Video Enhancement to Reduce Reflection and Darkness Caused by the Sunglasses using Fusion Algorithm

Divya A.K, Bhagya H.K, Ujwal U.J

***Abstract:** The enhancement of video of a person wearing sunglasses to reduce the reflection and darkness is a very challenging task in computer vision applications such as video surveillance—the existence of reflections and darkness caused by sunglasses results in intrusive images. The absence of a clear eye diminishes the visible quality of the complete face image. The eyes under sunglasses are not identifiable if the reflection and darkness from the sunglasses are present. This paper demonstrates the reduction of adverse artefacts, such as reflections and darkness in the eye region, caused by sunglasses. The system is implemented using the fusion algorithm, which consists of three modules: eyeglass tracking on face images, reduction of reflection, and reduction of darkness through image enhancement methods. The image enhancement method includes a colour balance algorithm and a histogram stretching algorithm. Firstly, an automatic glasses presence detection model, based on a Robust Local Binary Pattern, identifies the imaging process of the ocular region covered by the sunglasses. Secondly, a non-convex optimization scheme, guided by landmarks on the glasses, effectively reduces reflections through several iterations. The image enhancement method, incorporating Colour Balance and Histogram Stretching, is used to identify eye regions within sunglasses. The resulting regenerated eye regions within sunglasses exhibit increased brightness, subtle darkness, and minimized reflection. Objective evaluation metrics, such as peak signal-to-noise ratio, structural similarity index measure, and logarithmic mean square error, are used to assess the strength of the proposed system. Qualitative evaluations are conducted to demonstrate the sound quality of eyeglass face images with reduced reflection and darkness.*

***Keywords:** Colour balancing, Histogram Stretching, Non-convex Optimisation, Robust Local Binary Pattern.*

I. INTRODUCTION

Enhancing videos has long been a focal point in specific and dominant regions, aiming not only to improve visual aesthetics but also to optimize performance in terminal tasks. The visible quality of the degraded footage is improved using video improvement techniques.

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The most active study areas in computer vision and pattern recognition [2] over the last ten years are statistical learning-based methods that have been applied to face analysis and synthesis. The standard techniques for face identification and detection are eigenface [3], neural networks [4]-[5] [22], and support vector machines [6]. Even though many individuals wear glasses, the majority of approaches require extracting facial features, such as the eyebrows and nose, using a non-glasses assumption on human faces. It is crucial to examine sunglasses for face detection, recognition, and synthesis, as it may be challenging to study a person wearing glasses if a "facial detector training" approach is used or if an identification system misidentifies them. People often avoided using sunglasses in facial identification systems for some reason. First, different material qualities [17], such as those of metal and plastic, present the distinctive appearance of glass frames. Second, unlike human skin, glasses have quite different reflective qualities. In some instances, the reflection on the glasses is the brightest part of the face. Third, while glasses are always adhered to the face and blend with the eyebrows, faces are always clearly differentiated from their backgrounds. Thus, eyewear detection may not benefit from tracking approaches.

Effective mechanisms for reducing reflection and darkness in sunglass images remain a significant challenge. Only minimal research has been done on eyeglasses for reducing reflection and darkness. The eye regions of the individual wearing sunglasses are invisible in the video, and they cannot be distinguished. Due to the darkness of the sunglasses, the eye areas will appear dark. Only a part of the light passes through sunglasses when it is incident on them. The area around the eye region will darken for this reason. Additionally, the sunglasses are highly reflective. Such reflection further lowers the video quality. By covering the glasses with an anti-glare material [18], these problems can be fixed. It might, however, cost more than a pair of sunglasses. Overall, improving video quality by reducing reflection and darkness poses a significant challenge, yet it is imperative for advancing overall video quality. Enhancing video clarity by mitigating darkness and reflections presents a growing challenge that requires effective strategies, particularly in identifying individuals wearing dark eyewear.

The proposed system requires a dataset that provides person faces with sunglasses. As this problem is rarely investigated in current literature, it is challenging to find some publicly available face databases.

The proposed system demonstrated 100 real-time databases of people wearing sunglasses. This database includes facial images with various sunglasses, featuring different levels of reflection and darkness. Evaluations and user research indicate a significant improvement in the quality of photos taken with the sunglasses.

II. LITERATURE REVIEW

Work involving eyewear photos and videos has been rare. The majority of studies have focused on the recognition, localisation, and removal of spectacles. Wu et al. [7] study, which sought to remove eyeglasses in facial photos automatically, is among the most intriguing ones. It uses a boosting-based algorithm to find eyeglasses. The removal of eyeglasses is then done using a statistical analysis and synthesis approach based on training data. With the training samples set, it is challenging to model the reflection using this method. Additionally, this method struggles with strong reflections. Yuan-Kai Wang et al. [8] introduce the Active Appearance Model (AAM) to eliminate eyeglasses from facial images. The locations where glasses occlude are found via an AAM search. The ellipse model is used to fit the location of the eyes, and then the adaptive threshold method is applied to enhance and remove the residual regions. The Principal Component Analysis (PCA) reconstruction method by J-S Park et al. [9] is utilized to remove the eyeglasses from the facial images to generate natural-looking facial photos. It removes various types of occlusions caused by eyeglasses. Liang et al. [10] applied the CTV (Color Total Variation) inpainting approach for the reconstruction of the glass region. The Deep Learning approach can reduce the noise from glasses.

Secondary image forms, glare, and occlusion by spectacles compromise the efficiency of eye detection. Using an in-depth analysis strategy, M Z Lazarus and S Gupta [11] suggested a Low-Rank Decomposition method to remove the glare and spectacle reflections. In this instance, the face alignment is typically not accurate. A non-convex optimization scheme by Tushar Sandhan, and Jin Young Choi [12] removes the reflections from eyeglasses. The experiment is conducted on frontal face image inputs, resulting in high-quality reflection removal and an improvement in the iris detection rate. Mao Ye et al. [1] presented a technique to reduce the undesirable artifacts caused by 3D glasses. A Bayesian model is used to minimise reflection and darkness in 3D glass images. The eye regions under glasses are identified by the Classification Expectation-Maximization method.

The underwater image dehazing algorithm introduced by Yu et al. [14] combines three main steps of homomorphic filtering, double transmission map, and dual-image wavelet fusion, used to intensify the underwater image. Real-world Underwater Image Enhancement (RUIE) by R.Liu et al. [15] evaluates the effectiveness and limitations of various algorithms to enhance visibility and correct color cast on images with hierarchical categories of degradation. A novel approach by O.G.Powar [16] to enhance underwater images by distance factor estimation along with a dehazing algorithm and histogram equalization, the dark channel before removing haze and noise effect, adaptive histogram equalization brightness of dehazed image is recovered. A fusion algorithm introduced by Weilin Luo et al. [13] with color balance, and histogram stretching is implemented for the enhancement of underwater images.

III. PROPOSED METHODOLOGY

The proposed system lightens and reduces reflection from sunglass images. This proposed framework is implemented using a fusion algorithm that incorporates tracking the position of sunglasses, reflection reduction, and image enhancement to reduce darkness, as shown in Figure 1. It focuses on the frontal face without any facial expressions, aiming to minimise reflection and darkness to identify the eye region under sunglasses better. This work includes three steps. First, track the position of the sunglass on the face in the images. For such a purpose, a model-based Robust Local Binary Pattern is developed. Second, a model that employs a non-convex optimisation approach is utilised to minimise the reflection. Third, colour balance and Histogram Stretching are adapted to enhance the image and identify the eye region within the sunglasses. Finally, the improved frame is regenerated with reduced reflection and darkness.

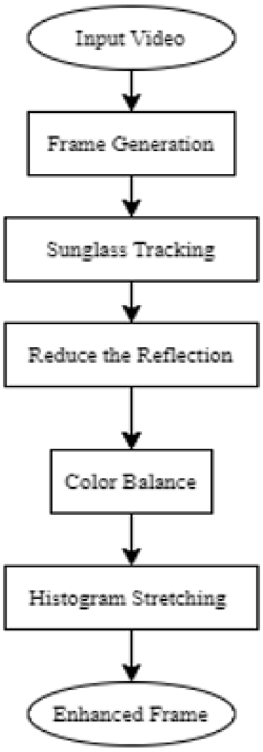

Fig. 1. Architecture of Proposed Method

A. *Sunglass Tracking*

Factors such as wearing glasses or sunglasses can hinder the reliable measurement of eye shape or intensity characteristics. However, context features prove highly valuable for localising eyes because they maintain firm relationships with other facial features in terms of both appearance and structural distribution. Initially, a face normalization algorithm is employed to isolate the eye region. Subsequently, Local Binary Patterns (LBP) and Robust LBP techniques are utilised to extract feature sets.

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This method recognises the eight facial landmarks. Four points are used to create a regression line to determine the alignment angle: the left outer eye, the left inner eye, the right outer eye, and the right inner eye. The faces in each image are then aligned and rotated to ensure that the eyes are in the exact location in each image. Then, in the original image, the area surrounding the eyes is computed. The corresponding area is cropped from the rotated image after the coordinates for the eyewear region's corners are found. Finally, a Support Vector Machine (SVM) is employed for classification. The SVM categorizes extracted feature histograms from normalized eye regions into two classes: glasses and no glasses. Thus, various types of glasses (e.g., sunglasses, sports glasses, reading glasses, safety glasses) are treated as belonging to the same category. SVMs are recognised for their efficiency in data classification and have demonstrated utility across various pattern recognition approaches, including facial recognition systems.

B. Non-Convex Optimization

The lack of clear visibility of the eyes not only diminishes the aesthetic appeal of a full-face image but also poses challenges for various computer vision problems. Even minor reflections can result in an unwanted overlay of visual information. In contrast to the thick and flat window glass, eyeglasses are thin, curved, and made from a variety of materials. An Anti-Reflective Coating (ARC), a transparent thin film, is applied to eyeglass lenses to enhance light transmission and reduce surface reflectance. The fundamental operation of ARC is represented in Figure 2.

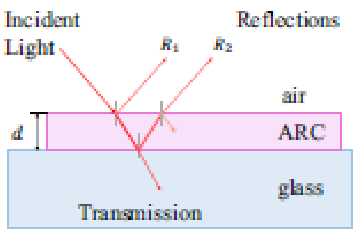

Fig.2. Anti-Reflective Coating

Since α<1, for a fixed I_{R_t}Zj can be updated for each pixel as,

$$z_{t+1}^{j} = argmin_{z^j}\left\{|z^j|^{\alpha} + \frac{\beta}{2}\left(z^j - D_i^j\, I_{R_t}\right)^2\right\} \qquad (1)$$

where z_t^j Is the auxiliary variable at each pixel?

Since this is a single variable optimization problem, it can be rapidly solved by using a lookup table-based implementation, which maps the values from $D_i^j\, I_{R_t}$ to z^j. We fill the Look Up Table (LUT) by generating 104 different gradient values between -0.4 and 0.4 for α = 0.6 and various other values. β. If the required value is missing from the LUT, it is determined through interpolation.

We further apply 2D FFT $\mathcal{F}$ to find the optimal update I_{R_t} quickly as given below in (2), where ϵ (= 10-16) avoids division by 0, $\overline{\mathcal{F}(.)}$ is a complex conjugate $\mathcal{F}(.)$, $\bar{1}$ It is a vector of the same size as I, with all elements set to 1. The operation o denotes element-wise multiplication, and division in (2) is also performed element-wise. Only $\mathcal{F}(z_t^j)$ It is computed at each iteration, whereas the remaining terms are precomputed once.

$$I_{R_t} = \mathcal{F}^{-1}\left(\frac{\lambda\sum_{j\in\mathbb{J}_\beta}\overline{\mathcal{F}(D^j)}\circ\mathcal{F}(D^j)\circ\mathcal{F}(I) + \beta\sum_{j\in\mathbb{J}_R}\overline{\mathcal{F}(D^j)}\circ\mathcal{F}(Z_t^j) + \gamma\mathcal{F}\left(\widetilde{W_{af}^T}\widetilde{W_{af}}I\right)}{\lambda\sum_{j\in\mathbb{J}_\beta}\overline{\mathcal{F}(D^j)}\circ\mathcal{F}(D^j) + \beta\sum_{j\in\mathbb{J}_R}\overline{\mathcal{F}(D^j)}\circ\mathcal{F}(D^j) + \gamma\mathcal{F}\left(\widetilde{W_{af}^T}\widetilde{W_{af}}\bar{1}\right) + \epsilon}\right) \qquad (2)$$

Constraints can be satisfied by adding the adaptive normalizing constant. ξ to I_{R_t} at each iteration, such that (ξ + $I_{R_t}[i]$) falls within $[\kappa\Gamma_t[i],\ I[i]]$. The ξ can be derived by solving the following,

three

$$min_{\xi}\sum_i \mathcal{U}\left(\xi + I_{R_t}[i] - I[t]\right)^2 + \mathcal{U}\left(\kappa\Gamma_t[i] - \xi - I_{R_t}[i]\right)^2 \qquad (3)$$

where $\mathcal{U}(x)$ is the general unit step function (i.e. $\mathcal{U}(x) = 1\ \forall_x > 0\ otherwise\ \mathcal{U}(x) = 0$), which penalizes only those elements that violate the constraints. After solving (3) by simple gradient descent, we update I_{R_t} For all I as $I_{R_t}[i] = \xi + I_{R_t}[i]$. Algorithm 1 summarises the entire optimisation scheme for reducing eyeglass reflection.

Algorithm 1: An Optimization Framework

Input: input image I; optimization weights λ, γ; total number of iterations T

Initialize: $I_{R_0} \leftarrow I, \beta = \beta_0$

For iteration t from 1 to T do

Update Z_t^j using (1)

Update I_{R_t} using (2)

$\beta = 2\beta, K = \frac{t}{T}$

Update $I_{R_t} = I_{R_t} + \varepsilon\bar{1}$ using (3)**Output:** reflection reduced image $(I - I_{R_t})$

C. The Fusion Algorithm

To enhance the sunglass region, a fusion algorithm is employed, which combines colour balancing and histogram stretching. To counteract any colour shifts in the image, scalar values of the Red, Green, and Blue channels are updated. Additionally, a technique known as "histogram stretching" is applied to the red channel to enhance the contrast and brightness of the images.

To mitigate colour shift effects, a colour balance algorithm is introduced. This algorithm ensures that the histogram's single-channel values in each colour channel of an image are adjusted to align at comparable positions. This approach begins by computing the average single-channel values for the three components: Red, Green, and Blue, denoted as m_R, m_G, and m_B, respectively.

Next, the average scalar value of the mean single channel values from the Red (R), Green (G), and Blue (B) channels can be derived as follows:

$$m_{ave} = \frac{(m_R + m_G + m_B)}{3} \qquad (4)$$

The difference between the average single channel m_R, m_G, m_B, and the mean scalar value m_{ave} can be calculated as:

$$\begin{cases} d_R = m_{ave} - m_R \\ d_G = m_{ave} - m_G \\ d_B = m_{ave} - m_B \end{cases} \qquad (5)$$

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Ultimately, the single channel values of the red, green and blue channels can be adjusted to align at similar positions through:

$$\begin{cases} R' &= R + d_R \\ G' &= R + d_G \\ B' &= R + d_B \end{cases} \tag{6}$$

Where R', G', and B' represent the pixel values of the R, G, and B channel components of the processed image, respectively.

To enhance the contrast and brightness of an image, histogram stretching is performed. A common issue encountered with many image enhancement algorithms is the tendency for excessive compensation in the red channel. In this approach, a histogram stretching algorithm tailored explicitly to the red channel is introduced. This algorithm adjusts the histogram stretching process based on the intensity of red light. A scalar value threshold, denoted as R, is established to assess the depletion of red light. Initially, the average single channel value, denoted as R_{ave}, of the red channel, is calculated as:

$$R_{ave} = \frac{1}{n}\sum_{1}^{n} R_i \tag{7}$$

Where R_i is the single channel value of every pixel, and n is the total number of pixels.

Next, R_{ave} is compared to the threshold R to assess the depletion of red light. If $R_{ave} \geq R$, the depletion of red light is considered minimal. Conversely, if $R_{ave} < R$, the depletion of red light is deemed significant. In the event of minimal depletion, histogram stretching is applied to all three channels: R, G, and B. However, when the depletion of red light is significant, histogram stretching is solely applied to the G and B channels, leaving the R channel unaltered to avoid overcompensation.

The histogram stretching accepts the algorithm as:

$$I_{new}^c(i,j) = \begin{cases} 0 & I_{old}^c(i,j) < i_{min}^c \\ 255 \times \dfrac{I_{old}^c(i,j) - i_{min}^c}{i_{max}^c - i_{min}^c} & i_{min}^c \leq I_{old}^c(i,j) \leq i_{max}^c \\ 255 & I_{old}^c(i,j) > i_{max}^c \end{cases} \tag{8}$$

Where c is with R, G, B channels if $R_{ave} \geq R$, while G, B channels if $R_{ave} < R$; i_{min} the minimal value; i_{max} the maximal scalar value; $I_{new}^c(i,j)$ Represents the updated scalar value at pixel point (i, j) after the histogram is stretched; $I_{old}^c(i,j)$ Is the original scalar value at the same point? Both the minimal i_{min} and maximal i_{max} scalar values are determined through a threshold of pixel number ht. The satisfactory threshold h_t is selected as n × 0.255% based on trials.

IV. RESULT AND DISCUSSION

Three algorithms are introduced to address images of individuals wearing sunglasses. Initially, Robust LBP with SVM is employed to locate the regions of sunglasses in facial images. Subsequently, a non-convex optimization algorithm is utilized to mitigate reflections. Lastly, histogram stretching, focusing on the red channel, is implemented to enhance the brightness and contrast of the sunglass images.

Results are presented in Figure 3. The images under different brightness levels are considered. Figure 3a is the input image with reflection and darkness. Figure 3b shows the result of the processed method, which is a clear, enhanced image. The pictures with more reflection, as in images 1 and 4, result in poor performance. The pictures with less reflection, such as images 1, 5, and 7, yield good performance.

1

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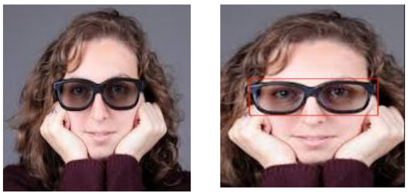

(a) (b)

Fig. 3. Results of Various Sunglass Images. (a) Input Images, (b) Enhanced Images

As human subjective consciousness can affect the assessment of visual effects, objective evaluation becomes essential to authenticate the enhancement techniques implemented in image processing. The study employs several classic objective evaluation metrics, namely PSNR (Peak Signal-to-Noise Ratio), SSIM (Structural Similarity), and LMSE (Logarithmic Mean Square Error). Typically, higher contrast correlates with better image quality. In this study, RMS contrast is utilized and takes the following form:

$$\sigma_{I_{w\times h}} = \sqrt{\frac{1}{w\times h}\sum\left(I(x,y) - \frac{1}{w\times h}\sum I(x,y)\right)^2} \quad (9)$$

where $\sigma_{I_{w\times h}}$ Is the RMS contrast of an image with the dimension of $w \times h$; $I(x,y)$ Is the pixel value at the point (x, y). Peak Signal-to-Noise Ratio (PSNR) [19] stands as a widely adopted objective measure for image assessment, relying on pixel error analysis. A correlated error sensitivity can be established to gauge the satisfaction level of processing outcomes. A higher PSNR value indicates less distortion. The formulation of PSNR can be expressed as:

$$MSE = \frac{1}{w\times h}\sum_{i=0}^{w-1}\sum_{j=0}^{h-1}[I(i,j) - K(i,j)]^2 \quad (10)$$

$$PSNR = 10 \times \log_{10}\left(\frac{(2^n - 1)^2}{MSE}\right) \quad (11)$$

Where I is a processed image with the dimensions $w \times h$ While K is the original image with the exact dimensions, MSE represents the loss function. N represents the number of bits per pixel, typically considered to be 8. Structural Similarity Index Measure (SSIM) [20] serves as an index for assessing the similarity between two digital images. Generally, a higher SSIM value indicates less distortion in the image. It relies on three comparison metrics between images x and y: luminance (L), contrast (C), and structure (S).

$$SSIM(x,y) = l(x,y)c(x,y)s(x,y) \quad (12)$$

Logarithmic Mean Square Error (LMSE) [21] is a metric for assessing the quality of images, which calculates the difference between two images. It is helpful for images with a dynamic range, such as in high dynamic range imaging. LMSE is designed to reflect the logarithmic nature of human visual perception, where the human eye perceives differences in brightness logarithmically rather than linearly. Zero LMSE indicates perfect similarity between the images. It increases with a greater difference. LMSE is formulated as follows:

$$LMSE = \frac{1}{N}\sum_{x}\left(I_{log}^{ref}(x) - I_{log}^{dist}(x)\right)^2 \quad (13)$$

Where N represents the total number of pixels, I_{log}^{ref} is the transformed reference, and I_{log}^{dist} It is the transformed, distorted image. Table 1 presents the evaluation metric results obtained through PSNR, SSIM, and LMSE for seven images analyzed to assess visual effects. Generally, it is noted that the proposed method demonstrates superior performance.

Table I. The Processed Image Evaluated by Metric PSNR, SSIM, and LMSE

Input Images	Proposed PSNR	SSIM	LMSE
1	26.361	0.5673	0.435
2	19.6782	0.8542	0.245
3	24.9471	0.6892	0.410
4	22.056	0.8834	0.205
5	27.302	0.5342	0.453
6	25.2046	0.5672	0.437
7	30.4849	0.7437	0.492

V. CONCLUSION

A Fusion algorithm incorporating RLBT, Non-Convex Optimisation, Colour Balance, and Contrast Stretching is proposed to reduce the reflection and darkness present in sunglass images. RLBT, including SVM, identifies the region of the sunglasses on face images. The Non-Convex Optimisation technique reduces the reflection present on the sunglass. The Colour Balance and Contrast Stretching techniques enhance the sunglass region by adjusting the brightness level. The result of the proposed method is the enhanced image where we identify the eye region within the sunglasses. This experiment improves the visual quality of sunglasses. The experiments state the effectiveness of the proposed method. In addition to visual effect assessment, objective metrics such as PSNR, SSIM, and LMSE are employed to gauge the efficiency and strengths of the proposed fusion algorithm. The algorithm proposed here demonstrates superior enhancement compared to others. Ensuring real-time performance, particularly when handling images of sunglasses with high levels of reflection and darkness, cannot be guaranteed. Future endeavours will focus on refining the algorithm to eliminate reflection and darkness, while also enhancing its real-time performance.

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