

Driving Behaviour Monitoring For Intelligent Transportation Systems

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Abstract- This paper includes a drowsiness prevention device since current safety measures are followed to increase the driver's awareness which includes the use of standard rumble strips on roads reference, installation of GSM, sensors and other studies uses signal processing embedded of an expensive vehicle. The technology uses internet of things so that the vehicle owner can monitor the driver's drowsiness everywhere during work hours. The study focuses at the eyelid movement that is not yet mentioned to the previous study. This proposed system continuously scans the eyelid movements of the driver and once drowsiness is detected the device automatically alerts him using a random-typed alarm. It automatically forwards the report to the vehicle owner from the web page through internet access. The project received consistent results through evaluation and testing as it successfully detects and alerts a drowsy driver.

Keywords- Transportation, IoT

I. INTRODUCTION

Driver fatigue has been the main issue for countless mishaps due to tiredness, tedious road condition, and unfavourable climate situations [1]. Every year, the National Highway Traffic Safety Administration (NHTSA) and World Health Organisation (WHO) have reported that approximately 1.35 million people die due to vehicle crashes across the world. Generally, road accidents mostly occur due to inadequate way of driving [2]. These situations arise if the driver is addicted to alcohol or in drowsiness [3]. The maximum types of lethal accidents are recognised as a severe factor of tiredness of the driver. When drivers fall asleep, the control over the vehicle is lost [4]. There is a need to design smart or intelligent vehicle system through advanced technology [5]. This paper implements a mechanism to alert the driver on the condition of drowsiness or daydreaming. A camera monitors the driver's eye blinking, eye closure, face detection, head posture, etc. with face landmark algorithm and Euclidean distance in the behaviouralbased approach. These characteristics help to measure driver fatigue and instantly alert him with the help of voice speaker and forwarding an e-mail to a person (owner of vehicle) who can make him

conscious [6]. An email is being transmitted to a destination using IoT module, which relies on wireless transmission [7, 8]. But the proposed system is being integrated by a credit card-sized computer known as Raspberry Pi3 and Pi camera which can trace an eye movement [9] thereby monitoring intensity of collision effects that happen at the time of accident and alerting the emergency ward of the hospitals or owners that are nearby to the accident spot along with GPS location of the accident [10, 11].

1.1. Problem Statement.

An IoT-based system is designed to avoid countless mishaps due to drowsy drivers' behavioural and psychological changes by focusing on driver's eye movements. In addition to monitoring the intensity of the collisions impacts during road accidents, it is also required to keep records of the location for taking supportive action.

1.2. Contribution to This Work.

The drowsiness of driver and impact of collision monitoring or alert system is constructed using IoT technology along with Raspberry Pi. For finding the fatigue or sleepiness of driver, a Pi camera can be used during driving. Apart from it, the vehicle needs to be well mounted by crash sensor and FSR sensor for detecting the extremity of collision. When the drowsiness is detected, the driver is alerted by voice speaker and a mail sent to the vehicle owner. Similarly, suppose any sudden collision happens due to drowsiness. In that case, the data collected from the sensors and the alert message are messaged to the nearer hospitals nearby the prone location from Google Maps link where the mishap has happened.

The rest of the paper has been organised as follows: in Section 2, the literature review is included. Section 3 describes about components which are used for designing the proposed system. Section 4 illustrates the proposed system with a block diagram along with a brief explanation of the methodology with a flowchart in Section 5. The result analysis is discussed in Section 6. Finally, a conclusion of the paper with its future work is detailed in Section 7.

II. LITERATURE REVIEW

Drowsiness of driver can be determined with different aspects using vehicle-based, psychological, and behavioural measurements implemented through different predictive algorithms as discussed in the following sections.

2.1. Face and Eye Detection by Machine Learning (ML) and Deep Learning (DL) Algorithms. Jabbar et al. [2] proposed Convolutional Neural Network (CNN) technique of the ML algorithm to detect microsleep and drowsiness. In this paper, detection of driver's facial landmarks can be achieved through a camera that is then passed to this CNN algorithm to properly identify drowsiness. Here, the experimental classification of eye detection is performed through various data sets like without glasses and with glasses in day or night vision. So, it works for effective drowsiness detection with high precision with android modules. The algorithm of Deep CNN was used to detect eye blink and its state recognition as provided by Sanyal and Chakrabarty [12]. Saleh et al. [13] developed an algorithm of LSTM and Recurrent Neural Networks (RNN) to classify driver's behaviours through sensors. Ed-Doughmi et al. [14] analysed the driver's behaviours through the RNN algorithm. It specially focuses on construction of real-time fatigue detection to prevent roadside accidents. This system formulates a number of drivers' faces, which works on multi-layered 3D CNN models to identify drowsy drivers and provide 92 percentage acceptance rates.

2.2. FPGA-Based Drowsiness Detection System. A low intrusive drowsiness detection system using field programmable gate array (FPGA) has been designed by Vitabile et al. [15]. This system focuses on bright pupils of eyes which are detected by IR sensor light source embedded in a vehicle. Due to this visual effect, the retinas identified up to 90%, which helps to find drivers' eyes for analysing drowsiness through a number of frames for avoiding serious mishaps. Navaneethan et al. [16] implemented a real-time system to track human eyes using cyclone II FPGA.

2.3. Eye Recognition System Based on Wavelet Network Algorithm. Jemai et al. [17] introduced a technique for drowsy warning system using wavelet networking. That network tracks eyes with the help of classifying algorithms like Wavelet Network Classifier (WNC) that relies on Fast Wavelet Transform (FWT), which specifically leads to binary way decision (conscious or not). The physiological aspects are heart beat rate and electrocardiogram that are repeatedly extracted through wavelet transformation with regression technique for fatigue detection, designed by Babaeian et al. [18]. This principle worked on heart rate data classification

through wavelet network which can find an average way of drowsiness alert system.

2.4. Fatigue Detection Using Vehicle State (Steering Wheel) Algorithm. Arefnezhad et al. [19] proposed a noninterfering drowsy detection system based on vehicle steering data using neurofuzzy system with support vector machine and particle swarm optimization algorithm. Mutya et al. [20] established a system to resolve the problem of drowsiness using steering wheel algorithm. It is basically based on image-formed or pictorial-based steering movement and the CNN algorithm for proper classification of drowsiness, which can also reduce false drowsy detection rates.

2.5. Drowsy Alert System Designed Using Electroencephalography (EEG), Electrocardiography (ECG), Electrooculogram (EOG), and Electromyogram (EMG) Algorithm. Budak et al. [21] designed a drowsy detection system through EEG technique which is designed with various components like AlexNet method, VGGNet method, and wavelet transform algorithm. This process effectively analyses the state of sleepiness using the brain indicator signal (EEG), camera, and sensors that are activated with the help of machine learning method to alert drowsy driver. Hayawi and Waleed [22] proposed a method to observe drowsiness through signal of Heart Rate Variability (HRV) which is obtained using EEG sensors. Hayawi and Waleed [23] established an intrusive method for measuring eyeball movement using EOG technique to construct a fatigue alert system that is also embedded with an Arduino controller board with K Nearest Neighbors (KNN) classifier to improve the percentage of accuracy. Song et al. [24] proposed a system to identify the fatigue of driver through the movement of muscular skin of eyes which is processed using EMG sensors with the help of a human machine interface. Similarly, the closure of eyelids and muscle part movements are also observed through the EMG sensors signals that function with the help of ESP8266 to provide or monitor the drowsy data on the Internet, which is designed by Artanto et al. [25]. Ma et al. [26] designed a driving fatigue detection system by measuring the EEG signals. It provided a robust platform for detecting drowsiness which is based on a deep learning process to find the accuracy of fatigue through EEG signals. But the deep learning process is structured through a principal component analysis network (PCANet) that pre-processes EEG data to create accuracy of detection. This process was tested in small sample size and offline mode, but it violates the accuracy in a large population of samples in real-time situations. Due to that reason, the IoT module is used to test online or offline in large sample sizes. Ma et al. [27] proposed an efficient application for the detection of driver fatigue through facial expression. Here, the facial movement is observed by deep learning of

multiblock local binary patterns (MB-LBP) and AdaBoost classifier. But it is also used to accurately and quickly detect drowsiness with the help of a fuzzy inference system. When the driver wears a glass, then the accuracy of detection is decreased. So IoT modules are used to make it more intelligent and to improve accuracy level of fatigue detection.

2.6. Fatigue and Collision Alert System Using Smart Technique. Chen et al. [28] implemented a smart glass to detect fatigue. The rear light of the vehicle is automatically flashed with a message being sent using the IoT module or cloud environment. Kinage and Patil [29] proposed a system to detect the drowsiness using eye blinking sensors and any accidents or collisions that happened; then, the vibration sensor was integrated with heart rate measurement sensor for forwarding alert message to the authorized user. So, it is also attached to the GPS and GSM device for tracking the location and transmission of message. Siva Reddy and Kumari [30] introduced a system to control cause of unconditional mishaps using Arduino board with sensors which operated through camera. But it is an efficient system with less estimation cost for construction of it. Jang and Ahn [31] implemented a system to detect an alcohol addict and drowsy drivers through sensors, where these elements are integrated with the Raspberry Pi controller module. So, the IoT modules are also used to send messages for any abnormal driver activities, which are properly invigilated with the help of a webcam (image processing) and controller unit. A new process has been developed for regular vigilance of facial detection and eye blink state, which predicts the driver's drowsiness. In addition to extra sensors, voice recognition application and machine learning methods are used to enhance the process of alert [32].

In the existing system, the fatigue of the driver is calculated through the eye or facial movements, deep learning, FPGA-based, ECG or EEG or EOG, vehicle steering movement, etc. But the implementation of the IoT-based technique helps to smartly control the various issues of driver drowsiness by the automatic buzzing of alarm, easily tracing the mishap location, and warning to the owner by sending emails or messages.

3.3. Speaker. It is an audio- or voice-generating device which can convert electromagnetic waves into sound [35]. If the driver's drowsiness is detected, then a voltage is supplied as an alert to generate regular programmed voice sound [36], which is depicted as in Figure 1(c).

3.4. Crash Sensor. It is an electronic equipment that provides safety and detects an impact through vibrations. Due to drowsiness, any type of crash may happen; then, it detects the impact of collision [37] as shown in Figure 2(a).

3.5. Force Sensitive Resistor Sensor (FSR). Special types of resistors known as force sensitive resistor, whose resistance may differ, according to pressure or force on it. So, it is made by a thick polymer sheet which is operated in different environments [38]. Due to good shocking resistance, it is integrated in this system as depicted in Figure 2(b).

3.6. GPS Module. This module is used to track the vehicle's location, if any serious collision occurs with a drowsy driver. It is the main component to detect the latitude and longitude of any area on the Earth with date and time from satellite. In this system, the mishap location is easily traced and the location is forwarded using GPS [39] as depicted in Figure 2(c).

III. PROPOSED SYSTEM

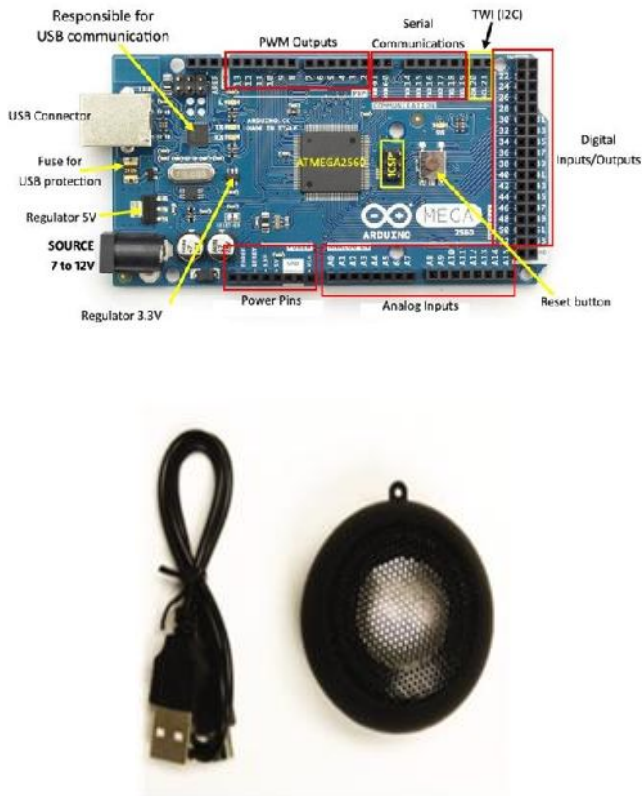
The proposed system here is designed to minimise the occurrence of countless mishaps due to the drowsy driver. Nowadays, fatigue of driver causes road accidents every now and then across the world. So, these activities should be required to automatically handle an implementation of smart alert system or vigilance in a vehicle which is an objective of this system. To analyse different behavioural or visual-based attitudes of the driver, face movement and eye blink are measured to study the state of the driver. Here, eye blink is mainly focused to detect drowsiness of the driver. The threshold value of an EAR lies above 0.25 without any effect of exhaustion. When a driver automatically shuts down, then the threshold value of EAR falls below the given range. A threshold value of drowsy eye blink sample represents the number of video frames of the driver's closed eyes. If the consecutive counting frames increase above the range of the threshold value, then the drowsiness of the driver is detected. Here, a Pi camera is used to regularly record the total movement of an eye through which the threshold value of an EAR is calculated. A counter is also included in it for counting occurrence of frames. Suppose that it exceeded above a range of 30. In that case, a voice is activated by a speaker and a mail is automatically sent to an authorized person of the vehicle which is generally processed at the time of drowsiness detection. The described modules work properly through Raspberry Pi3 which is programmed in Python programming language. Figure 3 depicts a test scenario of the proposed system.

The mail is received by an authorized one, who can alert the sleepy driver by ringing to him, if that drive is still not awake after turning on the voice alert message in the speaker. Thus, this process is successfully performed to detect a driver's drowsiness and detect the collision impacts due to braking of the vehicle through crash sensor and Force Sensitive Sensor (FSS). Due to the occurrence of the collision,

the data collected from sensors and the location data are sent to an authorized person (owner) or any near hospitals with the help of a GPS module (Google Maps link).

successful integration of IoT modules is robustly used to prevent the cause of mishaps and also warns the drowsy driver to avoid careless driving. The Internet of Things (IoT) is helping to manage various real-time complexities like handling complex sensing environments and also provides a very flexible platform to control multiple connectivity.

The IoT module is a very reliable way of capturing images of the drowsiness of the driver as well as sending an alert message to the owner for awareness.



(c) Speaker module Figure 1: Basic requirement with IoT devices

V. PROPOSED METHODOLOGY

When the Pi camera model V2 is successfully integrated with Raspberry Pi3, it continuously records each movement of the driver’s face. This proposed work specially focuses on behavioural measures of the driver with severity measurement of collision in following sections. The EAR is accurately calculated due to the use of Raspberry Pi3 model B and Pi camera modules to make a persistent recording of face landmarks that are localized through facial landmark points. But the Raspberry Pi3 model B and Pi camera modules are securely processed due to the operating system of the controller and predictable secure shell (SSH) keys. The use of SSH host keys provides secure network communications and helps to prevent unauthorized communications or file transfers. The IoT-based application is being developed through the integration of some IoT modules like wireless sensors, GPS tracker, Pi camera, and smart code for detecting drowsiness of the driver. So, the above modules are properly integrated with the Raspberry Pi controller module that intelligently controls and smartly warns a drowsy driver. The

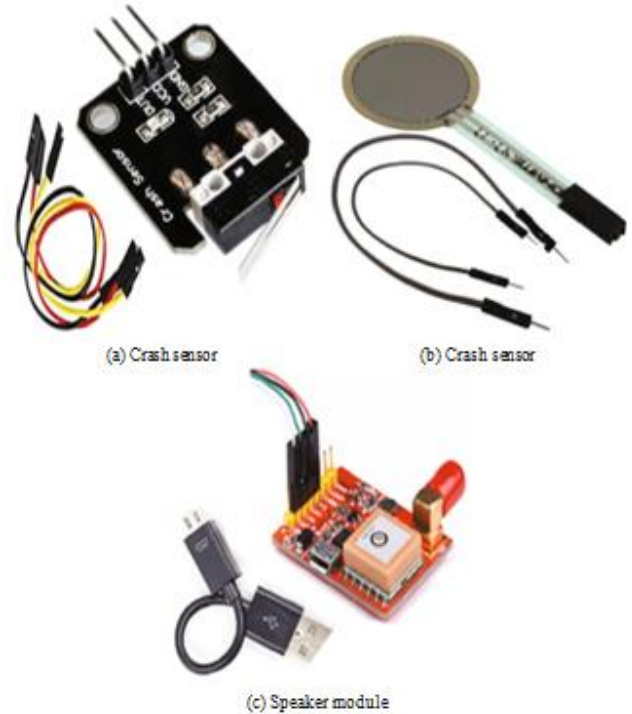


Figure 2: Basic sensor device requirement.

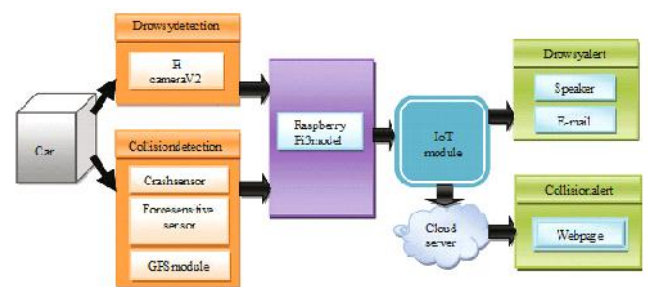


Figure 3: The proposed system: drowsy detection to drowsy alert.

5.1. Drowsy Eyes and Face Detection. The step-by-step methods for detection of drowsy drivers in the scenario are previously explained in Figure 4, and the various steps are as follows:

- (i) Step 1: video recording
- (ii) Step 2: face detection
- (iii) Step 3: eye detection

(iv) Step 4: drowsiness detection (combination of steps 2 and 3)

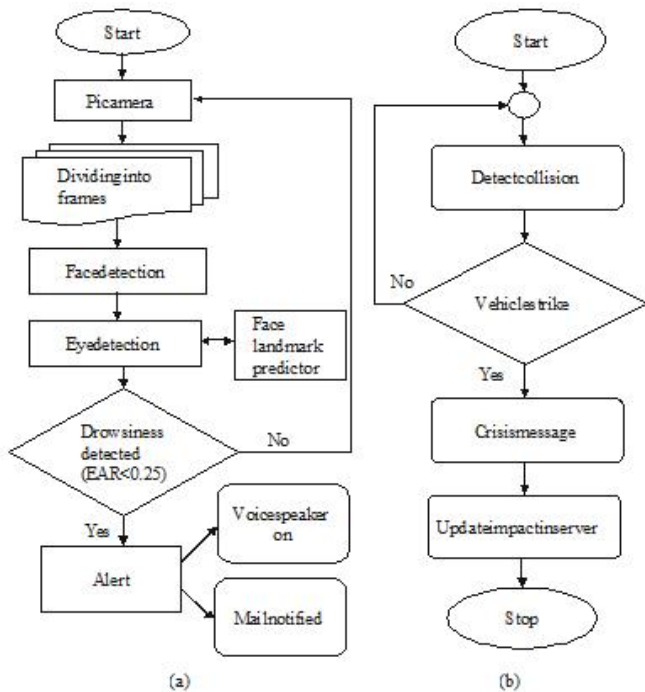


Figure 4: A flowchart of the (a) drowsy detection system and (b) collision detection system

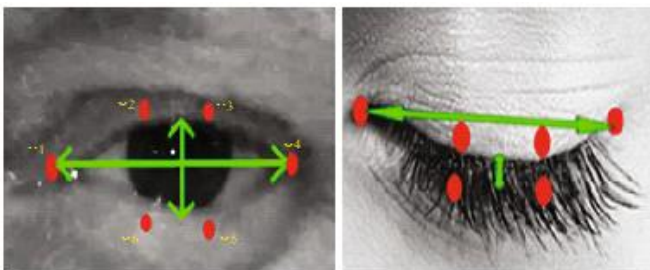


Figure 5: Eye landmarks (6 coordinates) of opening and closing eye

The Raspberry Pi3 camera is an 8-megapixel video camera which captures continuous video stream in good quality. Recorded video stream is converted into a number of frames which are forwarded to face detection step. The face detection is analysed by face landmark algorithm, which can detect eye, mouth, and nose from facial appearance. Actually, this detection technique works with Python-based library package like OpenCV. OpenCV is used for real-time image processing which is implemented by computer vision algorithm. When facial features are successfully detected, the next step, like eye detection of drowsy drivers, is possible to focus through facial landmark predictor algorithms. So, it can convert that image frame format to Gray scale level, where detected eye areas are traced by six coordinates as depicted in

Figure 5 Now, it is needed to calculate EAR which measures the distance between vertical and horizontal eye landmark points by using a Euclidean distance (ED) method as in Equation (1). The calculation of the distance of the eyelid section is made as points. So, it is represented in Python program which is explained below:

- (i) $A = \text{dist:euclidean}(\text{eye}^{1/2}, \text{eye}^{1/6})$
- (ii) $B = \text{dist:euclidean}(\text{eye}^{1/3}, \text{eye}^{1/5})$
- (iii) $C = \text{dist:euclidean}(\text{eye}^{1/1}, \text{eye}^{1/4})$

where $x_1, x_2, x_3, x_4, x_5,$ and x_6 are 6 landmark coordinates which are shown in Figure 2(b). The EAR value of the left and right eyes is averaged during synchronous eye blink. The threshold value of EAR remains constant when both eyes continue to be open, where values will be randomly changed during eye blink. The threshold range of EAR is above 0.25 that means the driver’s eyes are unlatched. If any drowsiness of the driver is detected from video frames, it happens due to drop of its threshold value below 0.25. When the number of frames is more than 30, then the voice speaker is turned on and a mail is sent. So, the Raspberry Pi3 is programmed to operate a speaker by using a software which can convert text-to-speech (TTS) conversion technique. TTS in speaker is more reliable for a sleepy driver to be alerted than other sound. All the statements of the speaker are coded as follows:

The above code is having a text message like wake up; it will be converted to speech by *espeak* synthesizer and operating system (os) module in Python.

The Raspberry Pi also forwards a mail at the time of fatigue detection to the driver to be more vigilant to avoid a number of mishaps. The mails are transferred through Simple mail Transfer Protocol (SMTP) that is accessed as a predefined library *smtplib* in Python. The SMTP client session object is created by using *smtplib* module to send mail source to destination. Here, the MIME protocol is used to define a multipart section of a mail like subject, to and from parts. The mail is securely transferred from drowsy driver unit to an authorized person (owner of vehicle or any) through Transport Layer Security (TLS) and server port number 587 for <http://smtp.gmail.com> server, which is shown in program section Figure 6.

5.2. *Collision Detection.* The collision alert system is generally constructed by a combination of crash sensor and force sensitive register for providing data about collision impact [40]. So, the data related to impacts of collision are collected to measure the severity of mishaps due to drowsiness or unconscious driving. The cause of severity is monitored through following stages:

- (i) Stage 1: Python script
- (ii) Stage 2: local database

The IoT module or server forwards detected data to program script which is based on Python. Here, Python script is specially preferred for reliable communication with connected sensors. When any crashes of vehicle occur, then the respective sensors generate information which detects the range of severity as well as the location of collision that are recorded in database which is shown in Figure 4. The location of accident is fetched from Google Maps link with longitude, latitude, time, and date that are accessed through the Raspberry Pi module. The longitude and latitude of a location are specially calculated by using the haversine technique to measure the distance of earth surface between two points

VI. CONCLUSION

This research provides a robust method for detecting drowsiness of drivers and collision impact (severity) system in the present time. This method generally combines two different systems in one integrated system. But the existing techniques are based on psychological or vehicle-based approach to detect drowsiness of drivers and also, the severity of collision is separately measured, but such technique is highly intruding as well as fully turns on the physical environment. So, the proposed system is used to construct a no intruding technique for measuring drowsiness of the driver with severity of collision due to braking or mishap. This system's main components are the Raspberry Pi3 model B module and Pi camera module that are used for persistent recording of face landmarks that are localized through facial landmark points then to calculate EAR. However, if the calculated EAR value increases from the threshold range, then the eyes are kept open and no change in the state of system occurs. Similarly, if the EAR value falls from the threshold range, then the system urgently alerts using speech speaker and warning e-mail to the authority (owner) for extra supportive alertness to the driver. In addition, measurement of collision severity (impact) is made through implementation of sensors with the GPS module to properly track the location of accident thereby alerting the nearer medical service centre to serve emergency diagnosis.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

VII. ACKNOWLEDGMENTS

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