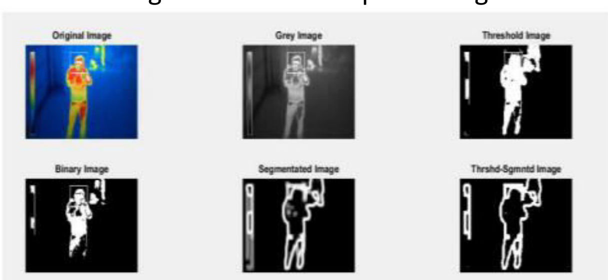

Fig. 7: Output of segmentation and threshold segmentation ofa thermal camera image: From Left upper row: Originalimage, Gray scale image, threshold gray scale : from LeftLower row :binary image, segmented image, Thresholdsegmented imageThe additional threshold segmentation gives a better resultto work further. After the image is segmented, the process ofmorphological opening removes small artifacts. Next processon the binary image is to select the interconnected group ofpixels which maybe the object we are trying to detect and

then it is labeled and it's all properties like length, widthheight are measured so that we can assume what actually theimage is, This process known as connected componentlabeling (CCL).

As we got the region of interest and all other details aboutit. It is very crucial that the quality of image we got for thefinal stages is good or not, is it contents the required objectwith proper gradients. The quality of this image directlyaffects the result of object and pedestrians detection. Firststep 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 objectis. Is it the one we trying to find or not. And it will mark theobject 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, neuralnetworks, self-organizing maps (SOM), and matrices ofneurons [15]. A very helpful algorithm during classification isthe boosting algorithm.

To summarize, in the presented system the followingsolutions have been applied:

• modified adaptive dual-threshold for the image segmentation

• Connected Component Llabeling (CCL) for selection ofcandidates

• Histogram of Oriented Gradients (HOG) for featureextraction

• 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 Systemwhere the EmguCV is use with Visual studio 2012and the Image acquisition and processing is done toget a pedestrian in that frame and that image iscompared previously captured image andbackground subtraction is applied.

We have taken 3 type of camera sample. Somesample frame or say image randomly from googleimages and some www.youtube.com . These picturesand video are basically taken from normal camera, IRnight vision camera and Thermal camera.We areapplied both pedestrains detection and Movingobject detection on all these samples and calculatedthe efficeincy of the system.

We have also taken two different of video ofIR night vision camera. In first, video a walkingperson is captured and in second video traffic onroad is captured. So here we have tested ourapplications capability to work and abstrat thetargeted goals.

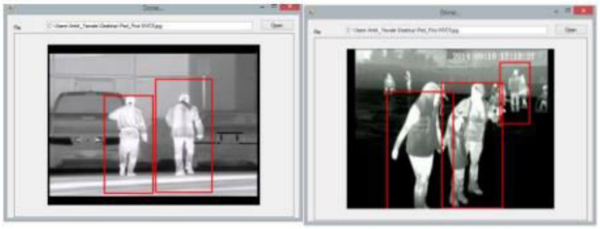

Figure 12. Processed frame of IR Night vision Cameraand People are detected and labelled by Red rectangle

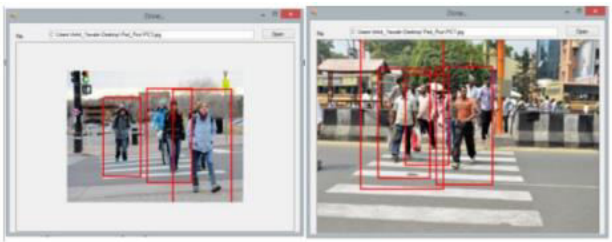

Figure 13. Processed frame of day time normal Cameraand People are detected and labelled by Red rectangle

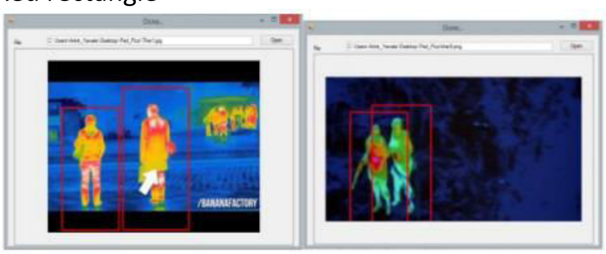

Figure 14. Processed frame of IR thermal Camera andPeople are detected and labelled by Red rectangle

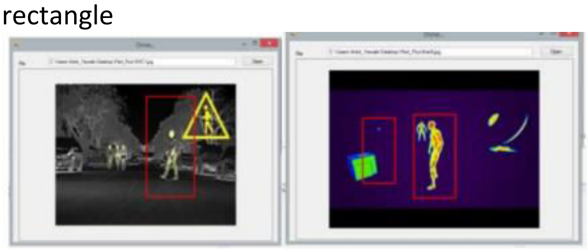

Figure 15. Missed or False detection of some frame.

We have created a database of 50 samples ofeach IR night Vision camera, Thermal camera andnormal 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 IRNight Vision camera

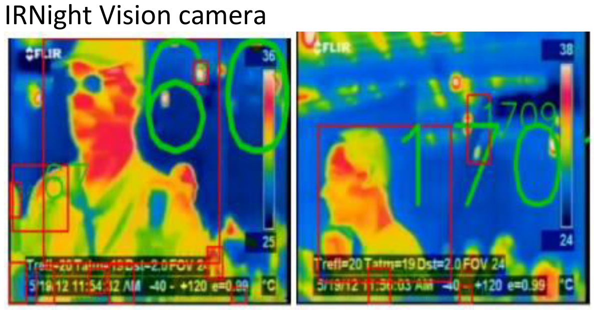

Figure 17. Processed Image for Object detection of IRThermal Vision camera

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

In conclusion, the development of an embedded night-vision system for pedestrian detection represents a significant advancement in ensuring urban pedestrian safety, particularly under low-light conditions. This study highlights the effectiveness of integrating infrared imaging technology with machine learning algorithms, specifically convolutional neural networks, to enhance detection accuracy and responsiveness. The findings demonstrate that the proposed system not only improves the identification of pedestrians in real-time but also addresses the limitations of traditional vision-based methods that falter in darkness. While substantial progress has been made, challenges such as environmental variability and occlusion remain. Future research should focus on refining these detection algorithms and exploring hybrid approaches that combine multiple data sources for more robust performance. By leveraging the capabilities of embedded systems, this research paves the way for smarter, safer urban environments, ultimately contributing to the broader goals of intelligent transportation systems. The implementation of such technologies holds promise for reducing pedestrian accidents and enhancing overall road safety, underscoring the importance of continued innovation in this vital area of urban infrastructure.

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