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Driver's Head Tracking with Pose Estimation using Computer Vision technology under 2D environment.

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Abstract-The integral part of driver monitoring system is analyzing driver's head conduct, particularly head dynamics which are potent indicators of driver's focus of attention. Continuous assessment of head pose and dynamics in real time under 2D is quite challenging. In this paper, we present a single webcam for head tracking with pose estimation prominent to work in 2D environment and capable of operating continuously and robustly.

Keywords: Driver distraction, Risk control, Image Processing, Head tracking, Pose estimation, Alarm generation/Audio Signals.

Introduction

Road accidents have earned a dubious distinction. According to WHO the total number of road traffic deaths remains unacceptably high at 1.24 million per year. With over 130,000 deaths annually, India has overtaken China and now has the worst road traffic accident rate worldwide. The significant factor responsible for these fatalities is driver's inattention or distraction due to fatigue which leads to drowsiness. Continuously monitoring driver behavior in real time under 2D environment is quite challenging but effective. Out of which estimating head pose is even more difficult. Automobile industries had put in action the technology which majorly focuses upon driver awareness with the changing environment rather than driver alertness.

Over the past few decades, researchers, Industry experts and Academic Institutions are involved in developing cost effective and reliable Advanced Driver Assistance System (ADAS). Potent results were obtained using non-intrusive methods for head pose and dynamics. From the viewpoint of practical applications, computer vision technology approaches are preferred intrinsically. Various efficient algorithms and methods have been developed by researchers to detect driver drowsiness.

The conceptual approaches for estimating head pose is described under 8 categories which has been evolved from past researches, they are as follows:

1. Appearance Template Methods
2. Detector Arrays
3. Nonlinear Regression Methods
4. Manifold Embedding Methods
5. Flexible Models
6. Geometric Methods
7. Tracking Methods
8. Hybrid Methods

Within the scope of computer vision technology, recently [1] interpretation for head pose estimation is given by continuous angular measurement across 3 degrees of freedom i.e. pitch, roll and yaw angles. The sense of introducing distributed camera framework as a 3D model provides solution using geometric method for both facial feature tracking and improves head tracking accuracy and computation time. Mbouna *et al*. [2] focused on visual features such as Eye Index (EI), Pupil Activity (PA) and Head Pose (HP) to analyze eye state and head pose. Sequence of video segments is classified into alert or non-alert driving events using SVM.

Unlike distributed camera, Smith *et al*. [3] considered rotation of head and blinking as two important cues for driver inattention using single camera. Color predicates and optical flow is utilized for tracking head and facial features. Furthermore apart from geometric methods, combination of texture based tracking methods and Kalman filter is evenly implemented [4]. In this AAM model is applied to track frontal face. Proposal is concerned more about estimation and prediction of head pose.

In virtual environments technology required to accurately measure location and orientation of human head is coordinate system, more specifically geometric methods with 3 degree of freedom which works on concept of direction made by angular changes. We focused on 2 D environment rather than 3D model considering single degrees of freedom i.e. yaw for determining head pose. Head tracking with pose estimation is conducted on variation in pixel representation of video sequence from referenced point i.e. center of head, instead of angular measurements.

Based on the existing state of art for head pose estimation, this paper instantiate an algorithm which is largely motivated by geometric method and global coordinate system but incorporates single degree of freedom and infer orientation of head on pixels change.

Basic Problems in Head Tracking and Pose Estimation

Camera Pose: Basic 3 degree of freedom (DOF) of a head is the key factor for analyzing driver's focus of attention. Position of camera in real time with respect to frontal face may vary significantly.

Complex Background: There is a great point of differentiation between studies conducted under laboratories and naturalistic driving conditions. Changes occur in the background when the driver is on-road.

Occlusion: Visibility of facial features relative to head may be partially occluded by various objects such as hands or sunglasses.

Illumination conditions: Ever-shifting intensity of light even due to climatic changes affects the tracking process as well as results.

Additional hardware: Although, the usage of multi-cameras may give depth information and can upgrade the performance, but they can increase the cost and setting complexity of the system. They also require manual calibration.

Overview of the System

Monitoring driver's head movements from frontal pose in a continuous manner requires cost effective and efficient system to justify the drowsy state. For this, we propose a single camera i.e. webcam inside the vehicle. The activities undergone by webcam are comprised of face detection, eye region extraction, head tracking with pose estimation and eye tracking.

A. Face Detection and Eye region Extraction

In the first stage, we initiate with identifying the face region and separating it from the background noise in the window size defined. The technique used for this purpose is Viola Jones which makes use of Haar-features for Adaoost algorithm. Number of stages carried out for the process is:

1. Haar feature selection.
2. Creating Integral image.
3. Adaboost.
4. Cascade classifier.

For eye region extraction this particular Adaboost algorithm is advanced with JEER method which helps to localize eyes on face by drawing out center nodal point. The procedure consists of following steps:

1. Possible areas of eye region.
2. Necessary condition for existence of eye region area.
3. Define area of eye region.
4. Filter out non-face images.

B. Head Tracking and Pose Estimation

Most commonly used technique for tracking head in context of computer vision technology is interpreting the position and orientation of head relative to view of a camera. We introduce a procedure to track driver's head in 2D environment from a single webcam. Out of classification category for head pose estimation algorithms; we make use of geometric methods. For that purpose Center of gravity approach is taken into consideration to locate the center of head in pixel representation and identify the change in pixels from reference position which in turn will justify the movement of head from its original position.

Center of gravity (COG) algorithm is comprised of localization of center in head and noticing change in pixels due to angular movements of head in frontal view. Overview of an algorithm is as follows:

1. Grab an image from video feed.
2. Apply Blurring to RGB image.
3. Convert RGB to HSV – for color detection.
4. Apply HSV thresholding to binary image.
5. Calculate sum of x-axis, y-axis and total pixels if count of pixels is within some possible area of window size.
6. Detecting only on y-axis, COG = $\frac{Sum\ of\ y-axis\ pixels}{Total\ pixels}$, localize a red line along x-axis as center for head tracking.
7. If COG exceeds through defined threshold value, mark it as drowsy state of driver by visual effect or audio signal.

Identification of head with pose estimation is considered on frontal view with 4 discrete orientations, they are mentioned below:

- Left.
- Right.
- Forward.
- Backward.

Experimental Results

We used the real time data of participants to track head and estimate the change in pose. It is a Proof of concept (POC) and hence the experiments were conducted in front of a webcam under three different day lightning conditions i.e. center light, left light and right light.

The above results from Figure 1-4 depict the tracked drowsiness state for above mentioned possible orientations. The video sequence tracking is carried out by converting RGB to HSV for color detection to locate the center of head, assign a value to it and check out the variations in pixels after movement from the referenced point. Table I shows the respective computation time in microseconds occurred for the selected threshold value which is being assigned out of a range to get drowsy state under appropriately minimum deviations of head. Head position is set automatically when driver comes in contact with the camera. Offset referred here resembles the angular movements of head represented and calculated in the form of change in pixels from center point as localized.

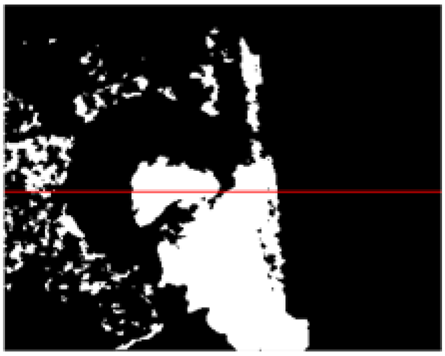

Fig.1.Tracked drowsy state when driver’s head tilts to left.

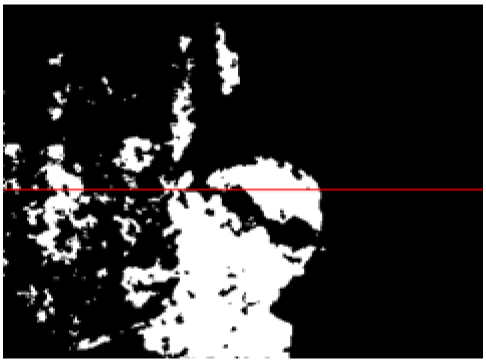

Fig.2.Tracked drowsy state when driver’s head tilts to right.

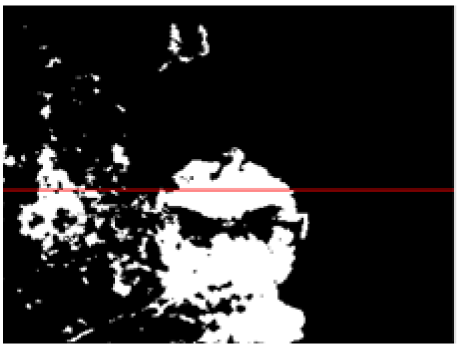

Fig.3.Tracked drowsy state when driver’s head bends forward

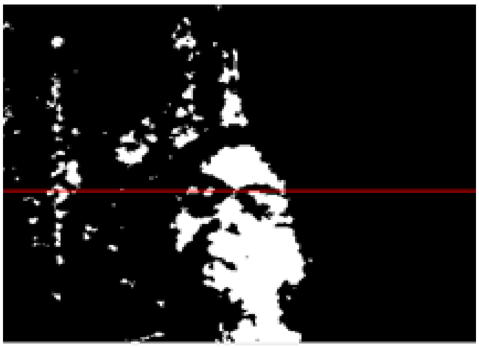

Fig.1.Tracked drowsy state when driver’s head bends backward.

Further comparisons in Figure 5-Figure 8 were made between offset value change and computation time calculated for those four orientations viz. right, left, forward and backward under the daylight conditions viz. center light, left light and right light to extract the most possible situation of drowsy state and how fast the system is capable to detect.

Figure 5 measures the calculation speed relative to offset value; it depicts the gradual change in computation speed as per variation in head position from center. It is observed that when the center light is passed on frontal view of driver, the immediate detection of drowsiness for right head movement is faster than rest other orientations.

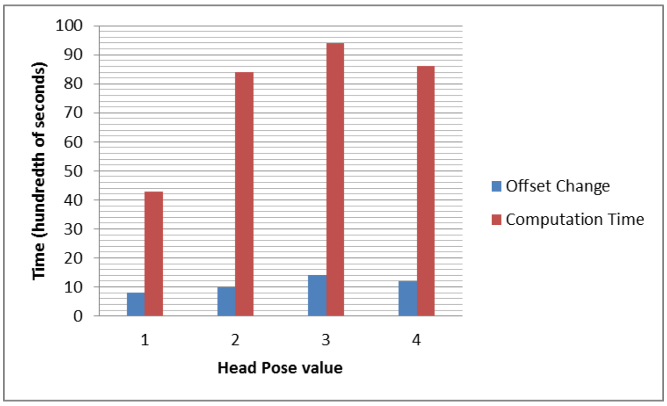

Fig.5. Effect of offset change on computation time under Center light

TABLE.1 Computation time for four discrete orientations under three different day lightning conditions.

LIGHT VARIANT	THRESHOLD VALUE	SET HEAD POSITION	OFFSET CHANGE	COMPUTATION TIME(µsec)
	12	3/4/5		
Center light				
Right move	12	3/4/5	8	43000000
Left move	12	3/4/5	10	84000000
Front move	12	3/4/5	14	94000000
Back move	12	3/4/5	12	86000000
Left light				
Right move	12	3/4/5	12	87000000
Left move	12	3/4/5	4	77000000
Front move	12	3/4/5	14	63000000
Back move	12	3/4/5	8	65000000
Right light				
Right move	12	3/4/5	18	66000000
Left move	12	3/4/5	11	78000000
Front move	12	3/4/5	23	64000000
Back move		3/4/5	17	50000000

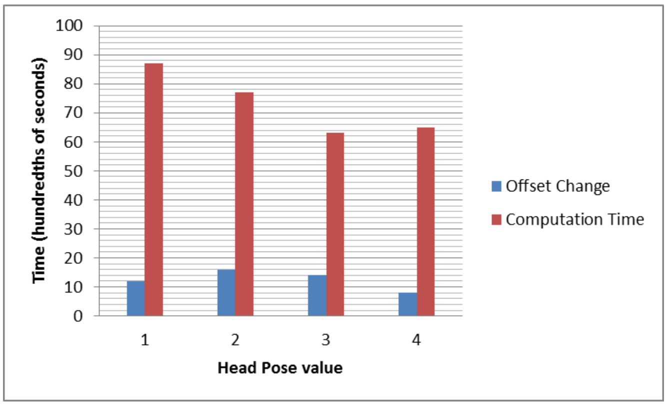

Fig.6. Effect of offset change on computation time under Left light

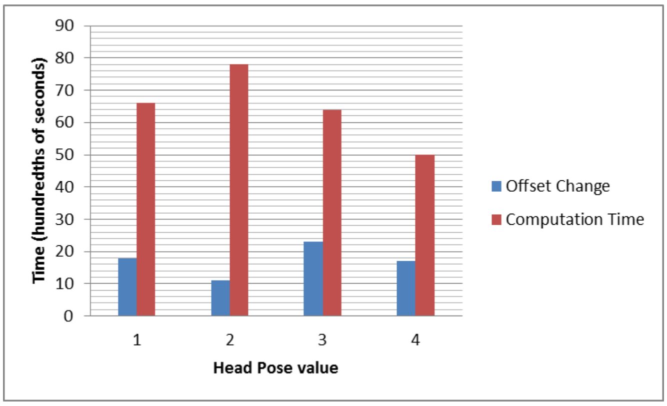

Fig.7. Effect of offset change on computation time under Right light

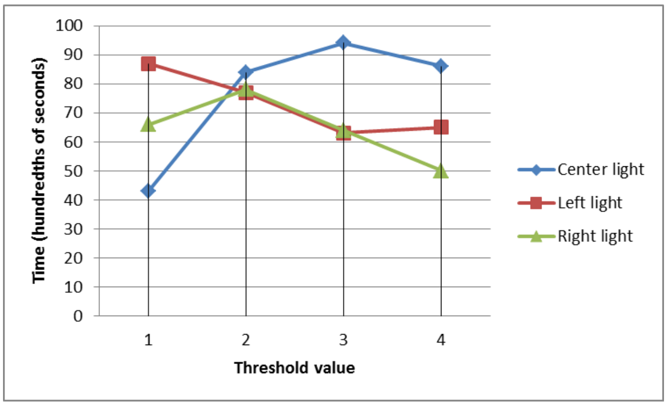

Fig.8. Comparisons between 3 different daylight conditions and threshold value

In turn, a left light effect on the frontal view shows backward deviation is instantly detected in Figure 6.In the presence of right light on face in Figure 7, left rotation of head is found out to be more easily detectable for drowsy state than other orientations. Lastly in Figure 8 all three lightning conditions are compared with a common threshold value, so that it should be able to justify the most specific one responsible for detecting the drowsy state of driver in minimum amount of time.

Conclusion and Future Work

We contribute a new approach that represents a point of difference over previous head tracking with pose estimation perspectives. Instead of working on traditional 3D model, we established the process of head tracking in 2D environment using COG. Furthermore, apart from calculating angular measurements made by 3 degrees of freedom, system focused on variations in pixel representation for showing change in position and orientation of head. Additionally the illumination changes while tracking is also considered under three different lightning conditions. Out of which consequences of Center light stood much faster and took minimum amount of time in justifying the drowsy state of driver.

Further extensions to this system could be extracting facial features such as eyes from face and can focus on open and close state of eye rather than gaze direction. As head and eye dynamics are of special interest in detecting drowsiness.

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