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Image Filtering Techniques Used for Monitoring Driver Fatigue: A Survey

Abhishek Bhardwaj, Pareesha Aggarwal, Rishi Kumar, Nidhi Chandra

Amity School of Engineering and Technology, Amity University, Noida, U.P, India

Abstract- Driver fatigue is one of the important factors that cause traffic accidents, and the increasing number of accidents due to lessened driver's acuity and diligence level has become a problem of serious concern. Therefore, how to avoid this problem has become a topic of discussion. In order to detect and remove this cause of road accident many driver fatigue detection methods have been proposed which can detect the mind state of driver such as drowsiness or inattention, for generating some warning alarms to alert the driver. In this paper we have discussed some of the method that can be used to detect the driver's fatigue. And on the basis of our study, we have proposed a new technique that can improve the results of the earlier discussed methods.

Index Terms- *Driver Fatigue Detection; kalman Filter; Uncented Kalman Filter; PERCLOS*

I. Introduction

In the last 10 years to avoid many accidents due to driver's fatigue many countries all over the world have begun to pay attention to driver safety problem and to investigate the mental state of driver relating to driver safety.

Driver's state of mind and fatigue is one of the most important reasons of traffic accidents. Drivers with a lessened diligence level suffer from a marked decline in their abilities of perception, recognition, and vehicle control, which poses serious danger to their own life and the lives of other people.

The study says that in France, the National Police Administration concludes that 14.9 percent of accidents causing human hurt and 20.6 percent of accidents causing death are fatigue related. According to statistics the leading cause of fatal or injury-causing traffic accidents is driver fatigue. Therefore, how to avoid fatigue driving efficiently can help prevent many accidents, and also save money and reduce personal suffering.

Without any solution this problem will increase with time. So, there is a need of designing some systems that can detect the drowsiness or inattention of the driver and can generate some warning alarms to alert the driver and the other people in the vehicle.

In the recent years many techniques and methods which can detect whether the driver is tired have been proposed by researchers and few of them have been implemented. But, due to a variety of factors, despite the success of existing systems and approaches for extracting characteristics of a driver using computer aided technologies, and other current efforts in this area, it is a challenging issue to develop a driver fatigue detection system.

The one of the main factor is the variety of eye moving speed of driver, external illumination interference and realistic lighting conditions. In the realistic lighting condition the eye motion is highly nonlinear. So the use of driver fatigue detection method that is based on linear movement of driver eye is very difficult in real scenario.

In references [3, 6], Qiang Ji et al. have made significant improvements of facial fatigue detection over existing techniques. However, their methods need infrared (IR) eye detector, or bright pupils and steady illumination. Their eye-tracking method that used Kalman filtering is a linear system estimation algorithm. In fatigue detection system, the eye motion has the high nonlinearity of the likelihood model that the standard Kalman filter is no longer optimal in realistic driving environments.

To tackle some of those problems, in reference [1], ZHANGs have also proposed a new real-time eye tracking based on a nonlinear unscented Kalman filter for diver fatigue detection.

But these proposed systems/detectors works on IR image which is a problem.

To tackle this problem we have proposed a system that can be used without IR illuminator that illuminates a person's face and use an IR-sensitive camera to acquire an image.

Further sections are organized as: description of Eye tracking with Kalman filtering, Mean shift eye tracking, Kalman filtering-based fatigue detection system, proposed driver fatigue detection system in section II, III, IV and V respectively.

Finally the future work and a conclusion of the discussion are provided in last section.

II. Introduction

In references [3, 6] Qiang Ji et al., says that the motion of a pupil at each instance can be described using its position and velocity. Let (s_t, r_t) parameters be the horizontal and vertical positions of the pupil measured in pixels and (u_t, v_t) be the horizontal and vertical components of the velocity of pupil measured in deg/s. thus, the state vector at time t can be represented as $X_t = (s_t\ r_t\ u_t\ v_t)_t$.

The system can therefore be modeled as

$$X_{(t+1)} = \$\ X_t + w_t, \qquad (1)$$

Where, w_t represents system perturbation.

They further assumed that a fast feature extractor estimates $Y_t = (\hat{s}_t, \hat{r}_t)$ as the pupil position at time t. Therefore, the measurement model in the form needed by the Kalman filter is

$$Y_t = A X_t + z_t \qquad (2)$$

Where, zt represents measurement uncertainty. Specifically, the position of current frame t is estimated based on a simple local threshold in the neighborhood of the predicted position, assuming the existence of the bright pupil effect. Given the state model in equation (1) and the measurement model in equation (2) as well $\sum$ as some initial conditions, the state vector X (t+1), along with its covariance matrix $\sum$ t+1, can be updated using the system model and the measurement model.

III. MEAN SHIFT EYE TRACKING

The mean shift tracking algorithm is an appearance based eye tracking method, it find the target candidate that is the most similar to a given model in terms of intensity distribution, with the similarity of the two distributions being expressed by a metric based on the Bhattacharyya Coefficient[7]. This process is achieved by mean shift iteration.

The derivation of the Bhattacharyya coefficient involves the estimation of the target density *q* and the candidate density *p*, for which the histogram formulation is employed.

For instance, at location *y*, the sample estimate of the Bhattacharyya Coefficient for target density *q* and target candidate density *p*(*y*) is given by

$$\hat{}d(y) = d[\hat{}p(y), \hat{}q] = \sum_{u-1}^{m} \sqrt{\hat{}p_u \hat{}q_u} \qquad (3)$$

Where, m is the where m is the quantization level for histograms p and q. The distance between two distributions can be defined as

$$dist(y) = 1 - \sqrt{\rho[\hat{}p(y), \hat{}q]}. \qquad (4)$$

To reliably characterize the intensity distribution of eyes and non eyes, the intensity distribution is characterized by two images: even and odd fields, resulted from de-interlacing the original input images. They are under different illuminations, with one producing dark pupils and the other bright pupils.

During eye tracking, the target eye model must be updated whenever the bright pupil tracker tracks the eyes successfully in order to reduce the error propagation, resulted from the mean shift drifting.

IV. KALMAN FILTERING BASED FATIGUE DETECTION SYSTEM

Kalman filtering based fatigue detection system was proposed by Qiang Ji et al, according to reference [3, 6] only the Kalman filter based driver fatigue detection system cannot work on real time scenario. So, in order to tackle this problem, they propose a system which is the combination of a Kalman filtering tracking algorithm and the bright pupil effect due to an active IR illumination and the mean shift eye tracker.

Their eye-tracking method consists of two major modules. The first tracking module is a Kalman filter-based bright pupil tracking, augmented with a support vector machine (SVM) classifier for pupil verification. If the first eye tracking module fails, then the authors will activate the second module based on the mean shift tracking to continue eye tracking. And two modules alternate during tracking to complement each other.

The Kalman based eye tracking and the mean shift eye tracking have been described in the previous sections.

The Kalman filtering-based fatigue detection system is briefly discussed below with the help of flow chart in figure 1.

In The Kalman filtering based fatigue detection system a special IR illuminator has been used that illuminates a person's face and use an IR-sensitive camera to acquire an image. After locating the eyes in the initial frames, the Kalman filtering is activated to track bright pupils [3, 6]. If it fails in a frame due to disappearance of bright pupils, eye tracking based on mean shift will take over. These two-stage eye trackers work together, and they complement each other.

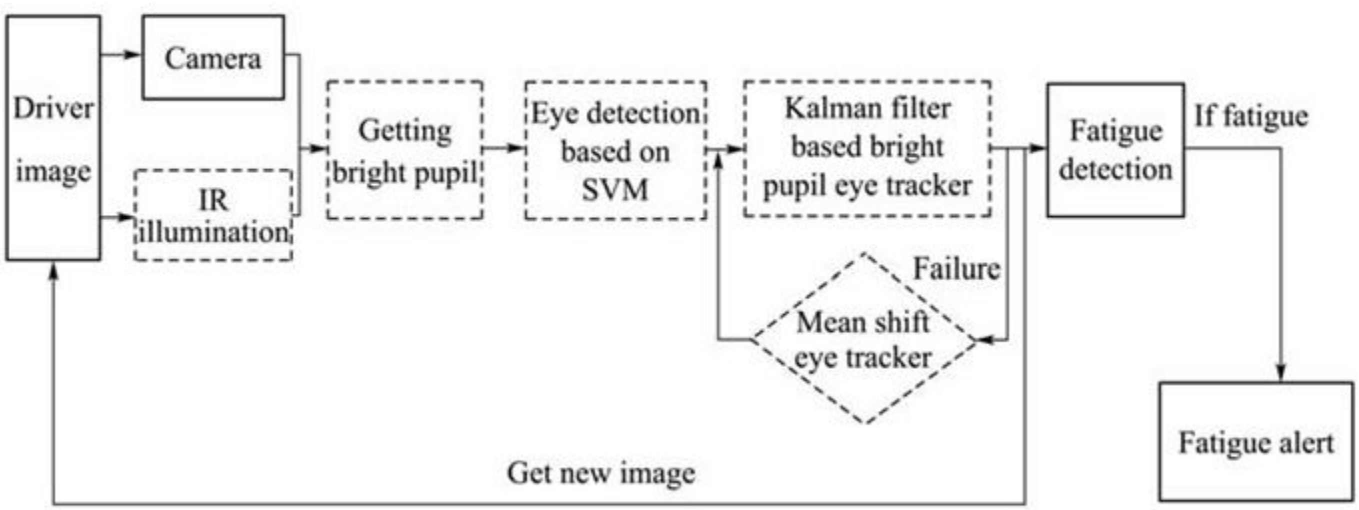

Fig 1. Flow chart of the Kalman filtering and mean shift based fatigue detection system

V. PROPOSED DRIVER FATIGUE DETECTION SYSTEM

After doing discussion about various proposed fatigue detection system it is now clear that the present systems works only on infrared illuminators and every method has its own respective drawback.

The standard Kalman filter works for systems which are based on bright eye effect and has tendency to follow linear eye motion and it loses focus if the face is moved fast or the camera is not able to get the red eye effect by any of the reason like bright light which can be caused by either headlight of a car or either by the high intensity of light by the sun. Mean shift based eye fatigue detection system when work isolated is not dynamic in nature and do not give the required result as per the application.

But when Kalman filter and mean shift eye tracking methods are used in combination and they overcome each other's disadvantages and are a big success as explained in [3,6] as mean shift gives Kalman filter focus whenever it loses it and Kalman filter gives dynamic behavior to the system. But this system still can't be called perfect as it still did not overcome the bright light disadvantage of the Kalman filter and fails in the case of bright light. So, there is a need of a system that can remove all these drawbacks. In order to do this we have proposed a system, which is a combination of Kalman Filter eye tracking, mean shift eye tracker, IR illuminator and in addition we have used a light camera which is used in case of bright light.

In this system two types of Cameras will be used, one IR camera and second light camera. This is an improvement over the system proposed by Qiang Ji et al. [3, 6].The flow chart of the proposed system is shown in the fig2.

In the proposed system we have given an alternative where we can overcome the disadvantage of the previous system in bright light and use a camera that can take driver image in bright light and the system can use the image taken in bright light for further working. In the case when the light conditions are higher than a level the cameras can switch and the control transfers to the light camera in bright light and when the light conditions decreases to that level then the cameras can switch again the control again goes back to the infrared camera. The main aim is to take image from the camera as the further working is done in same way in both the cases where first the Kalman filter is used and if the focus is lost by the Kalman filter the control goes to the mean shift filter which gives focus of the image back to the eye of the driver and transfers the control back to Kalman filter.

The control from one camera to other camera is not transferred in just one failure and the system don not even checks the light conditions by itself as doing it can cause noticeable changes in the efficiency of the system so to manage both these problems we have proposed a way in which if the Kalman filter failure regularly within a span of time in both the cases then we check the light conditions and if the light range is not appropriate according to that camera then the camera is switched.

In case a low cost system is to be made the light detection system can also be skipped and if the Kalman filter fails more than 5 times in 1 second the cameras are switched. Obviously this technique is not as authentic and reliable as the system where we use the light detection system but this is a good form of cost cutting.

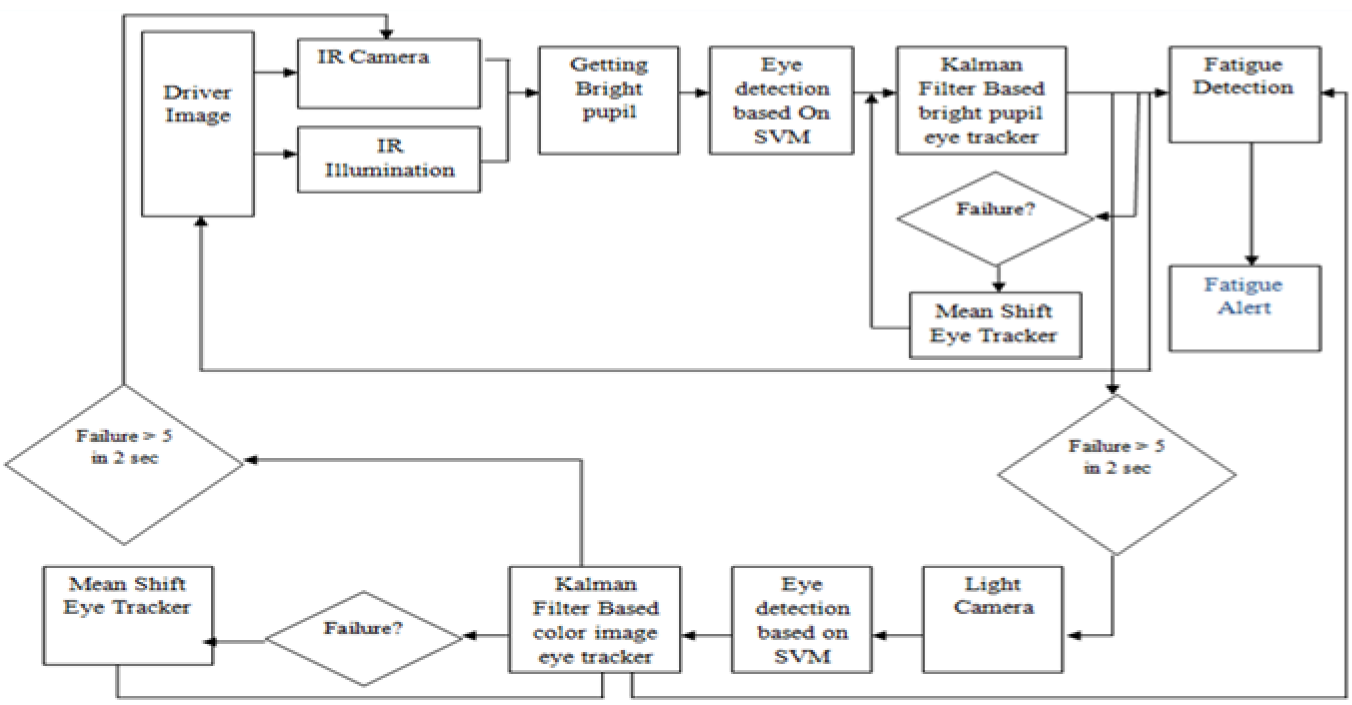

Fig 2. Flow chart of the proposed fatigue detection system

VI. CONCLUSION AND FUTURE WORK

In this paper we have briefly described the working of the Kalman Filter eye tracking, mean shift eye tracking, one of the proposed driver fatigue detection system "Kalman filtering based fatigue detection system". But, these systems and techniques have their respective disadvantage. Our proposed system can overcome the drawbacks and disadvantages of these systems.

Further research will be focused on implementing the proposed idea in order to get the good results in detecting the driver fatigue.

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AUTHORS

First Author – Abhishek Bhardwaj, M-tech (pursuing), Amity School of engineering and technology, Amity University, Noida, U.P., India; Email-id: abhi14.amity@gmail.com

Second Author – Pareesha Aggarwal, M-tech (pursuing), Amity School of engineering and technology, Amity University, Noida, U.P., India; Email-id: paru.aggarwal2112@gmail.com

Third Author – Rishi Kumar, Assistant professor, Amity School of engineering and technology, Amity University, Noida, U.P., India; Email-id: rkumar25@amity.edu

Correspondence Author – Nidhi Chandra, Assistant professor, Amity School of engineering and technology, Amity University, Noida, U.P., India; Email-id:srivastavanidhi8@gmail.com