Using Image Processing Methods to Reduce Dazzle in the Eyes from a Digital Projector

Ying-Wen Bai**, Yu-Cheng Liu** and Cheng-Hung Tsai*

Department of Electrical Engineering**
Fu Jen Catholic University
Taipei, Taiwan, 242, ROC

Abstract—When someone is standing in front of a presentation screen, the contrast between the projector light and the indoor illumination is, as a rule, too great. This causes frequent contraction of the pupils of a person’s eyes and thereby great discomfort. In this paper we use the image processing method to reduce the light intensity towards a person’s face to the approximate level of the indoor illumination, thus reducing the pupil contraction frequency. Our design proposes three methods by using both the current computer vision technology-motion detection and face detection. Motion detection tracks the person’s location and infers the head position. Face detection, by using a combination of the two methods, tracks the location and speeds up the face examination process. These three methods all use a black oval mask to cover the face so that the eyes can avoid any dazzling light.

Keywords—Motion Detection, Face Detection, Projector, Computer Vision

I. INTRODUCTION

Most people use both the digital projector and the laser pointer for a presentation. If the content is not clear, if pictures can’t fully express their meaning or if people need to be interactive in front of the projector screen, they often enter the projection area during their explanation, although the projector directions warn users not to do so [1]. The reason for this warning is that the eyes will be exposed to the strong light of the projector. When exposed to this light for a long time, the eye may be damaged, sometimes even irreversibly [2]. Now most schools are using digital projectors as an auxiliary means in teaching, and both teachers and students have an opportunity to interact in the projection area. Although there are some products which use either an ultra-short throw projector or the back projection method to avoid direct light on the eye, the price of these new products is much higher than that of the general digital projectors. Moreover, there are some restrictions, such as the need for a large space, the projection distance, the installation height and the required projection size.

There is a typical motion detection method, “temporal differencing”, which uses the subtraction of continuous images. If the difference is zero, then the image includes no moving object, if the difference is not zero, it does. This approach has the advantage of good adaptability to any change in the environment. But if a moving object breaks up in the internal situation, the result is both incomplete contours of moving objects and an inability to provide complete information. This situation can be avoided by using another motion detection method, “background subtraction”. Background subtraction first pre-establishes a background image, and then subtracts the new image from the background image in order to detect moving objects [3-5].

We furthermore use two types of face detection: learning-based and feature-based. Learning-based detection mainly studies ways to detect the face, such as when Rowley learned about a lot of different facial features by using the neural network [6, 7]. The learning process with the neural network compares the whole image to find the location of the face. However, if the collected sample is not obvious enough, this leads to detection failure. Feature-based detection mainly handles facial features using color, edge detection and the shape of the face [8-10]. We use face detection by the Viola and Jones method which uses the learning-based method, which consists of a cascade of multiple strong classifiers (cascade of classifiers), in order to detect faces in images. This method has a good trade-off between computation and accuracy.

This paper includes six sections. Section II shows the environment set-up, Section III provides the software design, Section IV presents the experiment results, Section V shows the comparison table and Section VI summarizes the conclusions.

II. ENVIRONMENT SET-UP

Fig. 1 shows the environmental operation diagram. The personal computer is linked to both the digital projector and the Webcam. Through image processing the projector projects a black oval mask to cover a target location on the face.

Figure 1. Environment operation diagram.
Modules (a), (b) and (c) in Fig. 1 are three variations of methods which can be applied in this environment. Modules (a) and (b) involve setting the Webcam aligned with the same projection area and monitors. It is represented by the black line in Fig. 1, and module (c) is represented by a red dotted line. If anyone enters this area the system tracks the user moving displacement in modules (b) and (c) and also both face location and identification in module (a).

In order to make the Webcam capture image to match the screen, we measure coordinate data and find the distance. The formula is \( Z = \sqrt{x^2 + y^2} \), as shown in Table I. The \( Z \) is the distance between the Webcam aligned the screen in the modules (a) and (b) or toward the ground in modules (c) as shown in Fig. 1.

<table>
<thead>
<tr>
<th>( X \times Y ) (mm)</th>
<th>Ideal distance (cm)</th>
<th>Actual distance (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>320x240</td>
<td>4cm</td>
<td>4.5cm</td>
</tr>
<tr>
<td>800x600</td>
<td>10cm</td>
<td>9.7cm</td>
</tr>
<tr>
<td>1024x768</td>
<td>12.8cm</td>
<td>13cm</td>
</tr>
<tr>
<td>1280x1024</td>
<td>16.39cm</td>
<td>17cm</td>
</tr>
</tbody>
</table>

### TABLE I. MEASURED DATA

III. SOFTWARE DESIGN

Our software design contains three parts: motion detection, region of interest (ROI), and face detection. The three methods are based on motion detection. The first method is combined with ROI and face detection. This flowchart (Fig. 5) includes developments through node A to the end. The second and third methods only use motion detection to track people. The flowchart is similar from start to end, except through node A to the end, as shown in Fig. 5.

#### 3.1. Motion Detection

We use the background subtraction to find the moving object. The Webcam captures the video image which has a complex background. If the foreground object becomes a part of the image, the software removes the foreground object from the image in the background. To reduce computer computation, the system transforms the original image into a gray-scale image.

![Figure 2. Background subtraction](image1)

![Figure 3. The gray-scale image when transferred into the threshold](image2)

To find the foreground object the software first establishes the background image first and then subtracts the background image from the continuous image of the Webcam to get the foreground object of the image. Fig. 2 shows the background subtraction of the two gray images and finds the foreground object [11, 12]. The function is shown as Eq. (1). \( FG(x, y, t) \) is the gray image of the foreground at time \( t \). \( (x, y) \) represents the location of the pixels value. \( IG(x, y, t) \) is the Webcam-captured image transformed into a gray image at time \( t \). \( BG(x, y, t) \) is the pre-established background gray image at time \( t \).

\[
FG(x, y, t) = IG(x, y, t) - BG(x, y, t)
\]

Setting the threshold is dependent on finding a foreground object. The gray-scale image converts the original image pixel into values 0 and 1 according to the setting of the critical value of the threshold. \( FT(x, y, t) \) is the threshold image at time \( t \). The pixels for the foreground object are usually marked 1 as an interest; the others are marked 0, as shown in Eq. (2).

\[
FT(x, y, t) = \begin{cases} 
1, & \text{if } FG(x, y, t) \geq \text{Threshold} \\
0, & \text{if } FG(x, y, t) < \text{Threshold} 
\end{cases}
\]

This method filters out unwanted foreground objects. If there is some noise in the foreground, we use a filter to reduce it. The selection of the filter depends on the condition of the current image. If there is any salt-and-pepper noise, one can choose the median filter to filter out the noise and build a clean image. Fig. 3 shows the transformation of the gray-scale image into the threshold image after being filtered out. We use the morphological process to make the foreground image more clear and complete. \( FT'(x, y, t) \) is dilation shown as Eq. (3) and \( FT''(x, y, t) \) is erosion shown as Eq. (4).

\[
FT'(x, y, t) = FT(x, y, t) \ominus P(x, y, t)
\]

\[
FT''(x, y, t) = FT(x, y, t) \oplus P(x, y, t)
\]

We execute the opening operation which determines the erosion after the dilation. These methods are usually used to smooth image contours, narrow the neck, eliminate small islands and peaks.

To get a further clear image we use \( FCA(x, y, t) \), a connected components area of the foreground image. We set an area ratio of the connected components area (\( \text{contArea} \)) and image area (\( \text{imgArea} \)). If \( FT''(x, y, t) \) is smaller than this area ratio, \( FCA(x, y, t) \) would not establish the contour of this area and delete these pixels; otherwise the pixels adjacent to the contour will establish the foreground image, shown as Eq. (5), so we can target it.

\[
FCA(x, y, t) = \begin{cases} 
\text{show}, & \text{if } FT''(x, y, t) \geq \left( \frac{\text{contArea}}{\text{imgArea}} \right) \\
\text{delete}, & \text{if } FT''(x, y, t) < \left( \frac{\text{contArea}}{\text{imgArea}} \right)
\end{cases}
\]

#### 3.2. Region of Interest

![Figure 4. The gray-scale image when transferred into the threshold](image3)
We use the full search method to search the foreground image of the screen and obtain two points \( A(x-dx, y) \) and \( A(x+dx, y-dy) \). By using these two points we can set the ROI to locate the foreground object from \( FCA(x, y; t) \) after processing the image data [13]. Fig. 4 (a) shows our method of finding the foreground object from the ROI with less computation. Because face detection does not require a search of the whole image, we search the ROI image directly to find the ROI-independent foreground object shown in Fig. 4 (b).

3.3. Face Detection

Viola and Jones propose the face detection method by collecting a large number of samples to find the similar characteristics of the face. By this method the system receives the ROI image in comparison with the results of the motion detection. This method also contours the location of the face when it detects the face. If the software does not detect the face, it takes the next ROI image five times in succession to detect the face. If it still does not detect a face, the software goes to the start function.

3.4 Image Synthesis

As the last step we determine the face coordinates in order to set up a black oval mask and superimpose it on the background image. This serves just like a black mask on the face [14].

![Flowchart](image)

Figure 5. Software flow chart of the three methods.

IV. EXPERIMENT RESULTS

4.1. Defining the Indoor Environment

This environment is one where curtains cover any part of the entire area where it is not very bright. The user is standing...
about 30cm in front of the screen. We use a TES-1344A light-meter to measure the indoor illumination when the digital projector is not turned on. The reading range is 10 lux-15 lux in the indoor environment.

4.2. Measuring the Illumination

To measure the illumination of project locations with the digital projector we use a grayscale map. We know the environment background of the grayscale; the illumination, which is only about 10 lux on the darkest part of the map, can be as high as 250 lux on the brightest part of the map.

4.3. Equipment Specifications

In this experiment we use a digital projector, a personal computer Intel I5-750 2.67GHz, a 120-mega pixel Webcam and a light-meter.

4.4. Detection Rates of Face Detection and Motion Detection

The first method is face detection. This experiment benchmark is based on the face being turned towards the front when people are in front of the screen as shown in Fig. 6. The measurement is made within three seconds while the face stays in the projection area. If the face is detected, we count our measurement as a success; otherwise, our measurement is considered to be a failure. Table III shows the measurement data, of which A and B show the data from the two measurement areas. Zone A is in a complex projection area which contains a number of letters projected on the face. The complex projection area may result in misjudgment, because if the rectangular feature can’t compare the face, the failure rate will be higher in Zone A [15]. Zone B is not significantly different, because the face on the projection area is complete. If the environment lighting does not affect the overall face detection, then the detection rates can reach about 80 percent although they are arrived at under strong light.

The second method uses motion detection by using a Webcam aligned with the screen. After background subtraction and image processing the system receives the image from the foreground object. The system locks the user’s shape from the foreground image which can locate the head position in this area. From this position the system obtains the middle of the user’s block. The Webcam tracks the user’s body block and projects a black oval mask when the user is moving. By using motion detection, we obtain a detection rate of 91 % which is higher than the detection rate of the face detection in Zones A and B of Fig. 6. But the detection rate is not good in special slides when foreground object color or the mixed-up projection image is similar to the background. For example, the user takes a white keyboard in front of the white screen as shown in Fig. 4(b). After image subtraction of the background image, portions of the user’s body may be empty of the threshold image shown in Fig. 3. As a result, the connected components will not connect easily or continuously. Therefore, as the image processing is unstable, the system is not successful in this area.

The third method is similar to the second method, but we place the Webcam on the ceiling facing the ground shown as Fig. 6. The Webcam monitor area is concurrently the viewing area range. The main monitor area is our setting active area showing the location of the user. Fig. 7 (a) shows the Webcam monitor area, Fig. 7 (b) and (c) show the image processing results of the third method, and (d) shows the environmental image. As this solution is simply the background we can reduce the projection image causing the user’s body to be absent from the threshold image that, as a result, makes the threshold value difficult to use. The system can set the user’s height and locate the relative position of whoever has gone into the projection area on the screen. The system will then judge the user’s horizontal displacement. The user’s shape lock method is the same as in the second method. So we can easily obtain a clear foreground image when the Webcam faces the screen for motion detection. Table II shows that the third method is better than those used previously.
4.5. Implementation Results

Figs. 8 and 9 show the experiment results obtained by executing our program. Our design detects the face of the projection area and provides a black oval mask to cover the face. At this time the ratio between face illumination and indoor environment illumination is either 2:1 or 3:1. Table III shows the indoor brightness measurements of the background brightness with the projector both turned off and on, facing the white light projection.

![Figure 8. Live test 1](image1)

![Figure 9. Live test 2](image2)

V. COMPARISON OF OUR DESIGN WITH OTHERS

Table IV shows the comparison of our design with other products. Product A, which is our projector, is a general digital projector. Product B is the improved version of product A. Its main improvements are the avoidance of direct glare into the eyes and interactive whiteboard teaching. But this product has a very high price, almost double that of product A. Although product B uses the ultra-short throw technology, since the projection size is limited by the installation height and the distance from the wall, the projection area is generally smaller than that of Product A.

Our design combines most of the advantages of products A and B. We use the image processing techniques to reduce the dazzling of the eyes to a level similar to product B. Our design only adds the extra Web camera for around $20 to a common projector, and then our software can reduce any dazzling light.

VI. CONCLUSION

Through experiments we measure the illumination of the white light source of the projector and the light projected on the face in the dark environment. In our design the measurement data show that the illumination of the projected area of the face which is covered by the black oval mask projection area is 9-10 times lower. As the illumination of a user’s face covered by the mask is close to the indoor brightness when the user faces the strong light from the projector, thus the pupils do not contract frequently. In a real operation, as the user enters the projection area, the illumination of the face position is reduced to a safe level, which can avoid frequent pupil contraction.
area with the black oval mask, and as the eye feels comfortable, it is much easier for him to face the audience.

In this paper we propose the third method, that of using a Webcam from the ceiling, in order to overcome the disadvantage of the first and second methods by reducing the complexity of the image processing and raising the detection rate to 92%.

REFERENCES


