The Mechanical Design of Drowsiness Detection Using Color Based Features

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Abstract
This paper demonstrates design and fabrication of a mechatronic system for human drowsiness detection. This system can be used in multiple places. For example, in factories, it is used on some dangerous machinery and in cars in order to prevent the operator or driver from falling asleep. This system is composed of three parts: (1) mechanical, (2) electrical and (3) image processing system. After processing the input image and eye position detection, the system investigates the state of the eye, and in the case of drowsiness, the system activates the alarm. It also has the ability to track the eyes.

Keywords: drowsiness; face detection; eye state detection; feature selection and PERCLOS.

1- Introduction

Drowsiness detection system is particularly effective in industries on dangerous machinery like press in order to prevent the operator from falling asleep, and can prevent the creation of lots of dangers that are results of the human drowsiness. Many researchers have conducted studies on investigating the methods for people's drowsiness detection. These methods can be classified into two categories: (1) the first category uses electroencephalographic (EEG) method for detection that can sense physical and brain signals, analyzes the relationship between the signals and detects state and behavior [1]. But unfortunately, because these methods require lots of sensors, they are highly susceptible to noise, complex and expensive, (2) the second category is based on using image processing and template detection, such as blink detection [2] and head motion style, etc. In this category, PERCLOS (percentage of eyes closure and percentage of time that eyes are closed in a particular time) plays a significant role. The key point to calculate PERCLOS is distinguishing open eyes from closed eyes. Some of the literature in this area will be stated next.In [3] a system is designed that is composed of face detection, tracking eyes position, extracting them and eye state detection. this system, is created a program based on NI IMAQ, Labview vision .In [4] by using modified Susan operator , the inner corner of the eye in extracted in order to improve the precision of eye location. In this method, the correlation between an online generated template of an open eye in the process of eye tracking with the eye region extracted from the image is used. In [5], a method to detect driver drowsiness based on Kalman filter and eye tracking is described. Therefore in this paper a system composed of the second category methods and a mechanical system is described. This paper is about the fabrication of mechatronic system to detect human drowsiness and discusses based on eyes state detection. The advantage of this system over previous works (used in some cars such as Ford and Citroen c5) is that, in our system the camera has the ability to move. In the system, a camera is mounted on a one – degree – of – freedom base. And by considering the height of the person and his/her eyes range, the camera is automatically placed such that the eyes are in the camera box and this is also done in the case of the head height change. This system is fabricated in three stages: (1) mechanical system fabrication with one-degree-of-freedom translation joint, (2) design of an electrical circuit for use in DC motor, (3) programming in order to face detection and eyes state detection.

2- DESIGN OF SYSTEM MECHANISM

The advantage of designed system over previous ones is using mechatronic design methods for it. The system is composed of three parts: (1) mechanical, (2) electrical and (3) artificial intelligence, which are stated next individually.

2-1- Mechanical part

This model has little metal-metal contact surface, so there is little deterrent friction and due to low friction, low torque is needed for motion, and furthermore, this model has advantageous in terms of cost of manufacturing (figure 1 and 2). The structure of mechanism is as follows: by using the leadscrew, the rotational motion of the motor is converted to linear motion. In this mechanism, due to easy access, being low cost and being a prototype, a leadscrew is used, but that can be replaced by the following: (1) ballscrew, (2) rollerscrew, (3) fluid power and (4) rock and pinion.Required torque to move the load up and down is calculated as follows:

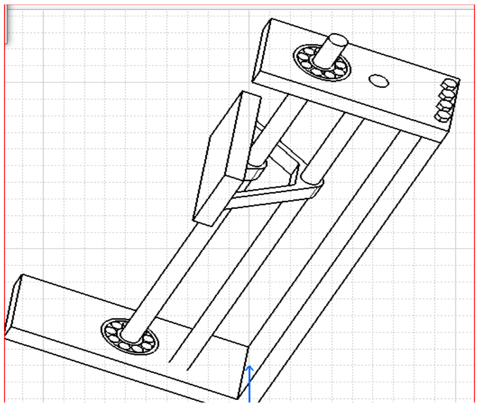

Fig.1. Designed model·

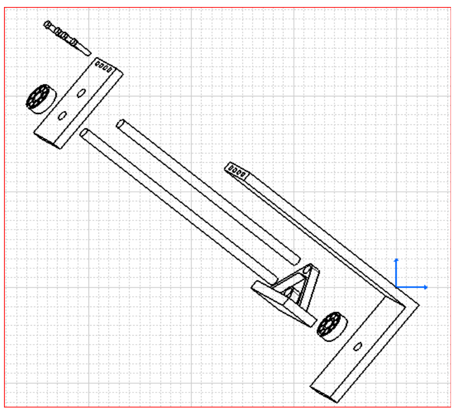

Fig.2. exploded view of the fabricated model.

$$T_{lower} = \frac{Fd_m}{2}\left(\frac{\pi\mu d_m - l}{\pi d_m + \mu l}\right) = \frac{Fd_m}{2}\tan(\phi - \lambda) \quad (1)$$

$$T_{raise} = \frac{Fd_m}{2}\left(\frac{\pi\mu d_m + l}{\pi d_m - \mu l}\right) = \frac{Fd_m}{2}\tan(\phi + \lambda) \quad (2)$$

In above equations, T is required torque to move the camera upward and downward, F is the load on lead screw, dm is average diameter of leadscrew, μ is friction coefficient, l is advance, ϕ is the angle of friction and λ is the angle of advance. Required torque, according to (1) and (2) is calculated as follows:

$T_{lower} = -0.007 N.m$

$T_{raise} = 0.0312 N.m$

Deep grove ball bearing with 10-millimeter diameter is selected due to its noise rotation, high loading capability and the ability to bear axial and radial loads. Figure 3 depicts the fabricated robot.

Fig.3. Image processing system (right), the fabricated robot (left)

2-2 Electrical part

The motor 37GB-353V&120 R.P.M &12 VDC is selected due to the following criteria: (1) accessibility of power supply, (2) calculated torque from previous equations, (3) reasonable price and (4) accessibility L298 is used in order to drive the motor (supplying the required startup current), and some diodes are used to protect the motor.

2-3-Interface with image processing software

The output of camera that is mounted on a base is transferred to pc using a USB port and after processing its output using the other USB port, is transferred to USB to serial converter module, and its output which will then be transferred to a microcontroller, then the microcontroller by processing information, will convert them to motor data, and then will send them to motor drivers.

3-Eye state detection

The final stage is eye state detection. For this, a camera is used which can interface with the pc through USB port. After interfacing with the computer, the implemented algorithm is run. Machine vision algorithm that is used here is as figure (5) [6].

3-1- Face detection

In order to drowsiness detection, first face region should be identified. Many methods have been proposed for the detection of the face. Methods that are based on skin color are the fastest methods [7]. When the face region is acquired, then the position of eyes will be found. In this robot, the focus is on face detection using color images. In color images, color information can be used to detect the skin position. Then by using another algorithm such as template matching, the position of the face can be identified.

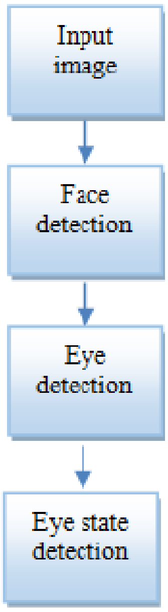

Fig. 4. Eye state detection flowchart

Skin detection based on color: In order to detect skin color, different color spaces such as RGB, HSV, YCrCb, and TSL can be used. For this, there are lots of algorithms. These algorithms are different with each other in terms of computational time and performance accuracy. Many algorithms are proposed in the field of skin detection based on color. The best method is as follows: in RGB color space, if these conditions exist in one point, that point is skin color: (1) R> 95, G> 40, B>20, (2) Max{R,G,B}-min{R,G,B} > 15, and (3) R-G| > 15, R> G , R> B . These regulations are proposed in wide variety of papers and its main advantage is the simplicity of regulations and using RGB color space. First, all points diagnosed as skin colors remain and the rest become black (zero). Because color information is only used for skin color detection, after skin detection, the color information of the image is eliminated and the image will become grey [7]. Region identification and non-facial region removal: After removal of points other than skin, the image background becomes black, and only the points that are of skin color will be remained. Now, in this black background that contains non-black regions, different regions that are candidates for being face, should be evaluated. Regions with the following conditions cannot be related to face: (1) the number of region points should be less than 200 pixels, (2) length or width of the region should be more than 200 pixels and (3) the ratio of the length to width of the region or the ratio of the width to length of the region should be more than 2.5. if the number of points in an area is less than 200 pixels, that region is identified as noise. If the length or width of a region is more than 200 pixels, it means that the area is too large and probably relates to huge objects that are of skin color. If the ratio of length to width or width to length of a region is greater than 2.5, it means that the above region is long and cannot be related to a person's face. Hands and feet are usually eliminated by these conditions. If existing neighborhoods have one of the above conditions, will be eliminated. The remaining neighborhoods are face candidates. Face position detection by template matching: Template matching method is used for remaining neighborhoods. For this, an image is used as a template. To obtain image pattern, one of the existing methods is averaging on a number of images. For this purpose, some images were selected from the website of the University of Tabriz that some examples are follow. The face regions are extracted from these images and are saved by the same sizes of 800×100 (figure 5). Then after graying and balancing their histograms, averaging is done on them. Used images and obtained average based on them are as follows (figure 6). After finding the template, by sliding the template on original image and finding their correlation, the regions that are close to template are extracted. In these regions, some peeks are seen. The noteworthy point in this stage is that, the approximate dimensions of the template face should be equal to the faces in the image. For this reason, some dimensions of template are compared with the original image.

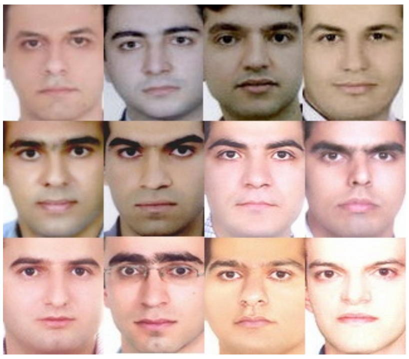

Fig.5. Image bank

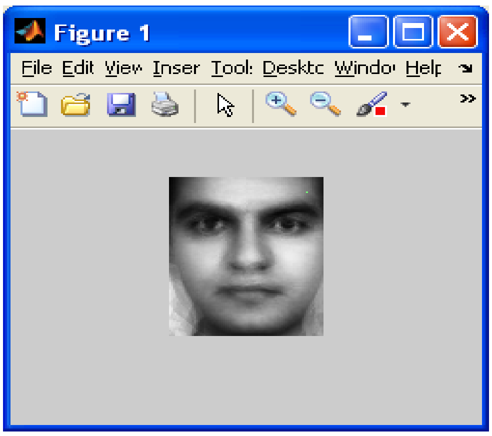

Fig.6. Template image

3-2- Eye detection

After face detection using the described algorithm, now the extracted face image is used to detect the position of eyes. Since pupils are symmetrical, so in order to detect the position of eyes, radial symmetry transformation is used. [11] suggests a transformation that uses local symmetry to highlight the focal points in a landscape. Low computational complexity and fast execution time make this method suitable for real-time applications. Next, this method is extended for use in pupil detection. In order to eye detection, our system is composed of the three modules. The modules are (1) preprocessing (2) symmetrical radial transformation and (3) candidate pupil generation and distance transformation respectively. Preprocessing: In order to overcome noises and light changes in the image, a5 $\times$ 5 Gaussian filter is implemented on the image, which is proved to be the simplest and most effective way for noise elimination. Radial symmetrical transformation: By inspection, it can be observed that, pupil is like a sphere and the color of pupil is darker than the surrounding pixels. So a symmetrical radial transformation is used to extract spherical featured points. Here we have used a method similar to the one proposed in [12]. It is worth noted that, only the upper portion of the image of each face candidate is used for the above processes because pupils almost appear in this region. Candidate pupil generation and distance transformation: Because transformation values around pupil are generally larger than other parts of the face, these values can be used to detect feature points such as pupils. Figure (7) depicts an example of different stages of processing of symmetrical radial transformation and pupil detection. Figure (7-a) depicts upper portion images of two candidate faces. Figure (7-b) is their sum, figure (7-c) is an image showing normed average, figure (7-d) is binary images of B, figure (7-e) is corresponding to distance transformation and figure (7-f) depicts detected pupil candidates [12].

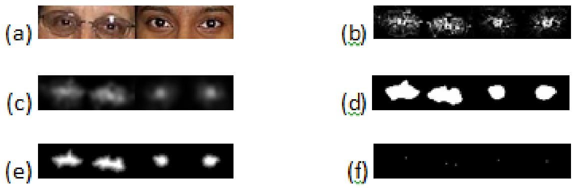

Fig.7. The results of processing the two examples in different stages of radial symmetry transformation and pupil detection.

3-3- Eye state detection

By pupil detection, eyes location can be identified, now the results of the previous stage can be used to detect eyes' state. Since the left and right eyes are unintentionally open or closed simultaneously, so their states are the same. Real drowsiness is an unintentional act. So it is better to consider only one eye. Another point that should be noted is eye detection in closed state. Pupils in the closed form are not visible. So the stated method will encounter a problem. Since, there is no need for pupils to detect the state of the eye, one can use the results of the algorithm up to binary stage and then not to continue the algorithm, because the algorithm can detect the region of eyes up to this point. Examples of images of detected eyes are depicted in figure (8).

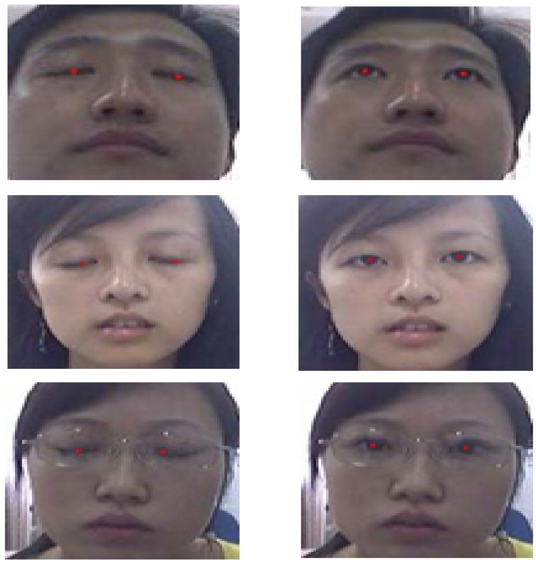

Fig. 8. the results of eyes' open and closed states detection [13]

LBP features: If we suppose that x is the distance between the eyes, the width of left eye is 0.35x and its height is 0.74x. LBP can be used in texture analysis. For every 3×3neighborhood, LBP operator attaches a label to the central pixel. By using thresholding, every pixel in the neighborhood of the central pixel, an 8-bit binary number can be generated that will be attached to the central pixel. If pixels in the neighborhood of the central pixel were greater than the central pixel, they will be considered 1 and zero otherwise, and at the end, neighborhood 0s and 1s are written as a binary number. Then histogram consisting of counting all tags can be used as a descriptor. Figure (9) depicts the general concept of LBP operations.

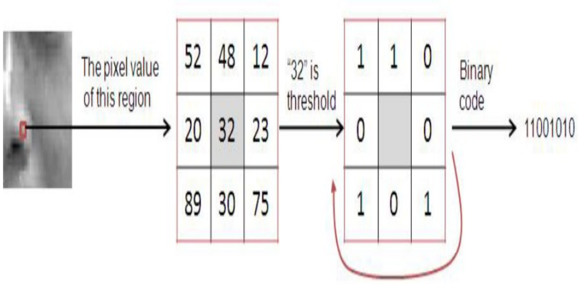

Fig.9. LBP operations

SVM classification for eye state detection: SVM tries to create an optimal Hyper-plane that minimizes the distance between the closest points to the two categories. To train SVM, the following steps must be performed respectively: (1) preparation of large data sets of images in open and closed state of the eyes and different gestures, for example data sets of ZJU eye blink [14], (2) manual labeling of all images, for example if the image was related to the open eye, the attached label should be 1+, and if it was related to the closed eye, the attached label should be 1-, (3) obtaining the LBP feature of each image and putting the feature and label in (f,l), and (4) training SVM using (f,l) and generating an optimal hyper-page using software packages like MATLAB. After training SVM, one can use it and input his/her own eye image and then acquiring our required output that is the state of the eye.

4- Drowsiness Detection

In the previous section, the procedure of obtaining the state of the eye was described. Now by using this method, we intend to detect drowsiness. To detect drowsiness, a camera is needed to send the sequence of images, so that after detecting the eye state in each image, one can judge on the drowsiness state. In this paper, the theory of PERCLOS is used to detect drowsiness. PERCLOS shows the rate of closing eyes [15]. This rate in PERCLOS can show drowsiness and is a very good way to detect drowsiness. In PERCLOS, there are three assessment criteria, which are 70P, 80P, EM. For example the criteria of 80P says that tiredness or drowsiness may occur when the eyes remain closed in 80% of the specified time. The proposed method in [15] is based on the amount of the eyes being open or closed, i.e. how much percentage of the eyes is open. But here we propose a simple method based on [15]. If it is supposed that the system can process every image in one second, if in four sequences of images, the state of the eyes were identified to be closed, then the drowsiness will be detected.

5-Conclusion

In this paper, design and fabrication of a system for drowsiness detection were stated. After running the system, first by using an algorithm based on skin color, the face is detected and then the position of the eye is detected and in the case of eye position change, the system will track it and every time that the eyes are moving away from the camera's field of view, the motor is automatically rotated so that the eyes remain in the field of view and this will increase the system's reliability so that the system will always have an output. Furthermore the system simultaneously can detect the closing of the eye, and in the case of eye closure time more than the defined value for the system, the alarm section will be activated.

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