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Motion Estimation of Driver's Head from Nostrils Detection

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Abstract

We propose a method of estimating driver's head movement by tracking a pair of nostrils. Nostrils clearly appear as a pair of dark areas in a facial image. Shape of nostrils have little influence of deformation compared to eyes. We use a concentric circular mask or density difference mask to detect difference of image density. We represent nostril position by a center of gravity of extracted nostril region, and apply moving average to a sequence of the detected nostrils positions. We decide reference positions of nostrils through a procedure that an interval of moving average is fixed into a standard cycle of model driver's head motion. We estimate driver's head movement from a difference between detected nostrils position and reference nostrils position. Cycle of driver's head movement is available for a measure of monitoring driving condition. Experimental results show the effectiveness of our proposed method.

1. Introduction

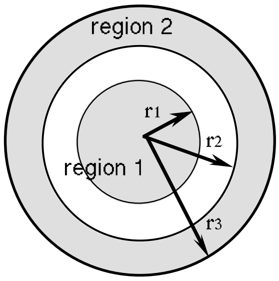
There are a lot of researches to prevent traffic accidents by monitoring driver's behavior. Methods for monitoring driver's behavior is generally classified in two types. One is to detect driver's behavior from a vehicle side. The other is to detect driver's behavior from a driver's side. The former includes monitoring the steering, acceleration, braking, shifting, gripping force of steering wheel, velocity of vehicle, latitudinal acceleration of vehicle, lateral deviation from the path and latitudinal position on the traffic lane. In the latter case, driver's behavior is detected from physiological signals and physical reaction. Physiological signal includes the brain wave, heart rate, pulse rate, skin electric potential, skin resistance, body temperature and so on. Physical reaction includes an inclination of the driver's head, sagging posture, gaze line, blinking, gripping force on steering wheel and so on. Eye camera, EOG(electro-oculogram) and some sensors are used to monitor a driver's condition. While they are put on his/her body, it is desirable that detection is made by non-contact method. Facial image is available for one of the non-contact methods. Facial image taken by video camera is used to detect and track important face parts. Driver's condition is estimated by tracking a change of shape and detected position around important face parts, such as eyes, irises and nostrils. Blinking is detected from a change of shape of upper eyelids and occlusion of irises by eyelids. Line of sight of driver's is estimated from iris position on the eyeball in both eyes. Motion of driver's head is estimated by tracking eyes or nostrils positions[1, 2, 3, 4].

In order to extract face parts from a facial image, Kass et. al. use active contour model(snake) to detect eyes and mouth[5]. Xie et. al. use deformable template model to detect eyes and mouth, and they use active contour model to detect eyebrows, nostrils and contour of face[6]. Chow and Li use circle Hough transform to detect outer boundary of irises and deformable template model to detect eyelids and mouth[7]. Chen and Chiang use shape, color and edge characteristics of face features to extract lips[8]. Reisfeld and Yeshurum describe symmetry transform to find facial feature points[9]. Katahara and Aoki use bilateral symmetry between and within face parts to extract important face part regions[10].

Nostrils clearly appear as a pair of dark areas in a facial image. Shape of nostrils have little influence of deformation compared to eyes. We use density difference mask to extract nostrils. We apply moving average to a sequence of detected nostrils positions to find a trend of motion. We estimate driver's head movement from a difference between detected nostrils position and reference nostrils position.

2. Density difference mask

Nostrils clearly appear as a pair of dark areas in a facial image. We use a concentric circular mask represented in Figure 1 to detect difference of image density. This density difference mask gives a difference between average density of region 2(area of concentric circle; outer radius is r_3 and inner radius is r_2) and average density of region 1(area of circle; a radius is r_1) as an output at a point of interest.



region 1 : circle (r_1)
region 2 : concentric circle (r_2-r_3)

P_1 : average density of region 1
P_2 : average density of region 2

P_{out} : P_2-P_1 (if P_2-$P_1 \leq 0$, P_{out}=0)

Figure 1. Density difference mask

3. Nostrils extraction window

Figure 2 shows typical example of nose of Japanese. We use a simple model of nostrils represented in Figure 3 to determine a size of nostril extraction window. We approximate nostrils to be ellipse, and define a half length of major axis as **r**. Horizontal distance between center of left nostril(**Cℓ**) and center of right nostril(**Cr**), namely **w** is nearly same as 4**r**.

We determine a size and position of nostrils extraction window for next frame as shown in Figure 4. The **Gℓ** and **Gr** respectively mean left and right center of gravity of nostrils at a current frame, and the **w** means horizontal distance between left and right center of gravity of nostrils. As shown in Figure 4, width of nostrils extraction window for next frame is same as (5/4)·**w** and height of it is same as **w**. Left and right nostrils extraction window for next frame are separately located on the left and right center of gravity of nostrils detected at a current frame.

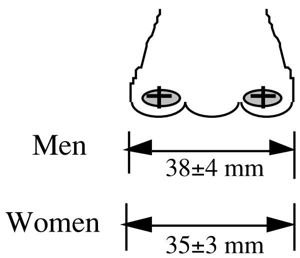


Figure 2. Typical example of nose (Japanese)

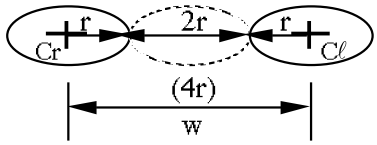


Figure 3. Simple model of nostrils

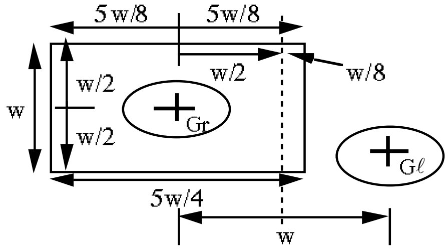


Figure 4. Nostrils extraction window (displacement)

4. Nostrils extraction

A set of difference of image density is obtained by scanning the density difference mask in the nostrils extraction windows. We make a histogram of difference of image density, then we apply p-tile method to the histogram to extract nostrils. A value of percentile is decided by a ratio of the area of modeled nostril to the area of nostrils extraction window as shown in Figure 5.

Nostril is extracted as the largest continuous region in the candidates of nostrils region after binarizing the outputs of density difference mask. We approximate the extracted nostrils using area, center of gravity, circumscribed rectangle and so on.

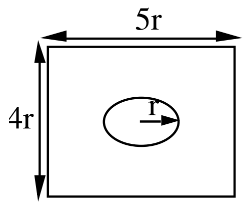


Figure 5. Nostril extraction window (area)

5. Moving average

We use moving average, in order to acquire the trend of data by smoothing. Generally speaking, data include irregular fluctuations, cyclic fluctuations and trend. Moving average suppresses irregular fluctuations of the dada. Moving average also make a trend of the data clear, even though the data include cyclic fluctuations, when an interval of moving average brings close to a cycle of the data. We can use moving average as a reference in the interval.

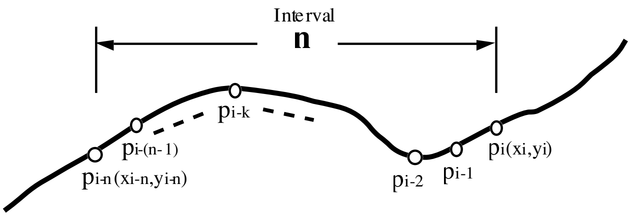


Figure 6. Moving average

Position $\mathbf{p}_i = (x_i, y_i)$ shown in Figure 6 represents a position at time i. Interval **n** shown in Figure 6 also represents an interval of moving average. We define moving average $x_i(n)$, $y_i(n)$ at time i, interval n, as equation (1).

$$x_i(n) = \frac{1}{n}\sum_{k=0}^{n-1} x_{i-k} \ , \ y_i(n) = \frac{1}{n}\sum_{k=0}^{n-1} y_{i-k} \qquad \dots (1)$$

6. Experiments

6.1. Image grabbing

A video camera is mounted on dashboard to make videotaping of a driver. Elevation angle of the video camera is fixed about 40 degree. Video output is digitized by 320x240 pixel, 8 bit gray level to make a image file sequence. The sequence of image file is processed off-line.

6.2. Mask size and p-tile value

Driver sits on a driver's seat with standard driving posture, therefore distance between a video camera and a driver is kept nearly constant. A driver's face looks nearly same size in the image sequence.

We decide a size of density difference mask, $\mathbf{r}_1$=3, $\mathbf{r}_2$=10 and $\mathbf{r}_3$=12 [pixel] respectively under this driving condition. The density difference mask outputs a difference between average density of region 2 and average density of region 1 at a point of interest. We determine a p-tile value for binarizing the outputs of the density difference mask as 20 %, by a ratio of the area of modeled nostril to the area of nostrils extraction window as shown in Figure 5.

6.3. Nostrils extraction

Figure 7 shows typical example of output of density difference mask. Figure 8 shows typical example of extracted nostrils regions. Nostril is extracted as the largest continuous region in the candidates of nostrils region after binarizing the outputs of the density difference. Figure 9 (a), (b) show center of gravity and circumscribed rectangle inside of the nostrils extraction windows in the facial image, respectively. Distance between the center of gravity and a position that output density of difference becomes largest, is less than 1.4 pixel length during measurement.

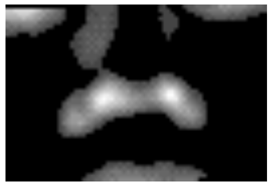


Figure 7. Output of difference mask

Figure 8. Nostrils region

(a) Looking to right side

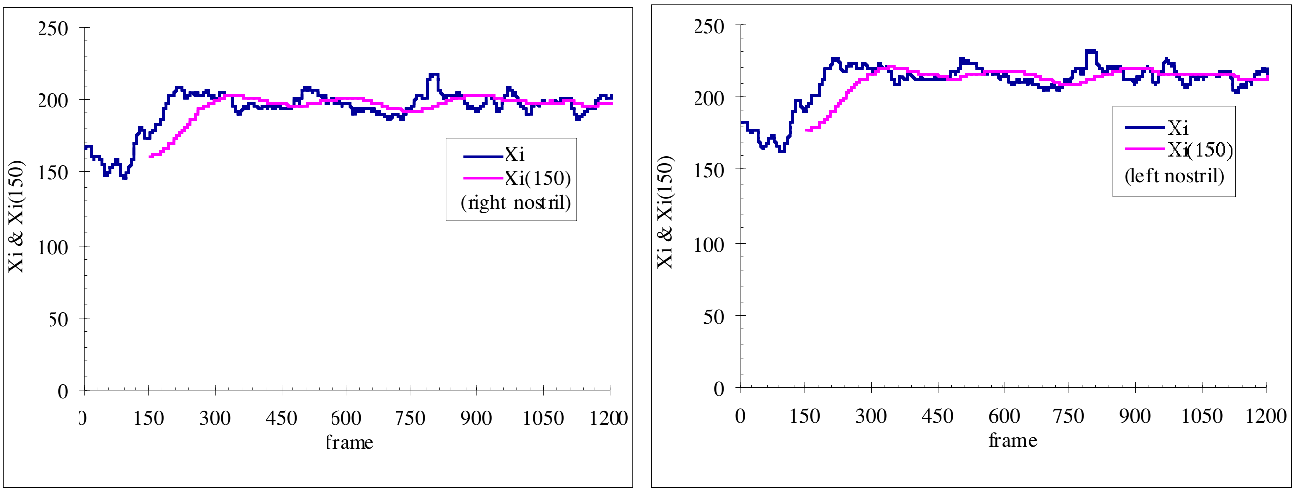
(b) Looking to left side

Figure 9. Typical example of detected results

6.4. Detected nostrils position

Figure 10 (a), (b) show horizontal change of detected right and left nostril positions; Xi and moving averages; Xi(150), respectively. Relatively rapid change of motion appears during 49th to 105th frame and 767th to 814th frame in the video image sequence, and driver changes the sitting position from 150th frame to 180th frame.

Model driver usually looks around his/her surroundings in a five-second cycle. We assume that cyclic fluctuations of the data become 5 seconds, in order to decide an interval of the moving average. We decide on an interval of the moving average to be 150 frames or 5 seconds. Moving average suppresses irregular fluctuations of the dada, and eliminates cyclic fluctuations of the data. The moving average shows reference position of nostrils.



(a) Right nostril (b) Left nostril

Figure 10. Detected nostrils and moving averages (interval 5 seconds)

6.5. Estimation of head movement

We estimate motion of driver's head from the results shown in Figure 10 (a) and (b). We use the midpoint of nostrils; Xci as a representative of nostrils position. Figure 11 shows change of the midpoint of nostrils; Xci, moving average of Xci for one second; Xci(30) and moving average of Xci for five seconds; Xci(150), respectively. We use moving average of Xci for one second; Xci(30) as an average of nostrils position to estimate motion. We also use moving average of Xci for five seconds; Xci(150) as a reference of nostrils position to estimate motion.

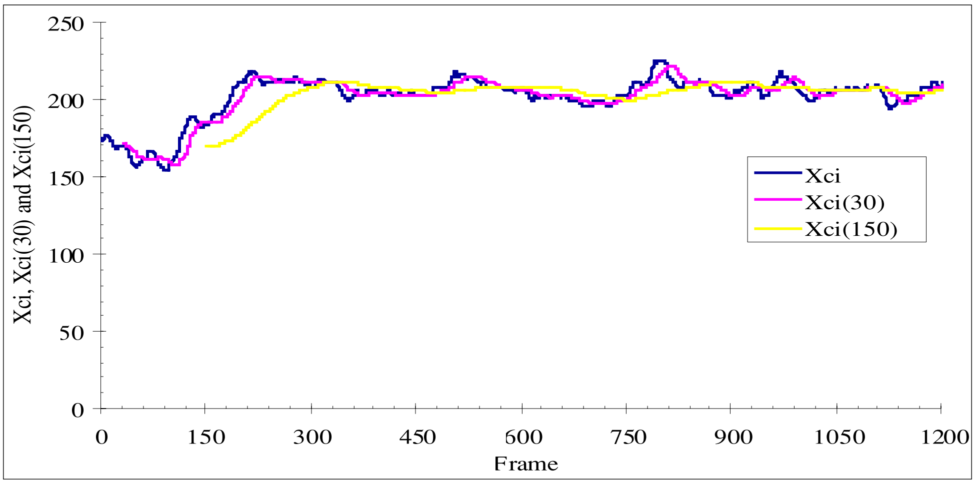


Figure 11. Change of nostrils position and moving averages

Figure 12 shows change of a difference between an average nostrils position; Xci(30) and a reference nostrils position; Xci(150).

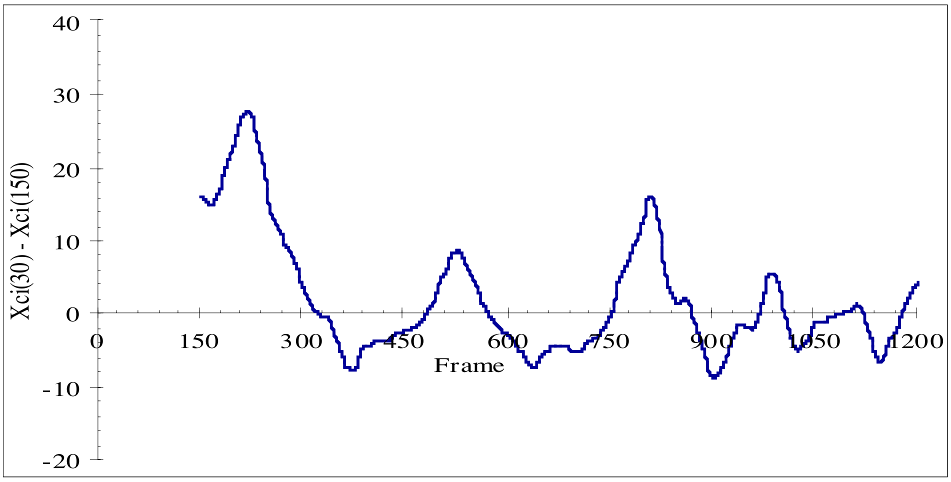


Figure 12. Difference between average nostrils position and reference nostrils position

We detect a derivation of nostrils position using a difference between an average nostrils position;Xci(30) and a reference position; Xci(150). When a value of the derivation will be positive, namely, current nostrils position locates in the right side from reference position, we can estimate that driver looks around left side. When a value of the derivation will be negative, namely, current nostrils position locates in the left side from reference position, we can estimate that driver looks around right side. Detection result shows salient difference between nostrils position and reference position at around 210th frame and 770th frame. Similar movement on the driver's appears in the video image sequence. Detection result also shows about ten seconds periodicity.

An angular resolution on head movement around frontal view is approximately one degree per pixel. We suppose that a change of gaze line with head movement occurs when gaze line moves larger than five degree. Nostrils position moves more than ten pixel under the condition in facial image. We apply this criteria to roughly estimate motion of the head. We can detect a state of looking around left side, but we can not detect a state of looking around right side because of relatively less movement of the nostrils position.

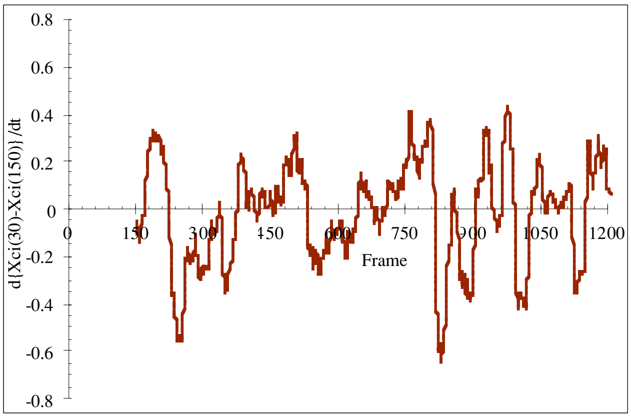


Figure 13. Instantaneous rate of change of a difference between average nostrils position and reference nostrils position

Figure 13 shows instantaneous rate of change of a difference between an average nostrils position and a reference position with respect to time; d{Xci(30)-Xci(150)}/dt. When a rate of change of the difference will be positive, namely, nostrils position moves leftward, we can estimate that driver's head moves leftward. When a rate of change of the difference will be negative, namely, nostrils position moves rightward, we can estimate that driver's head moves rightward. When a rate of change of the difference will be small, we can estimate that nostrils position moves slightly or less movement conditions. We decide a criteria for detecting head movement as the rate of change of a difference is larger than six pixel per second. We estimate leftward movement of the head as a rate of change of the difference will be larger than 6 pixel per second, rightward movement of the head as a rate of change of the difference will be smaller than -6 pixel per second, and less movement conditions of the head as a rate of change of the difference will be smaller than 6 and larger than -6. In addition, we account a motion that happens under six frames to be a same movement just before, by taking into consideration a consistency of motion.

Figure 14 shows motion estimation results. Figure 14 also shows leftward movement, rightward movement and less movement conditions.

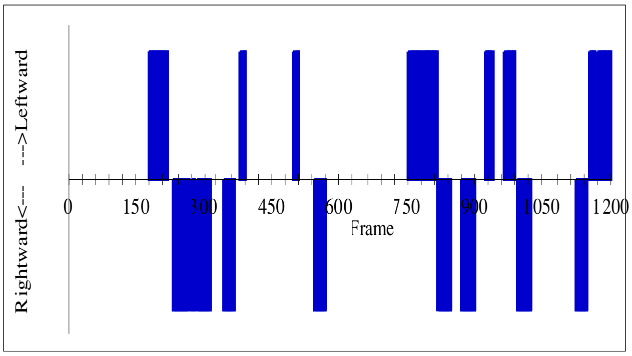


Figure 14. Estimated motion of driver's head

7. Concluding remarks

We extract nostrils using density difference mask in a facial image. We decide reference nostrils position by applying moving average to a sequence of detected nostrils positions. We estimate driver's head movement from a difference between detected nostrils position and reference nostrils position. Cycle of driver's head movement becomes a measure for monitoring driving conditions.

Nostrils may be temporarily occluded during steering wheel operation. We have to predict nostrils region by taking consistency of motion into consideration. Detecting and tracking nostrils are useful to estimate approximative movement of head. We think that we can improve reliability of motion estimation by tracking eyes and nostrils together.

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