An Integrated Design of a Smartphone Interface with Multiple Image Processing Methods to Reduce Shining Light from a Digital Projector

Ying-Wen Bai
Department of E. E., Fu Jen Catholic University
New Taipei City, Taiwan

Tine-Hsueh Lin
Department of E. E., Fu Jen Catholic University
New Taipei City, Taiwan

***Abstract*—In this paper we propose a smartphone to be used in open system platforms that combines with a projector to produce a black mask which when used together cover and track the speaker's face to reduce the strong light from the projector shining toward the speaker's eyes. This design uses the background subtraction to first eliminate the background of the captured image and then detect the skin color. In order to track the location of the speaker, this design also utilizes the face detection function to track the coordinates of the speaker's face. This design also uses the projection screen blocks to automatically calibrate the mask position based on the resulting distance calculation from the projector to the projection screen.**

***Index Terms*—Smartphone, Projector, Mask, Skin Detection**

I. Introduction

Recently, people may use a smartphone together with a projector in a presentation instead of either a desktop computer or a laptop. Sometimes the speaker may stand in front of the projector screen to explain the content to the audience. The projector's strong light may shine in the speaker's eye. This problem creates a need to superimpose a black mask to cover the speaker's face in order to reduce the harmful effect of this shining light from a projector [1].

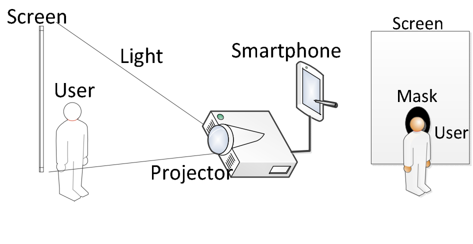
Under strong light from the projector, the accuracy rate of the face detection by a single image processing method may be too low. This design integrates both multiple image processing methods, face detection, background subtraction [2-4], and skin color detection [5-7], which are three methods that can be used to improve the accuracy rate of the face detection under strong light [8].

This design uses the edge detection and morphology to find the projection contours on the projection screen, and then subsequently to find speaker's face within this area [9-10]

II. Hardware Architecture

This design uses a smartphone with an open system platform which are present and combined in 81.5% of all of the smartphones manufactured in 2014. This design uses the video output of the smartphone, and the connecting line is from the micro connection which is converted into VGA. The projector also has the same VGA input

Figure 1(a) shows how a smartphone is connected to the projector. Figure 1(b) shows how this design uses the smartphone to superimpose the black mask on the speaker's face.



(a) (b)

Fig. 1. Hardware architecture.

III. Software Design Implementation

Figure 2 shows this design that uses an open source platform to program the user interface and application. This design, which performs both the image processing and the preview image on the user interface, also uses the edge detection modules and camera module and color resolution module and touch screen module to perform the image processing on the smartphone interface.

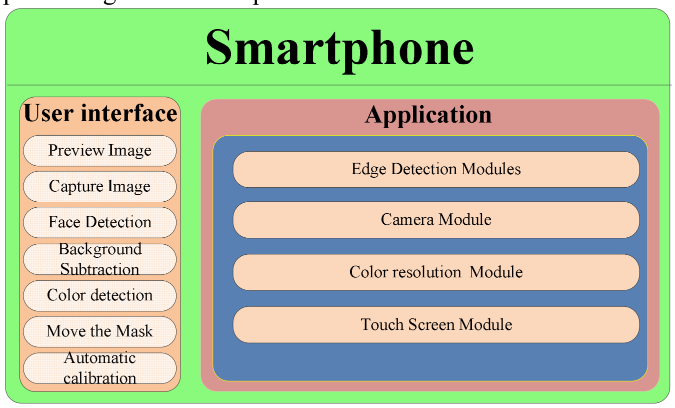


Fig. 2. This design's operation environment.

Figure 3 shows the software flowchart which is used to capture the background image. When the speaker enters the projector screen area, the smartphone will capture more images, perform face detection, skin color detection, and background subtraction detection to determine the location of the speaker's face. There are two ways to obtain the coordinates of the individual's face center. This design uses the two results to correct the error and then calibrate the coordinates of the

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speaker's face. And then this design superimposes the black mask at the correct location and tracks the speaker's face by using the mask. This smartphone interface design, which provides a button marked "end", allows the user to terminate the program.

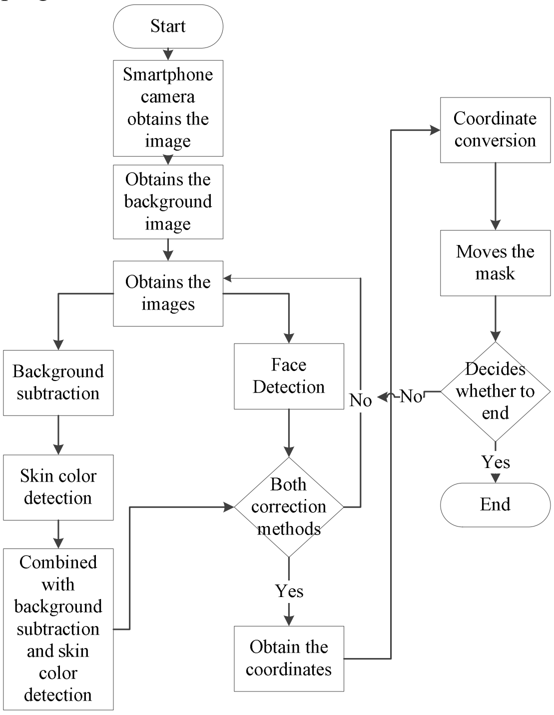

Fig. 3. The software flowchart.

A. Face Detection

This design uses the smartphone camera to capture the image, identifies the speaker's eye and then detects the speaker's face.

B. Skin Color Detection and Background Subtraction

As the previous design only uses face detection and thus may fail to recognize the speaker's eyes, this design integrates both the skin color detection and the background subtraction to increase the face recognition rate. If it only uses the skin color detection, it may detect many skin areas. This particular detection can't tell the user the location of the speaker's face. Hence, by integrating the background subtraction, although this design can identify the location of the speaker, it may be unable to identify the speaker's face location. After several tests and fine tuning of the integration design of these three methods, it can identify the location of the speaker's face. This design can also allow the user to choose the skin colors, and then use the background subtraction to remove the background based on the chosen skin colors.

Fig. 4 shows the user interface of the smartphone application and it shows the processing results of the captured image by using different methods of this design. Fig. 4 (a) shows the foreground image by using the background subtraction method. Fig. 4 (b) shows the background image obtained by using the background subtraction method. Fig. 4 (c) shows the processing that takes place by using the background subtraction method and by using white to represent the different background areas. Fig. 4 (d) shows the processing result by using the skin color detection method. Fig. 4 (e) shows the processing result by using the skin color detection method and background Subtraction method.

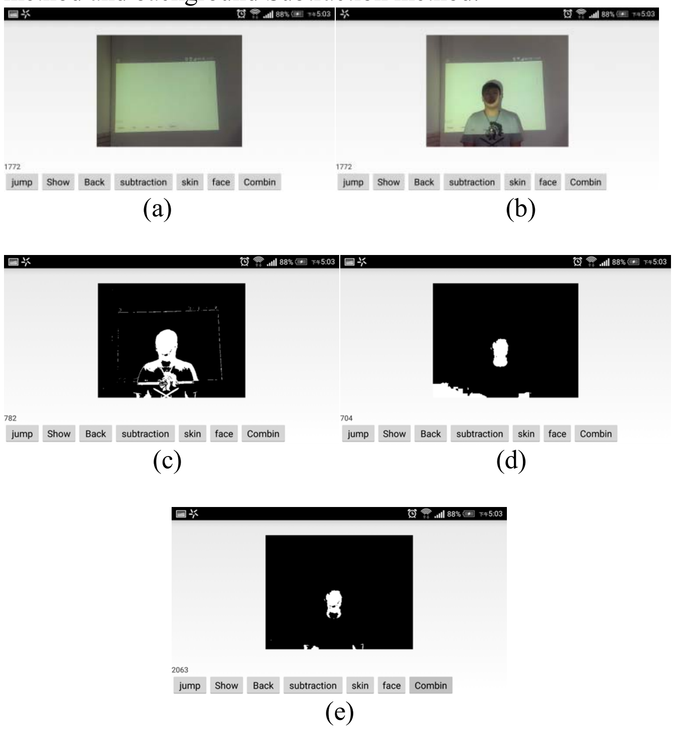

Fig. 4. The image process results display at the smartphone interface.

C. Some Common Mistakes

Table I shows the definition used in the coordinate conversion equations as shown in Eq. (1) to (4).

TABLE I. THE DEFINITIONS USED IN THE COORDINATE CONVERSION EQUATIONS

X_{sp}	Y_{sp}	Smartphone screen coordinates
X_I	Y_I	Image coordinates
R_{sp}		Resolution of the smartphone screen
R_I		Resolution of the image
C		Offset constant
X_{move}	Y_{move}	The mask offset
X_{start}	Y_{start}	Selection of the mask coordinates

This design uses Eq. (1) and Eq. (2) to convert the coordinates of the image coordinates into smartphone screen coordinates. The coordinates of the black mask will track the smartphone screen coordinates, which are X_{sp} , and Y_{sp} respectively. The smartphone screen image consists of the X coordinate and the Y coordinate. X_I *and* Y_I are the coordinates of the captured image pixel of the smartphone. Because the smartphone screen image is not at the top corner, C is the offset constant which is located at the top corner.

$$X_{sp} = X_I \times \frac{R_{sp}}{R_I} \quad (1)$$

$$Y_{sp} = Y_I \times \frac{R_{sp}}{R_I} + C \quad (2)$$

This design uses Eq. (3) and Eq. (4) to convert the projected location to the screen location by the calibration relation X_{move} and Y_{move}. X_{start} and Y_{start}. The offset for different coordinates must be calibrated in order to select the black mask coordinates.

$$X_{move} = X_{start} - X_{sp} \quad (3)$$

$$Y_{move} = Y_{start} - Y_{sp} \quad (4)$$

D. Automatic Calibration

Our previous design manually uses a touch screen function of the smartphone to decide the position of the mask at the beginning. This new design uses the image detection to automatically determine the position of the mask. Fig. 5 shows the digital projector projection on the projection screen. Fig. 6 shows the coordinate for the smartphone screen. This design uses image processing to find the area of the digital projector projection on the project screen, and this design uses the face detection to determine the location of the speaker.

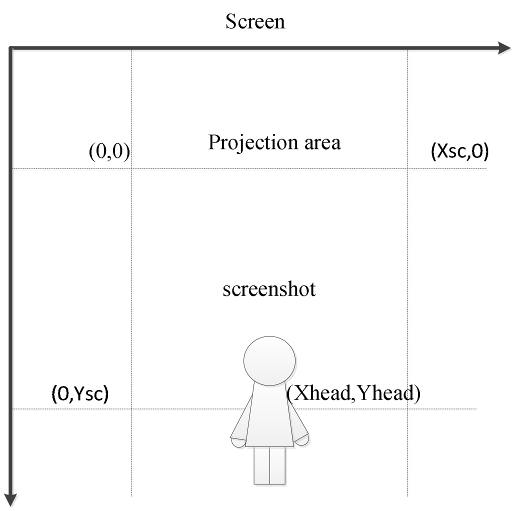

Fig. 5. Digital projector projection as shown on the projection screen.

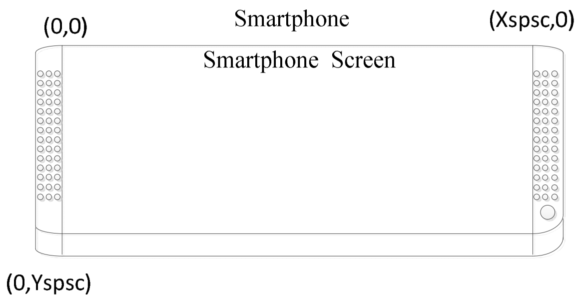

Fig. 6. The smartphone screen.

This design uses Eq. (5) and Eq. (6) to convert the coordinates of the region into the smartphone screen. X_spsc is the width of the smartphone touch screen, X_sc is the width of the projectors projection at the image, X_head and Y_head represents the head coordinates on the image, and X and Y is the digital projector projection on the projection screen at the image from the reference point to the coordinates.

$$X_{sp} = \frac{X_{spsc}}{X_{sc} - X} \times (X_{head} - X) \quad (5)$$

$$Y_{sp} = \frac{X_{spsc}}{X_{sc} - X} \times (Y_{head} - Y) \quad (6)$$

E. Mask Radius

If this design uses the same mask radius at the smartphone, it is necessary to determine the distance between the projector and the screen in order to change the mask radius at the screen. Therefore with this design the user needs to calibrate the distance between the projector and the screen in order to adjust the mask radius at the smartphone.

Table II shows the mask radius at the screen with different distances, and the mask radius at the smartphone.

TABLE II. THE MASK RADIUS AT THE SCREEN WITH DIFFERENT DISTANCES

The distance between the projector and the screen (CM)	Length (CM)	Width (CM)	The mask radius (CM)
90	52.3	40	6
108	63	48	5
123	71.3	54.6	4
135	78.5	60	3

If this design uses the same mask radius at the same distance between the projector and the screen, when the speaker is moving forward the mask cannot completely block the speaker's face as shown on Fig. 7.

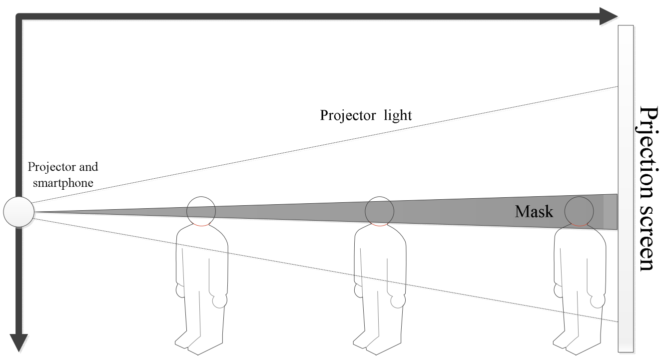

Fig. 7. The identical mask radius at the same distance between the projector and the screen.

Table III shows the different distances from the speaker to the projector. This design adjusts both the mask radius at the screen and the projector based on different distances, and also the mask radius at the smartphone.

TABLE III. THE MASK RADIUS BASED ON THE DISTANCE BETWEEN THE USER AND THE PROJECTOR

The distance between the projector and the screen (CM)	The mask radius based on the distance between the user and the projector is 120 CM (CM)	The mask radius based on the distance between the user and the projector is 100 CM (CM)	The mask radius based on the distance between the user and the projector is 80 CM (CM)
90	null	null	6
108	null	6	5
123	6	5	4
135	5	4	3

Fig. 8 shows this design uses face detection to determine the speaker's face size for the width on the image. And this design uses this face size to control the mask radius, so the mask can automatically adjust the size of the mask to protect the speaker's eye when the speaker is moving ahead.

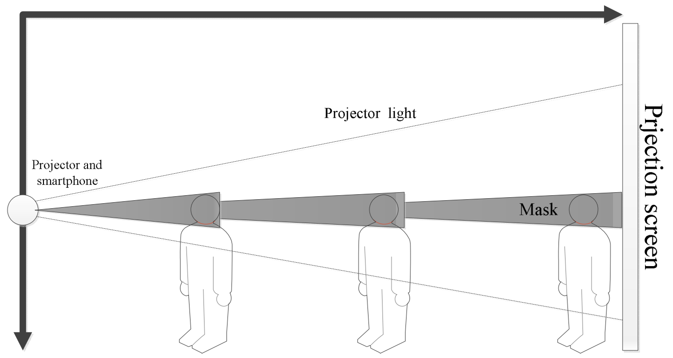

Fig. 8. The mask can automatically change size to protect the speaker's eye.

F. Region of Interest

Because the speaker's height doesn't change, when performing the image processing this design can remove the portion of the speaker's height that is above the region of interest as shown on Fig. 9, in order to reduce the computation time.

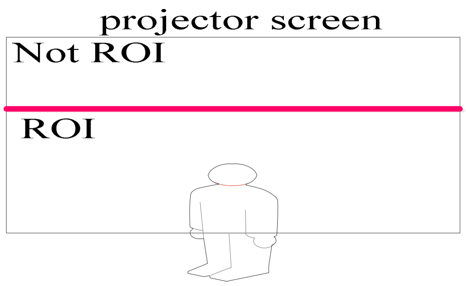

Fig. 9. The region of interest.

IV. EXPERIMENTAL RESULTS AND COMPARISON

Table IV shows a comparison of this design and other designs. Although Design A can reduce the projector's strong light, it uses two items: a depth camera to capture the images; and a desktop computer. Hence, this design makes it easier to simply use a smartphone interface to fulfill the similar function of the previous design.

TABLE IV. A COMPARISON OF THIS DESIGN WITH OTHER DESIGNS

	Design A [1]	Design B [11]	This design
Smartphone	No	Yes	Yes
Projector	Yes	No	Yes
Face Detection	No	Yes	Yes
Skin Detection	No	Yes	Yes
Mask	Yes	No	Yes

Table V shows the experiment results of this design by using multiple image processing methods which have been tested 100 times by three users. This design executes the program and captures the image. If it detects the speaker standing in front of the projector screen, then it will superimpose a black mask to cover the speaker's face for protection. If the face detection fails, for example when capturing the image from one side or from the back, the skin color detection of the background subtraction can help detect the image from either one side or the back. Hence the integration of the three image processing methods can increase the average accuracy rate to 94% as shown in Table V.

TABLE V. ACCURACY RATES OF DIFFERENT DETECTION METHODS

User	Face Detection	Skin and Background Subtraction	Face Detection, Skin Detection, Skin and Background Subtraction
1	87%	88%	94%
2	83%	86%	93%
3	85%	89%	95%

V. CONCLUSIONS

In this paper, we propose an integrated design for protecting eyes from the projector's strong light by utilizing a smartphone instead of a desktop computer. This design uses a smartphone to perform the face detection function and to determine the position of the speaker's face. In addition, it uses the skin color detection function to detect the skin color of the captured image and it also uses the background subtraction technique to eliminate the background of the captured image. This design also allows users to choose the skin colors.

This design also utilizes both the edge detection and morphology to find the projector's projection region on the image. This method can also automatically move the mask to track the speaker's face, and thus reduce the amount of the shining light from the projector.

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