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Removing Smoke from a Medical Video is Achieved Via Image Restoration

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Abstract. The high contrast for images and videos taken for a human body by the medical apparatuses is quite important to diagnose the patient case perfectly. The video testing is for gallbladder removed surgery using laparoscopy. The system that is proposed to process distorted videos-that been exposed to a distortion source- results in high brightness that affects the vision quality. The occurred distortion is not extensive, but it affects a limited part of the image. The frames of the video are restored based on displacement map calculation for each frame in the video. This displacement map describes an image that consists of values representing the difference between two frames. Moreover, these values are the distortion level added to every pixel in the image. The distant map is generated by a process so- called "Normalization" to convert its values from/to [0-1]. That calculation describes the distortion value experienced by video, on the other hand, global atmospheric that represents such a further brightness source affecting the video. The quality metrics such as Signal-to-Noise-Ration (SNR), Peak-Signal-To-Noise-Ration (PSNR) and Mean-Square-Error (MSE) are calculated on the basis of video and image frames for every frame in the video before and after the processing. The results showed that the proposed system is high-performing in terms of restoring every frame in the processed video.

Keywords. Image Restoration, Degradation Model, Medical Video.

INTRODUCTION

Digital video has become an integral part of everyday life. It is well-known that video enhancement as an active topic in computer vision has received much attention in recent years [1]. The main purpose of video enhancement is to supply viewers a good visual appearance to help them get objects' perception in videos sufficiently [2]. During data acquision some information is lost or changed causing bad visual quality blurring in satellite digital images. The sources of image degradation include lens point spreading, misfocus, motion, and atmospheric turbulence [3]. Degradation estimation is an important process for image restoration. The precise identification of the degradation type and level facilitates the subsequent restoration process because this approach allows the restoration problem to be considered a nonblind problem rather than a blind problem [4]. Image restoration is an emerging field of image processing in which the focus is on recovering an original image from a degraded image. Image restoration can be defined as the process of removal or reduction of degradation in an image through linear or non-linear filtering. Just as in image enhancement, the ultimate goal in restoration is to improve an image. Enhancement is a subjective process while restoration is an objective process [5]. Degradation Model an image can be caused by factors such as: Blur model and noise model. The blur model caused by motion, defocus, and the noise model caused by Gaussian noise, Salt and pepper noise and other types of noises [6].

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EXPERIMENTAL PART

Our proposed system is based on the typical computer vision approach for video restoration. It is designed based on three main tasks. The main tasks of our proposed approach are described and illustrated in Figure (1). The first task is based on importing different operation videos using different medical instrument's imaging systems video to record the entire operation and export different video extensions such as *.AVI, or *.MP4. During the first task, the recorded video is converted to a sequence of frames (images) and export them (save them) in a different folder. The second task of our first proposed system enhances and processes each single frame (image) that is extracted from the first step. Each enhanced frame (image) is exporting (saving) in a different subfolder. The last task (third one) of our proposed system is to re-construct the final output video based on using the enhanced frames and produce the final output video.

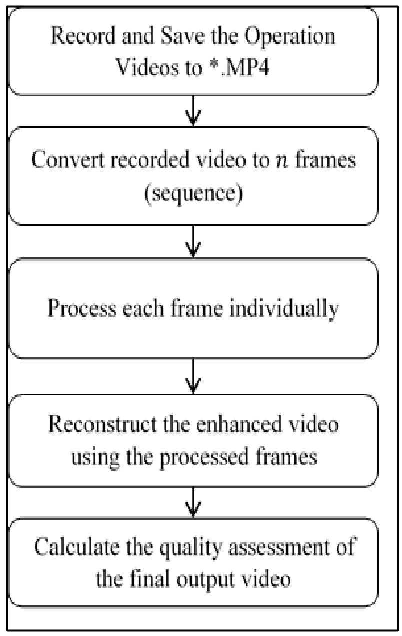

FIGURE 1. First Proposed Medical Video Restoration and Enhancement System Framework.

Our proposed system has three main stages. The first stage is the pre-processing stage, in this stage, the recorded operation video is converting to a sequence of frames (set of images). This stage is designed to process each frame (image) individually. The second stage is the processing stage (restoration and enhancement). In this stage, each individual frame is processed (restored/enhanced) by removing the cause of the degradation such as the fog (light) or the smoke. In this stage, we propose an unsupervised approach to enhance and remove the smoky for the operation frames based on the *dehazing* approach. The final stage (third one) is the post-processing stage. In this stage, the output video is reconstructed relying on the enhanced image frames. After recollecting all the processed frames, the final output video will display automatically. The framework of the first proposed system has three main stages that are:

- **Stage 1: Video Preprocessing (Video Frame Images Extraction)**

In this stage, the whole testing video is converting to sequence of images (frames), the outcome of this stage (single video frame set) is used in the next stage which is restoration and enhancement stage.

- **Stage 2: Video Restoration/Enhancement**

In this stage, each frame that is extracted from the testing video is enhanced and restored individually. We based on the computer vision approach using digital image restoration model to enhance each frame. Our approach is based on the unsupervised (unguided) image restoration to remove the Smokey atomosphic without any prior knowledge or learning scheme. This stage has different steps such as displacement image map extraction, distance map calculation, atmospheric estimation, and image restoration. The displacement image map is the transformation map that used to extract the additional amount of light (smoke) that each region in each image has without any prior knowledge about the degradation model or factors. Second, the displacement map is converted to the transformation map (distance map) that is used later to adapt out restoration approach for enhance and restore both light (which is in our case is called noise) and the blurring factors. Finally, each frame is stored based on the two calculated factors. The main process to extract the displacement map is given in equation (1) [7].

$$J^{displacement}(x) = \min_{y \in \Omega(x)} \left(\min_{c \in \{r,g,b\}} J^{c}(\mathrm{y}) \right) \tag{1}$$

Where $J^c(\mathrm{y})$ represents a color image for each single channel, $\Omega(x)$ represents the intensity pixel value of the window center that will be replaced in the gray scale image.

The whole approach of extracting and calculating the displacement map is based on the specific sliding window that goes over each single frame of each single color channel (RGB). Then, the minimum value of the light intensity value is obtained from each window and replaced as a center of the output grayscale image. The image restoration has been widely used to restore images that have been degraded by a known degradation model blurred and noise. To significantly restore each frame in the smoky (operation video that has a lot of light), we need to estimate the two degradation factors. The typical restoration model that is given in the equation (2) [8].

$$I(x) = J(x)\, t(x) + A\,(1 - t(x)) \tag{2}$$

Where $I(x)$ represents the degraded image frame (image that is smoky or has a lot of light), $J(x)$ is denoted as the original image frame (or the frame image that has no smoke or light), and A is denoted as the global light (or the global atmospheric light). The atmospheric light is the external resource that effect on each frame mage and added lighter to each image frame, and $t(x)$ is denoted as the transmittance map.

We assume that in each sub-window k that is used to extract the displacement map or we called it as a transmittance$\tilde{t}(x)$.The transmittance map is yielding to equation (3) [9].

$$\tilde{t}(x) = 1 - \min_{y \in \Omega(x)} \left(\min_{c} \frac{I^c(y)}{A^c} \right) \tag{3}$$

Transmission map estimation step that uses the displacement map (dark channel) to estimate the degradation factors after requires the normalization step using z-score normalization. The global atmospheric image light in our restoration approach represents A which is the global light factor (noise) that is obtained from the Smokey video (from each frame) during the operation. In this case, A is calculated based on finding the corresponding location of the dark spots in the original image. That means, the luminance value of each point (sub-region). In this case, we calculate the luminance value by finding the mean of each sub-region (mask) that is used to calculate or extract the dark image as is describing in equation (4).

$$A = \underset{y \in \Omega(x)}{mean} \left(J^{\mathrm{displacement}}(x) \right) \tag{4}$$

After both degradation factors are calculated and estimated based on the transmission map estimation $\tilde{t}(x)$ using equation (3). Also the global atmospheric image light A is estimated based on using equation (4), and the degraded image is already exist (which in our case is the video frames), now the degraded image $I(x)$ is known. Frames image restoration step that is used based on using both equation (3) and (4) is described in equation (5) [10].

$$J(x) = \frac{I(x) - A}{t(x) + A} \tag{5}$$

The final enhanced video is reconstruct again based on using the outcome of the second stage (frame image enhancement). This stage takes each single frames and starts to build the restored video. Figure (2) shows some examples of the proposed system video enhancement and restoration step using testing video gain.

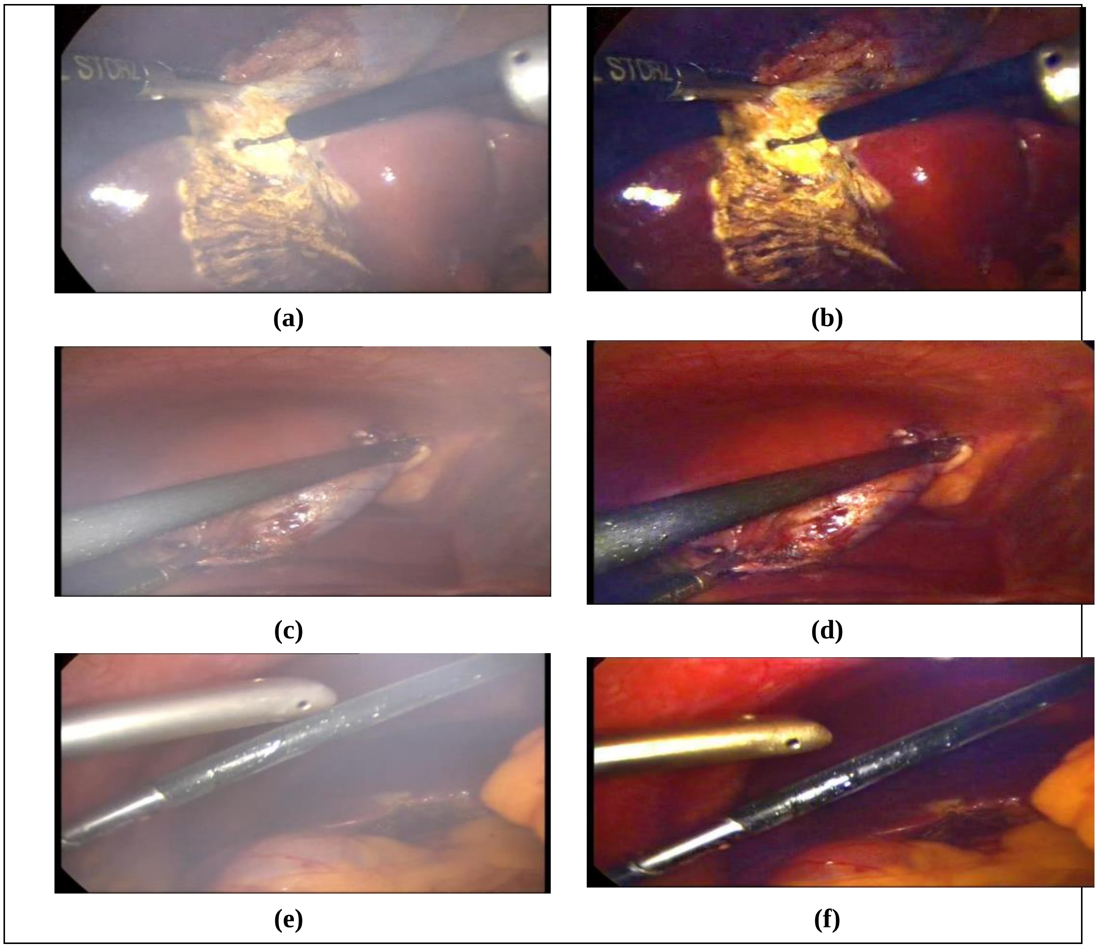

FIGURE 2. Image frame restoration results, (a), (c), and (e) original frames that are extracted from the testing videos, (b), (d), and (f) enhanced and restored image frames.

- **Stage 3: Video Post-processing (Frames to Video)**

The final enhanced video is reconstruct again based on using the outcome of the second stage (frame image enhancement). This stage takes each single frames and starts to build the restored video gain. Figure (3) shows some examples of the third and final step (post-processing stage) using different testing videos.

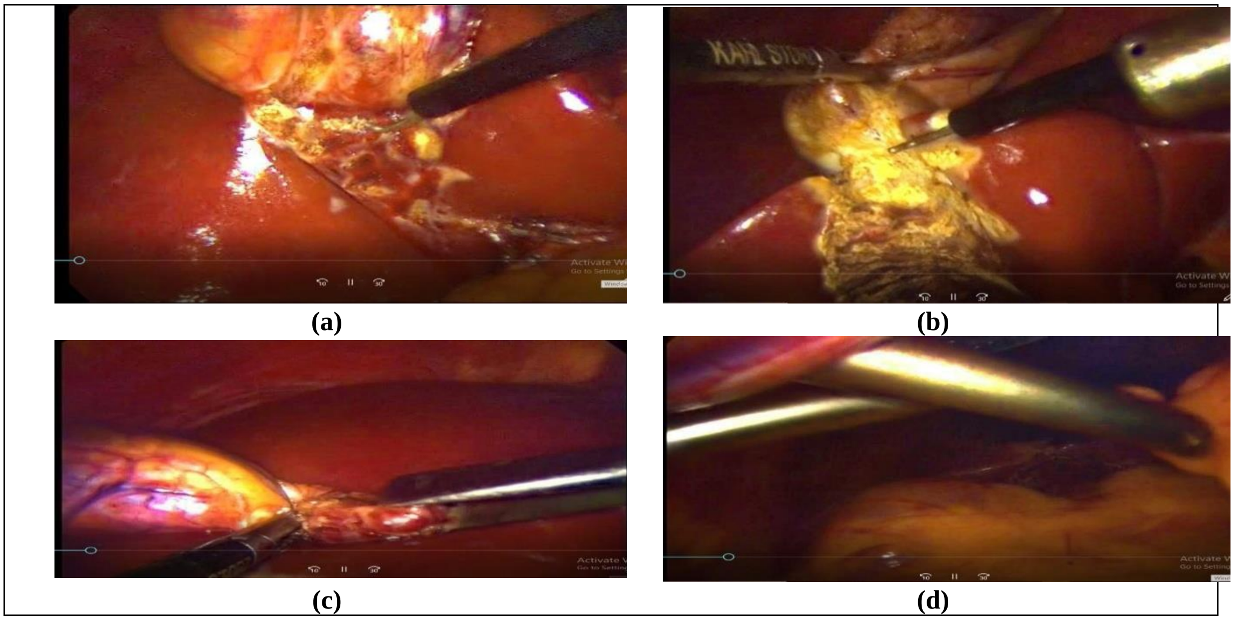

FIGURE 3. Post processing stage result, (a)-(d) final enhanced and restored video.

RESULT AND CONCLUSION

The performance evaluate of our proposed system based on the evaluate experiential results using different criterias such as Signal-to-Noise-Ration (SNR) [11], Peak-Signal-To-Noise-Ration (PSNR) [12] and Mean-Square-Error (MSE) [12] that illustrates in equations:

$$SNR \ = \ 10 \ log_{10} = \frac{mean \ [I(x,y)]}{SD \ [I(x,y)]} \tag{6}$$

Where $I(x,y)$ is input image, SD is the standard deviation.

$$PSNR = 10 \ log \left(\frac{D^2}{MSE}\right) \tag{7}$$

Where D denotes the dynamic range of pixel intensities, MSE is the Mean squared error which denotes the power of the distortion.

$$MSE \ = \frac{1}{MN} \sum_{j-1}^{M} \sum_{i-1}^{N} (I_{ref}(i,j) - I_{tst}(i,j))^2 \tag{8}$$

Where M and N size of image, $I_{ref}(i,j)$ is original image, $I_{tst}(i,j)$ Enhanced image.

In term of measure the quality of our proposed system experiential results visually, we use the image histogram to illustrate the difference between the original and processed results for each single frame in different individual testing video. Figure (4) shows a sample of the experimental results of the video enhancement and restoration using testing video that is taken. We notice that the image frame that is shown (c) is significantly enhanced and restored as well as its histogram (d). Comparing with the original image and its histogram (a) and (b). We can also notice that the histogram of the processed image frame that is shown in (d) is well distribute more than the original one that is shown in (b).

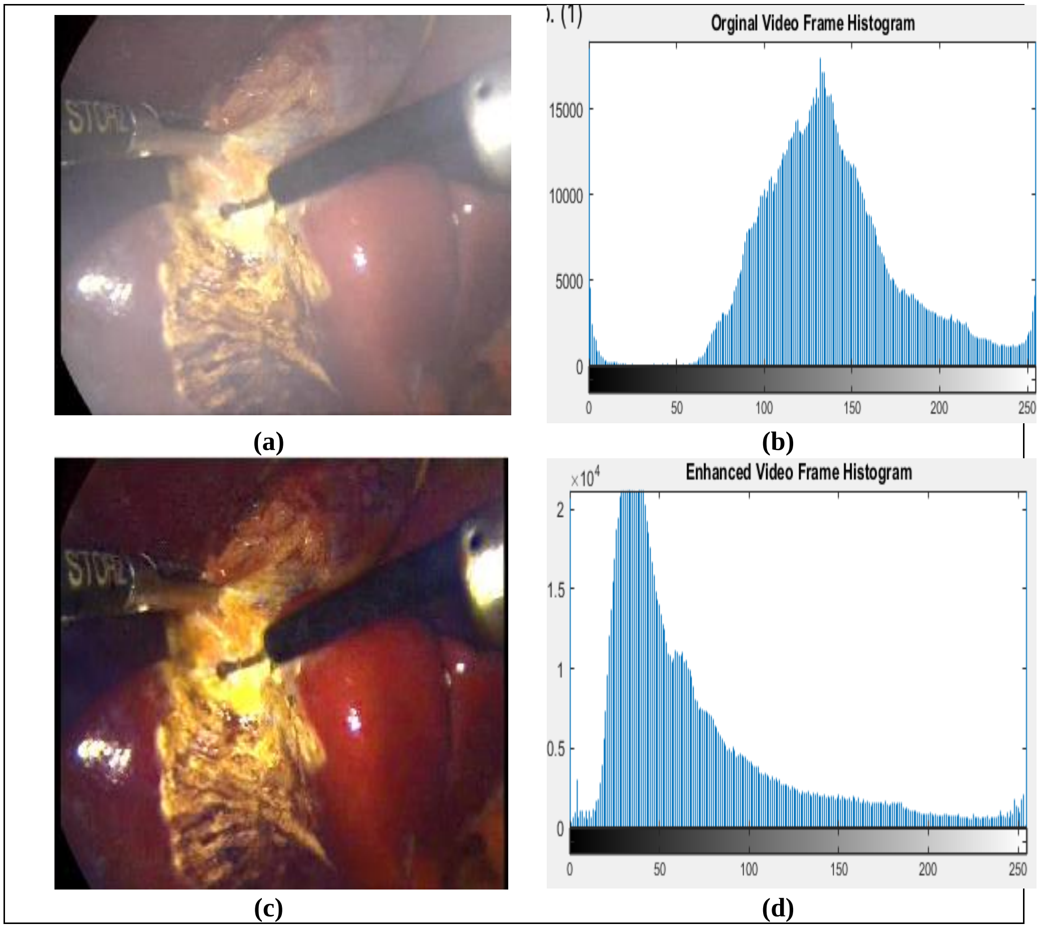

FIGURE 4. Subject experiential results of the processing stage (video enhancement and restoration) using testing video based histogram visualization, (a) and (c) are the original and the processed image frame respectively, (b) and (d) are the histogram of the original and the processed frames respectively.

We notice that in figure (4) (d) which is the enhanced image histogram, the histogram has been shifted to the left side of the histogram comparing with the original one that is showed in (b) which gives as an indication that most of the pixels now have intensity values close to the first half (dark pixels more than light ones). In another words, the amount of the external light has been reduced. In term of measure the experiential results objectively, different quality metrics are calculated to extract the amount of information that has been gained after processed and restored each frame. In this case, we use the standard objective quality assessment methods such as Signal to Noise Ratio (SNR), Peak-Signal to Noise Ratio (PSNR), and Mean Square Error (MSE). Table (1) shows the objective quality assessment for each individual frames that comes from testing videos.

In Figure (5), we notice that the MSE values of the processed/restored image frames (that is illustratedin the red curve) are improved and reduced comparing with the original MSE values (that is illustrated in the blue curve).

In both Figures (6), and (7), we notice that both PSNR and SNR for the processed and restored image frames (that is illustrated in the red curve) are improved and increased comparing with the original the PSNR and SNR values of the original frames (that is illustrated in the blue curve) which gives us an indication about how much improving we gain by using our first proposed video restoration and enhancement approach.

TABLE 1. Objective quality assessment of the experimental results of the processing stage using testing video.

Frame No	Original Image Frame			Restore Image Frame		
	PSNR	MSE	SNR	PSNR	MSE	SNR
1	44.797	43.970	2.114	48.962	16.853	11.974
2	44.964	42.310	1.953	49.072	16.430	12.293
3	44.339	48.863	2.398	49.023	16.617	10.085
4	45.577	36.737	1.701	48.883	17.162	14.203
5	47.387	24.220	1.747	52.722	7.090	10.001
6	46.314	31.005	1.776	52.618	7.262	10.272
7	46.472	29.899	1.838	53.651	5.724	9.424
8	46.344	30.793	2.001	52.116	8.152	9.462
9	45.900	34.106	2.215	51.599	9.183	8.894
10	46.748	28.058	1.550	51.828	8.711	11.202

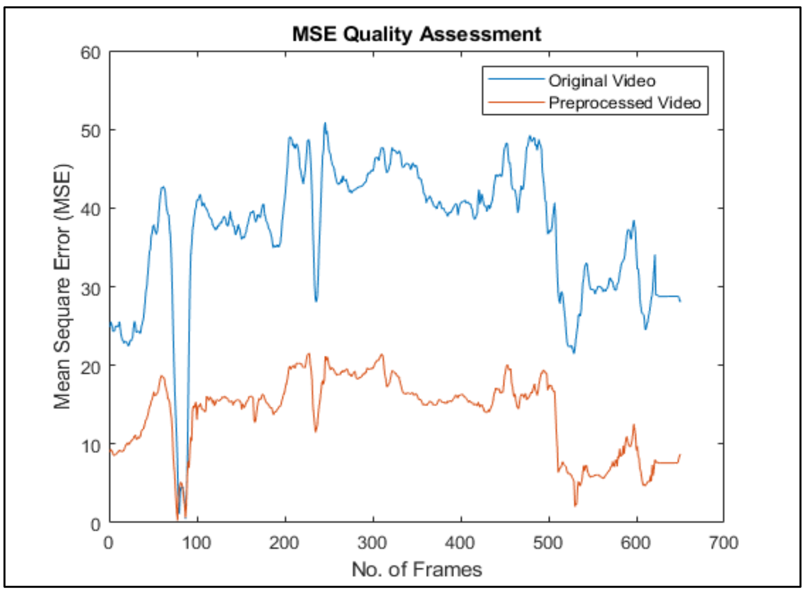

FIGURE 5. Mean square error (MSE) of the testing video.

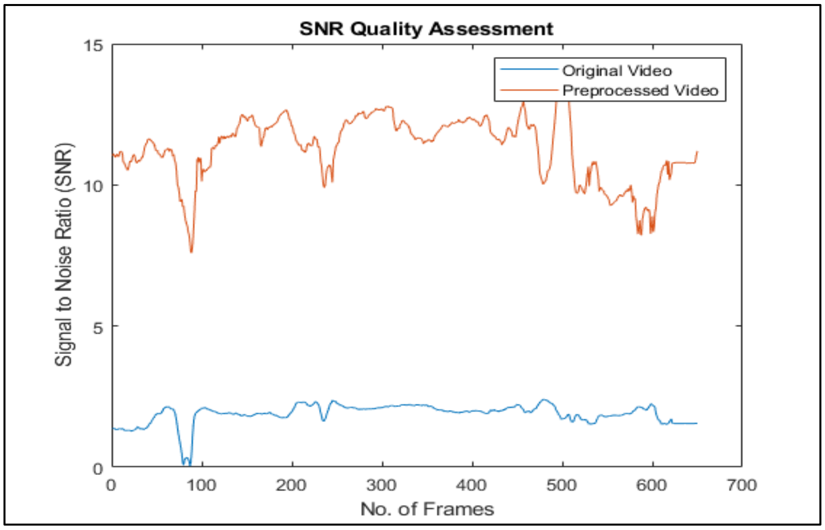

FIGURE 6. Signal-to-Noise-Ratio (SNR) of the testing video.

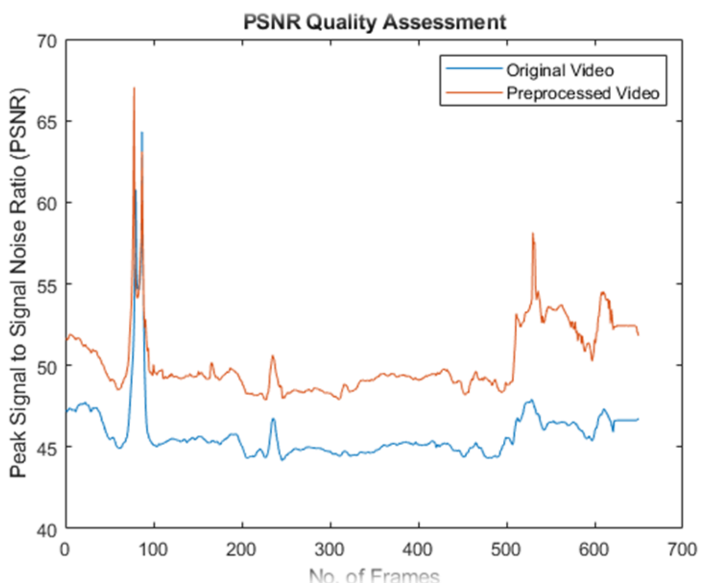

FIGURE 7. Peak-Signal-to-Noise-Ratio (PSNR) of the testing video.

Figure (8) shows the final MSE histograms of both the original and enhanced/restored frames that are shown in (a) and (b) respectively. We notice that the min-max of the MSE vales of the original image frames is [10-60] while the processed /enhanced MSE values have been reduced to be [0-25] which gives as an indication how much error has been reduced from the original image frames.

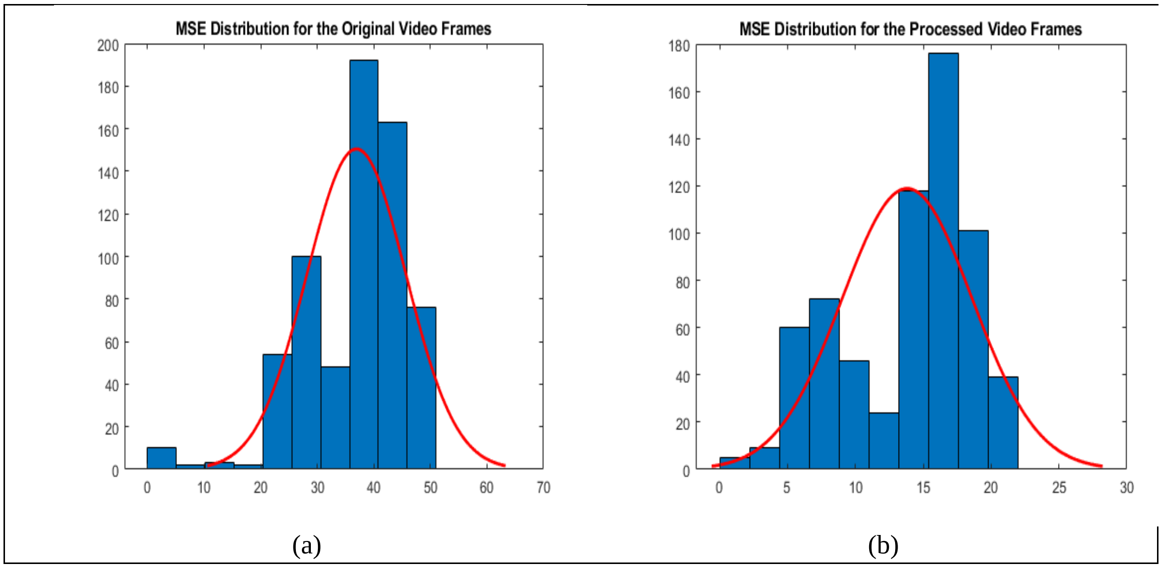

FIGURE 8. MSE values and the final distribution for both the original image frames (a) and the enhanced/restored ones (b).

In Figure (9), we notice that the min-max of the PSNR vales of the original image frames is [40-50] while the enhanced/restoration PSNR values have been increased to be [45-60] which gives as an indication how much information that the processed (enhanced /restored) image frames gain comparing with the original ones.

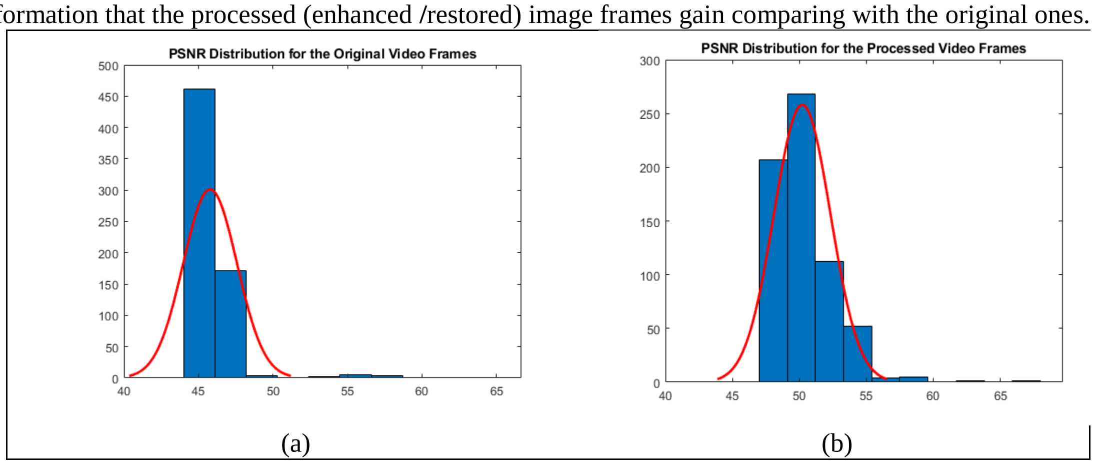

FIGURE 9. PSNR values and the final distribution for both the original image frames (a) and the enhanced/restored ones (b).

In Figure (10), we notice that the min-max of the SNR vales of the original image frames is [1-3] while the processed/enhanced values have been increased to be [8-14] which gives as an indication how much information that the processed (enhanced/restored) image frames gain comparing with the original ones.

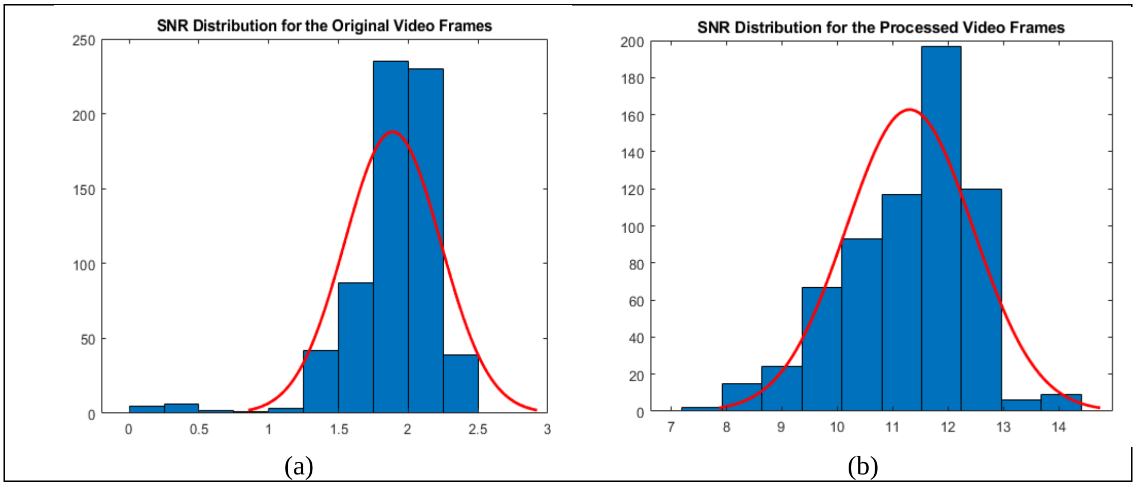

FIGURE 10. SNR values and the final distribution for both the original image frames (a) and the enhanced/restored ones (b).

CONCLUSION

Some reasons influential of the result of the medical videos, Light sources are an important factor in obtaining images. The experience of the doctors and the assistant staff plays a major role in the success of the operation in a short time which means that the operation situation. The time factor is also an important factor. In this paper, we solve the imagining systems issues by proposing software's for the medical video restoration. The proposed enhancement systems help to detect medical errors that may occur during surgery due to blurred vision and that negatively affect human life. The proposed system can significantly help and assist the surgeon performance either during or after the medical operation.

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