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Abstract. Wearing sunglass to hide face from surveillance camera is a common activity in criminal incidences. Therefore, sunglass detection from surveillance video has become a demanding issue in automation of security systems. In this paper we propose an image processing method to detect sunglass from surveillance images. Specifically, a unique feature using facial height and width has been employed to identify the covered region of the face. The presence of covered area by sunglass is evaluated using facial height-width ratio. Threshold value of covered area percentage is used to classify the glass wearing face. Two different types of glasses have been considered *i.e.* eye glass and sunglass. The results of this study demonstrate that the proposed method is able to detect sunglasses in two different illumination conditions such as, room illumination as well as in the presence of sunlight. In addition, due to the multi-level checking in facial region, this method has 100% accuracy of detecting sunglass. However, in an exceptional case where fabric surrounding the face has similar color as skin, the correct detection rate was found 93.33% for eye glass.

1. Introduction

With the flourishing advances in autonomous systems, video surveillance cameras integrated with image processing techniques are replacing human operators. These automatic video surveillance cameras have been used to detect suspicious persons, their appearance, and their activity in mass gathering places such as shopping malls, airports, rail stations and automated teller machines etc. One of the most important detection in suspicious persons' appearance is detection of sunglasses. Committing crime by wearing sunglass is very common, as it is one of the most available accessories to cover face. Therefore, various existing approaches [1-4] attempted to detect sunglass using video surveillance. The algorithm in [1] made use of facial components (eye, nose, mouth) feature to detect face covered by sunglasses. The facial components were identified using Viola Jones face detector and then SVM classifier was used to verify if the detected regions are covered by sunglass. However, the method in [1] failed to detect eye shaped sunglasses and reflecting surface of sunglasses, since the facial component detector used in the algorithm misguidedly detect these scenario as eye location [5]. The algorithm in [2] detected facial components using Gabor features and verified the presence of occlusion by sunglass using SVM. The use of Gabor features incurs high computational complexity, since Gabor feature is high dimensional and also needs additional dimensionality reduction scheme

[6]. Furthermore, [3] proposed another method using both elliptic face shape feature and skin color feature of face for sunglass detection. The algorithm detected head using a head-shoulder template and then detected face using ellipse fitting method [7]. In addition, [3] applied thresholding classification approach using skin color area ratio (SCAR) value of eye area to verify the presence of sunglasses. However, the head-shoulder template assumption is adopted from the experience of craftsmanship and not from an established theory or experiment [8]. In addition, the use of ellipse fitting algorithm in this approach requires redundant edge points' calculation through iterations and thus, suffers from high computational complexity. Similar to the approach of [3], the algorithm in [4] also utilized elliptic shape and skin color. In addition, the algorithm made use of Omega shape and face templates. The algorithm determined the exact head region by an energy-based algorithm and ellipse fitting. Then, the algorithm optimally approximates the Omega shape formed by the head and shoulder with a Gaussian function. An elliptical head tracker was used to match the head region. At the end, the method integrated two classifiers for verification. The classifiers were based on SCAR value and face template. However, this technique gives in general decision such as "normal" and "abnormal" for faces covered with different accessories. The algorithm does not give specific decision on detection of covered area by sunglass. In addition, this method requires a huge amount of mathematical computations.

From the above discussion it can be summarized that there are a number of limitations in the previous sunglass detection algorithms such as, erroneous detection of eye location, bulk and complex mathematical computations and unspecified or in general decision regarding covered area. To alleviate these problems, this study proposes a sunglass detection algorithm for video surveillance camera. The proposed algorithm utilizes skin color, elliptic face shape and facial height-width ratio(ρ) feature of face. Note that, ρ has been found as a unique feature and can be calculated by equation (1) [9].

$$\rho = 3WH^{-1} \tag{1}$$

where W and H represent the facial width and height, respectively as shown in figure 1. In addition it has been found that, value of ρ varies within a range of 1.44 and 2.12 for different races of people [10,11]. Furthermore, in our previous study, behavior of ρ value for different nature of covered faces (*e.g.* uncover, middle portion cover, lower half cover, upper half cover face) was analyzed [12]. The analysis showed that, the range, $1.44 \le \rho \le 2.12$ holds for uncover and middle portion covered faces

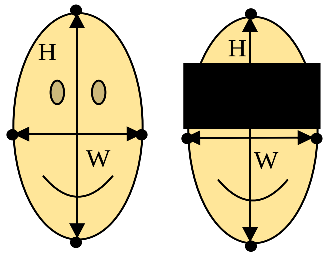

Figure 1. (a) Uncover (b) middle portion cover.

as shown in figure 1. Consequently, other nature of covered faces exceeds the range $1.44 \le \rho \le 2.12$. It is important to note that, the nature of sunglass covered face is considered as middle portion covered. By employing three facial features, the proposed algorithm requires only four edge points (top most, bottom most, left most and right most point) around facial region to evaluate presence of a sunglass. Thus the proposed method can avoid complex computation for redundant edge-points extraction of ellipse fitting method. Moreover, the algorithm includes two inspection levels to assure specific location and detection of sunglass. Also, the multilevel inspection involves less complex mathematical derivations and thresholding classification approach using covered area percentage (*CAP)*. The threshold value of *CAP* has been validated in terms of Average-Max-Min chart. Performance of the proposed method has been demonstrated in terms of correct detection rate. The correct detection rate is determined using equation (2) similar to [13].

$$Correct\ Detection\ Rate = \frac{N_{correct}}{N_{correct} + N_{incorrect}} \times 100 \quad (2)$$

where $N_{correct}$ is number of correctly detecting a case and $N_{incorrect}$ is number of incorrectly detecting the case.

The rest of the article is organized as follows. Section 2 presents the step by step description of proposed algorithm. Description of experiment including data acquisition process, experiment demonstration and discussion on result are presented in Section 3. Finally some concluding remarks have been given in Section 4.

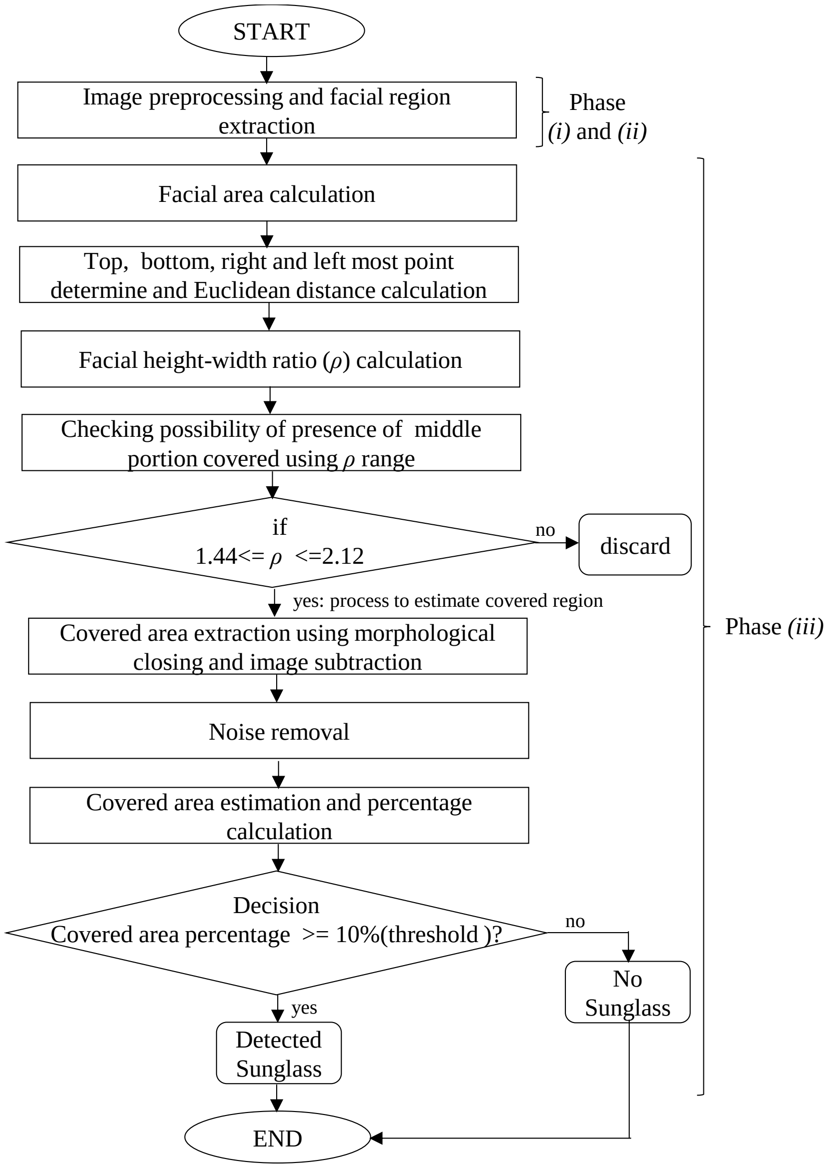

Figure 2. Flow chart of the algorithm.

2. Proposed Algorithm

Figure 2 illustrates the flow chart of the proposed algorithm that includes three phases; (*i*) image preprocessing, (*ii*) facial region extraction and (*iii*) sunglass detection. Size and illumination of input image will be normalized and reduced in the first phase. Next, facial region will be extracted using skin color information in the second phase. Finally, sunglass will be detected using the ρ feature and the area of covered face. Specifically, this phase employs two inspection levels. The first inspection level checks for the presence of middle portion covered area using ρ range. If the face image passes the first inspection with ρ range, the proposed method extracts the covered area using morphological closing and estimates the percentage of covered area. Finally, the face image experience the second inspection level using covered area percentage value to give decision for sunglass detection. Each step of the flow chart is described in details in the following subsections.

2.1. *Image preprocessing*

The input RGB images are size normalized by down sampling the original size of input image to 250x250 pixel using MATLAB function *imresize()*. Facial region is detected using skin color information in YCbCr color space, since using skin color information in YCbCr is an effective approach to detect facial region [14,15]. Note that, influence of illumination causes noise during image conversion process. Furthermore, the performance of the skin pixel classification can be improved by applying color correction process [14]. Therefore, the input RGB image is illumination compensated by using Gray world algorithm [16] prior to converting into YCbCr.

2.2. *Facial region extraction*

Skin pixel classification is performed applying thresholding approach on pixel values. Threshold value range for Cb and Cr is defined as Cb= [77 127] and Cr= [133 173]. This range has been found to be robust against different skin tone and under influence of fabric color in our previous article [17]. The facial region is extracted in the form of a binary image, B_{face}, with skin color pixel as 1(white). Then, the B_{face} is further processed to detect sunglass.

2.3. *Detection of sunglasses*

In the proposed algorithm, the area of facial region is calculated and denoted as $Area_{face}$, with the total number of 1 (white) pixel in B_{face}. Following the previous studies, the method considers the facial region extracted using skin color as elliptical shape. Then the algorithm determines four points, *i.e.* the top most point T_{point}, the bottom most point B_{point}, the left most point L_{point} and the right most point R_{point}, from the facial region in B_{face}. The algorithm calculates Euclidean distance for $d(T_{point}, B_{point})$ and $d(L_{point}, R_{point})$. The method considers $d(T_{point}, B_{point})$ and $d(L_{point}, R_{point})$ as facial region's height H and width W, respectively. The method is also used to calculate the ρ according to Equation 1 using the determined facial region's width W and height H. The algorithm verifies the calculated ρ by checking its range to specify the nature of covered face. If the calculated ρ value is found within the range $1.44 \leq \rho \leq 2.12$ then the face image is either uncover or middle portion cover. The algorithm then further evaluates the facial region to detect sunglass. The algorithm applies morphological closing operation on B_{face} to fill in the gaps in facial region. To preserve the circular nature of face shape and to fill in the largest gap inside the face the algorithm uses a disk shape structuring element of radius of 25 pixels for morphological closing. The covered region is extracted by subtracting B_{face} from the morphologically closed image. The extracted region is presented as 1 (white) pixel in the resultant image of subtraction operation. The noise is removed from the resultant image using *bwareaopen()* function of MATLAB to eliminate the extra pixels from the image after introducing morphological closing. The area of covered region, $Area_{cr}$ is calculated with the number of 1 (white) pixels of extracted covered region. The covered area percentage (*CAP)* is obtained using equation (3).

$$CAP = (Area_{cr} \times (Area_{cr} + Area_{face})^{-1}) \times 100 \quad (3)$$

If the estimated covered area percentage is $CAP > 10\%$ (threshold), it is considered that sunglass is detected. This threshold value is proven, in our experiments, to be optimal for distinguishing among uncover face, eyeglasses and sunglasses wearing faces.

Table 1. Summary of Dataset.

Cases	Lens color	Frame color	No of images
Uncover face	NA	NA	90
Eyeglasses wearing face	Transparent	Transparent, Black, Brown, Blue	90
Sunglasses wearing face	Black, Brown, Blue	Black, Grey, Brown, Blue	90
		Total images =	270

3. Experiment Design

3.1. Data acquisition

To conduct an experiment in a practical scenario we have constructed a dataset as shown in table 1. As shown in the table, three face covering cases are considered; (*i*) uncover face (*ii*) eyeglasses wearing face (*iii*) sunglasses wearing face. The lenses of the eyeglasses are transparent in color with different colored frames such as transparent, black, brown and blue. The lenses and frames of the sunglasses are mostly black, grey, brown and blue. In this experiment 270 images (90 images per case) were from 30 subjects (15 male and 15 female). Note that, indoor environment with two illumination conditions were considered; (*i*) room illumination and (*ii*) room illumination in the presence of sunlight (window side). The images are taken in three sessions; (*i*) session 1: Morning (8.00 am-10.00 am) (*ii*) session 2:Mid-day (12.00 am-2.00pm) and (*iii*) session 3: Afternoon (4.00pm-6.00pm). The subjects are instructed to sit on a chair which was placed in front of a wall white background. In addition, the subjects had to keep their back upright and face straight. We set the camera on a tripod, which is placed at a distance of 2 feet from the subject. Only frontal face of the subject has been captured. Since the proposed method down sample the images to 250x250 pixels, the method is independent to the camera resolution. The images are captured using a 5MP camera. The experiment data was analyzed with MATLABR2014a software in an Intel(R) Core(TM)i5-2400CPU, 3.10GHz computer. Some sample images of three cases are given in figure 3.

(a) (b) (c) (d) (e) (f)

Figure 3. Sample images of dataset captured under different illumination and session (a)-(b) uncover face (c)-(d) two types of eyeglasses wearing face (e)-(f) two types of sunglasses wearing face.

3.2. Experiment demonstration

This sub-section presents demonstration of the proposed algorithm on the sample images of three cases. A message box is used to show the detection result in terms of the ρ value estimation, covered area percentage estimation and the status according to the estimation. Figure 4 and figure 5 show the cases of uncover and eyeglasses wearing face, respectively. Both the cases are detected as "No Sunglass". For both cases ρ value is within the range $1.44 \le \rho \le 2.12$, but the covered area percentage (*CAP*) is below threshold 10%. Figure 6 shows the case of sunglasses wearing face and the case is detected as "Sunglass detected". In this case, ρ value is within the range $1.44 \le \rho \le 2.12$ as well as the *CAP* is greater than the threshold 10%.

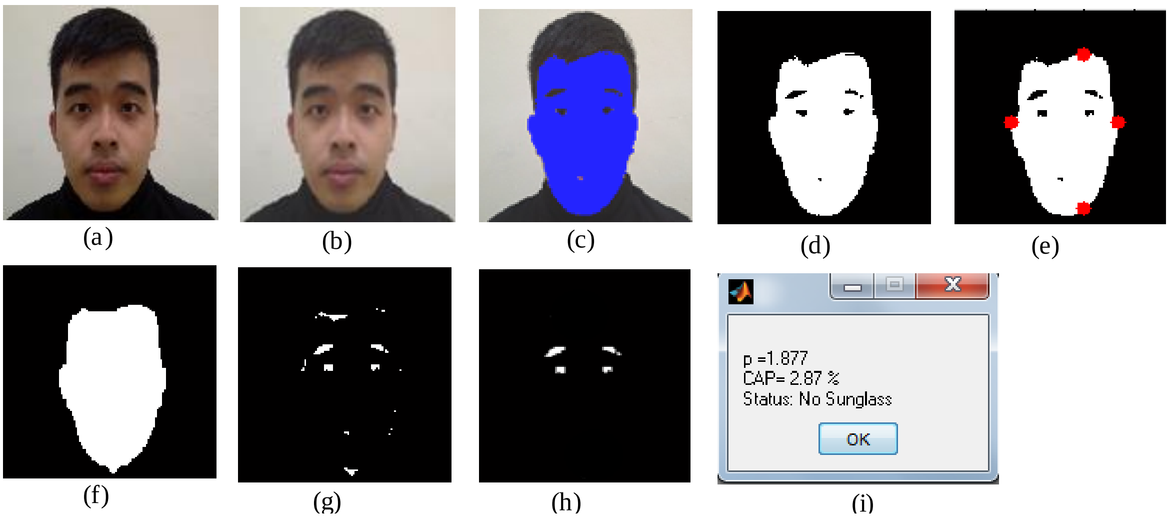

Figure 4. Application of proposed algorithm on Uncover facial case (a) input RGB image (b) illumination compensation (c) skin pixel (blue) in YCbCr color space (d) extracted facial region (e) top, bottom, left and right most point determination and ρ calculation (f) morphologically closed image (g) extracted covered area after image subtraction (h) covered area after noise removal (i) result: "No Sunglass" (right detection) since ρ value is within the range $1.44 \le \rho \le 2.12$ and *CAP*< 10%.

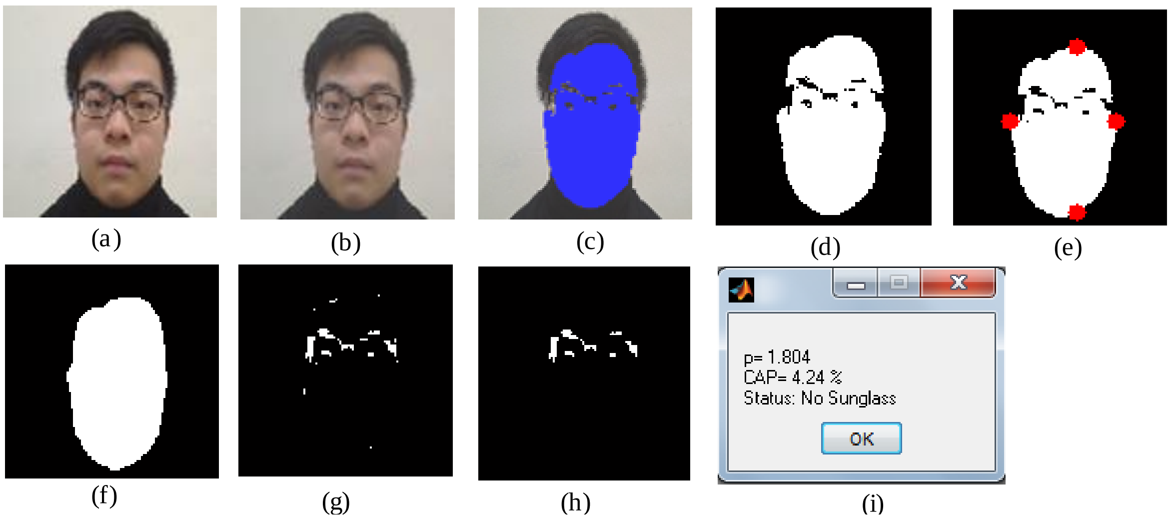

Figure 5. Application of proposed algorithm on Eyeglasses wearing facial case (a) input RGB image (b) illumination compensation (c) skin pixel (blue) in YCbCr color space (d) extracted facial region (e) top, bottom, left and right most point determination and ρ calculation (f) morphologically closed

image (g) extracted covered area after image subtraction (h) covered area after noise removal (i) result: “No Sunglass” (right detection) since ρ value is within the range $1.44 \le \rho \le 2.12$ and *CAP*< 10%.

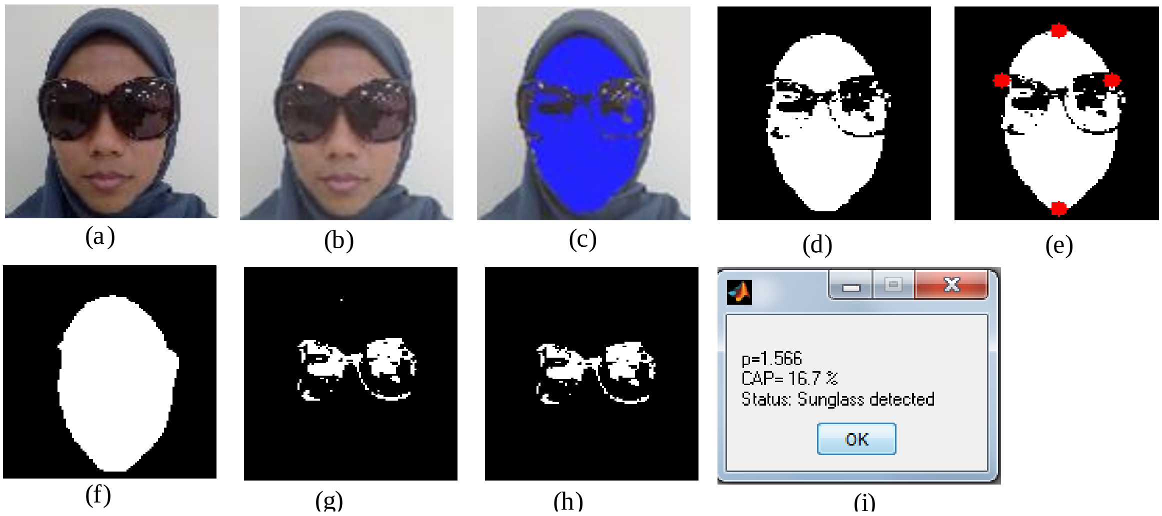

Figure 6. Application of proposed algorithm on Sunglasses wearing facial case (a) input RGB image (b) illumination compensation (c) skin pixel (blue) in YCbCr color space (d) extracted facial region (e) top, bottom, left and right most point determination and ρ calculation (f) morphologically closed image (g) extracted covered area after image subtraction (h) covered area after noise removal (i) result: “Sunglass detected” (right detection) since ρ value is within the range $1.44 \le \rho \le 2.12$ and *CAP*> 10%.

3.3. Discussion on experiment results

The experiment evaluates *CAP* value for the total 270 images of three facial cases including 90 uncover face, 90 eyeglasses face and 90 sunglasses face. An Average-Max-Min chart has been presented in figure 7. As demonstrated in the figure, the average *CAP* value for uncover, eyeglasses face and sunglasses face are 2.32%, 4.47% and 16.53%, respectively. From this result it is evident that, average *CAP* value for sunglass wearing faces is much higher than that of uncovered and eyeglasses wearing faces. Moreover, the *CAP* value ranges from around 1% to 3% for uncover face, 2% to 6.5% for eyeglasses faces and 10% to 18.5% for sunglass wearing faces. This implies that, for both uncover and eyeglasses face the *CAP* value remains less than 6.5%. On the other hand, the *CAP* value of sunglasses wearing faces is greater than 10%.

One of the reasons behind the high *CAP* for sunglass and low *CAP* for eyeglasses is the lens and frame color. Although the lenses of eyeglasses are transparent, the frames are in different color *i.e.* transparent, black, brown and blue. As a result the algorithm can easily detect skin color pixel through the transparent lens. In addition, the algorithm detects only the small area of dark colored frame as covered and hence the *CAP* is lower for eyeglasses face. The explanation is justified by the experiment demonstration given in figure 5. On the other hand, the lens and frame color of sunglasses are black, grey, brown and blue. Therefore, the algorithm cannot detect skin color pixel through the dark colored lens and detects a wider area as covered. This results in the higher *CAP* value for sunglass wearing faces. The explanation is justified by the experiment demonstration given in figure 6. Therefore, the algorithm detects a facial case with ρ value ranging between $1.44 \le \rho \le 2.12$ as “Sunglass detected”, when the algorithm also find *CAP* value greater than 10% for the facial case.

The proposed algorithm achieves 100% correct detection rate for sunglass detection with the above conditions. Figure 8 demonstrates correct detection performance of the proposed method. As depicted in the figure, the correct detection rate for uncover face and eyeglass wearing face is 93.33%. Due to some rare facial cases, where hijab fabric color surrounding the face is similar to the skin tone, the hijab is misdirected as face area [17]. Therefore, the elliptical shape of extracted facial region becomes distorted. This leads to a misapprehend ρ value and thus, the facial case is discarded during ρ value checking. However, according to our previous study [17], this limitation can be addressed by analyzing influence of different shades of hijab/niqab fabric color on skin and non-skin pixel classification and, by designing a uniform color component thresholding approach which is robust against fabric color influence. In addition, the proposed method is experimented with uniform background in the present study. Future research will be carried out for outdoor dynamic environment.

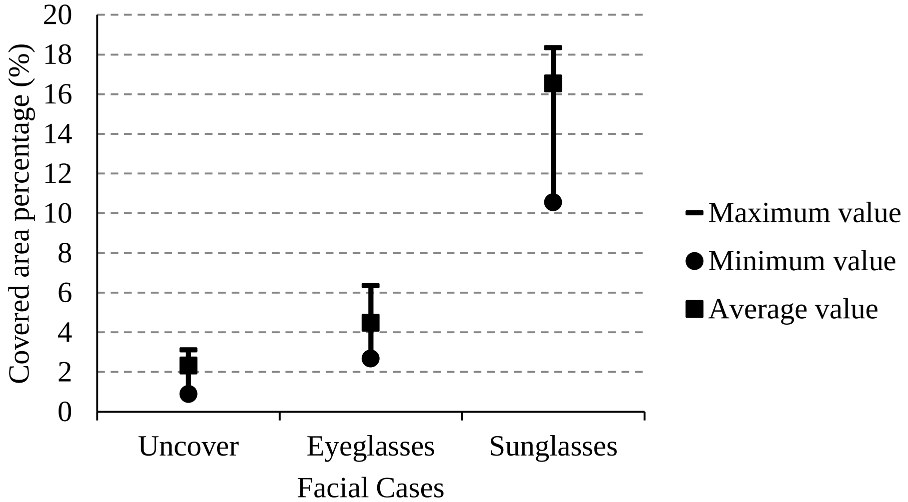

Figure 7. Average-Max-Min chart plot of covered area percentage (*CAP*) value for all the images of three facial cases.

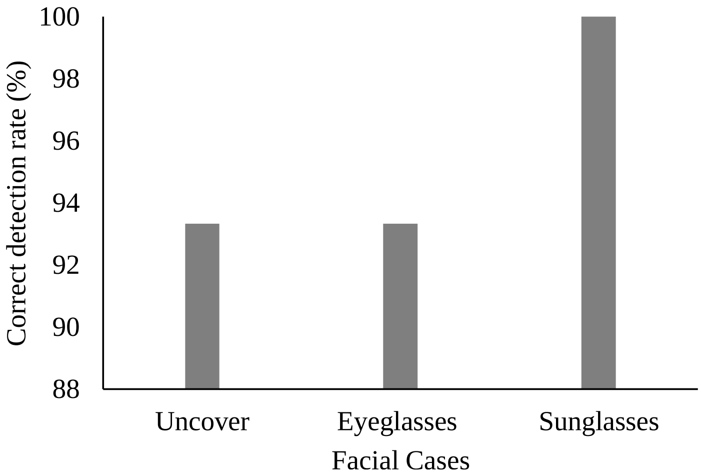

Figure 8. Correct detection performance of the proposed method.

4. Conclusion

In this paper sunglass detection method has been proposed for automation of surveillance camera. Covered area of face was calculated using a novel facial geometry called height-width ratio. The experiment was conducted in practical scenario of both room illumination and in the presence of sunlight. The result of the experiment revealed that, the sunglass can be detected in both scenarios. In addition, due to the multi-level checking on facial area, the proposed method can differentiate normal eye glass and sunglass with high detection accuracy of 93.33% and 100%, respectively. A variety of shapes for sunglass frame will be considered in future study. In addition, future research will embark on fixing the limitation of misapprehended ρ value due to similarity of hijab fabric color and skin tone of the face.

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