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Original Article

Image Restoration Quality Measurement using Noise Filters

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Abstract *- The aim of this project is to implement different features of image restoration. We consider a vectorised picture and take pictures of it with our mobile for two configurations, the first lit by natural light, the second without the light. Those photos apply different transformations on the original image as rotation, change of the scale, integration of unwanted environment in the picture, etc. We will see a method to restore those photos and compare them to the original image. The comparison will be made by using two indicators: the Peak Signal Noise Ratio (PSNR), measuring the quality of reconstruction of the image, and the Structural Similarity Index (SSIM), evaluating the similarity between pixels. Finally, the complementary analysis will be performed to increase the restoration quality between the pictures, like using a noise reduction filter or function to increase the correspondence between histograms.*

Keywords *- Histogram equalization, Noise reduction, Peak signal to Noise ratio, Sharpening, Structural Similarity Index.*

1. Introduction

Images are captured and produced to store valuable information about any incident. The process of image construction and restoring the original image is a primary concern. Capturing valuable images of persons and different projects came into concern in the 1950s. Both US and former Soviet Union scientists started different space programs to capture stunning images of Earth and different parts of the Solar System. Such images contained untold histories about different planets and spaces. The images were subjected to degradation due to being distant and the limitations of machines because of vibrations [1-2]. Image Restoration is the process by which we can identify the unknown real image from the degraded version. The degradation is primarily due to image formation, transmission and also the addition of noise [3][25]. Also, due to interference appearing in the camera and surroundings, images get blurred [4-5]. With the advancement of technology in the past decade in imaging, computing and communication technologies, the concern related to image degradation has been greatly overcome by image denoising, deblurring and computer vision and machine imaging. Now image restoration and reconstruction has become the primary tool to handle different low-level image vision tasks coming from different areas of research[6-7]

2. Literature Survey

In digital image processing, several processing techniques are used for processing, enhancing and restoring with removing the noise from images. Nowadays, many processing techniques are implemented for image processing from the elementary stage. Among them, image restoration techniques are very important in different fields. Areas like digital imaging, medical imaging, astronomy, modular spectroscopy, and remote sensing are familiar to everyone as image restoration greatly impacts these fields. Interferences occur during image construction due to noise like Gaussian Noise, Multiplicative Noise, and Impulse Noise. Blurriness due to motion blur, Gaussian blur, atmospheric blur, uniform blur exists due to camera focus, position, wide lens quality, long exposure degradation and, wind speed etc. [8]

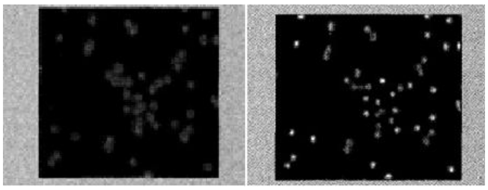

Fig. 1 Original Image and Restored QAR Image [1]

To remove these types of noises, we need different types of filtering processes like a mean harmonic filter, Gaussian filter, median filter, Weiner filter, inverse filter with maximum likelihood, and max filter. Among these Wiener filter and inverse filter are mostly used. Maurya et al. worked on the reconstruction and restoration of images which were user-specific and overlapping, especially in the spatial domain. [9] Michael proposed the idea of reducing the blurriness of multidimensional images for the projector and out-of-focus layer. Yu et al. suggested algorithms to reduce noise, like Gaussian noise and impulse noise. They proposed restoring noisy and blurred images. [10] Multi-resolution texture analysis and image imprinting can be useful for restoring digital photos for neural network analysis for spatial analysis to train the weight adaptive KNN technique. Then, the pixel noise can be sufficiently reduced for image reconstruction.[11] To improve the quality of the pixel's intensity adaptive KNN strategy to mean shift has been used.

To solve the inverse problem, particularly deblurring CNN methods are used extensively for denoising and restoring. [24] Among all the filters, the median filter is the most complex and good for maintaining Peak Signal to Noise Ratio. The Arithmetic Mean filter removes blur from an image's edges but is not good at sharpening. [12] So here, we have used Median Filter and Gaussian Filter as they maintain the PSNR by reducing the image blur captured from mobile devices.

3. Restoration Model

The image restoration process consists of two types of sub-processes. The first process is Image degradation which deals with the degradation of an image due to the addition of different types of noise and blurring. The second process deals with reconstructing that particular image using different filters and recovering the actual image. [11] The process of restoration is shown in Figure 2. The Flow chart of this restoration project is depicted in Figure 3.

3.1 Degradation Model

Distortion is the primary reason for the degrading of the original image. Moreover, this distortion is due to the imperfection of the imaging system. [14] The original image gets blurred in a degradation model due to the degradation function and additive noise. We have taken degraded images due to the absence of natural light captured through mobile devices. The degraded image is described as $\boldsymbol{g} = \boldsymbol{h}^{*}\boldsymbol{f} + \boldsymbol{n}$ where g is the degraded image, h is the degradation function, f is the original image, and n is the added noise profile. [10, 16]

3.2 Restoration Method

To restore an image involves getting the original size (in terms of the number of pixels) and rotation and reducing noise by removing the unwanted "environment" objects and applying filters to reduce noise on the image. [17-18] Here, we will give back to the original content of the photo the same size and rotation as the ones of the original image. To do it, we use the "cpselect" Matlab function to select some pairs of points (4 points in our case) corresponding to the same positions on the original image (points called "fixed points") and on the photo (points called "moving points") as shown in Figure 5. Those points are then used to create a 2D projective with the "fitgeotrans" function. This projective defines the transformation to apply to the photo to create another image of the same size as an image of reference – the original image – and where the moving points have the same coordinates as the fixed points. This projective is applied thanks to the "imwarp" function. Finally, we use the "rgb2gray" to obtain the new image in shades of grey, to handle the potential coloration of the image by the camera and to make the data of the picture lighter, allowing the computing of the SSIM.

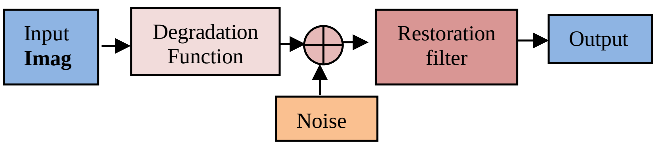

Fig. 2 Image Degradation Model[14]

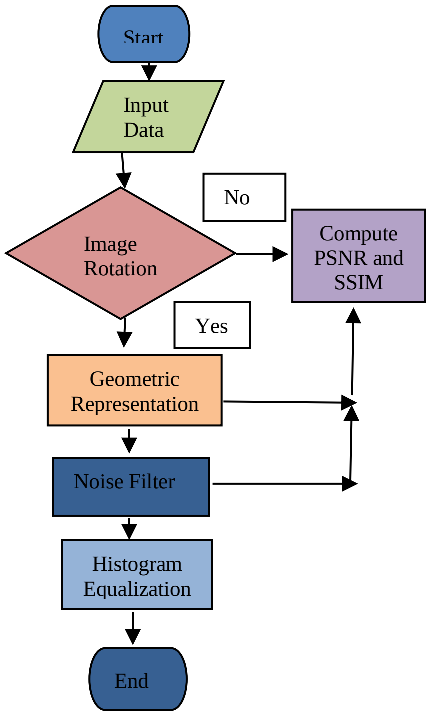

Fig. 3 Flow Chart of the Image Restoration Project

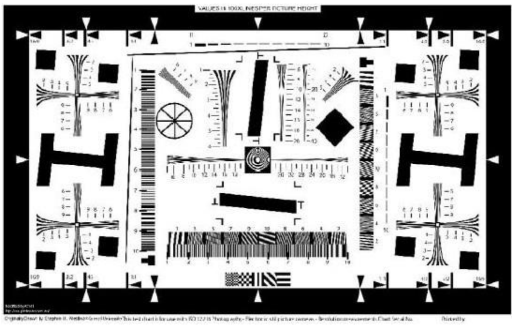

Fig. 4 Original Image

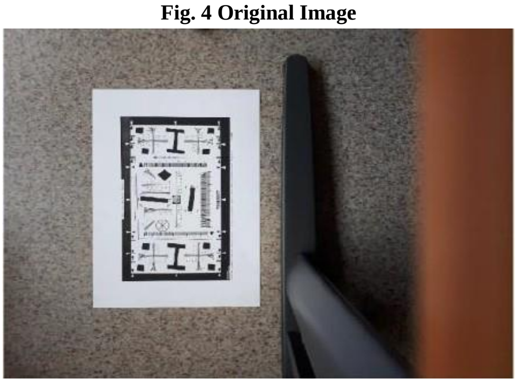

Fig. 5 Image captured by Samsung A5 in natural light

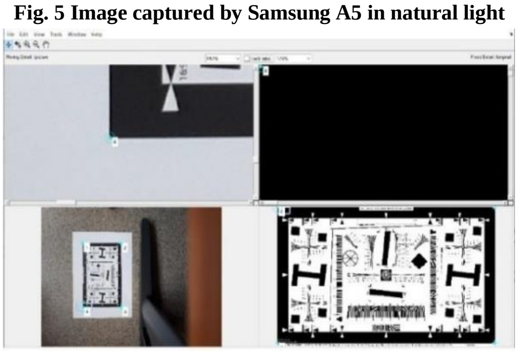

Fig. 6 Window of "cpselect" function where corresponding fixed and moving points are selected

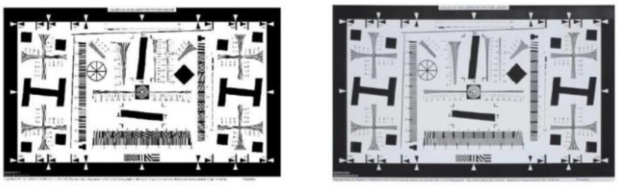

Fig. 7 The geometric transformation of the image of low resolution (at right) looks almost the same as the original high-resolution image (at left)

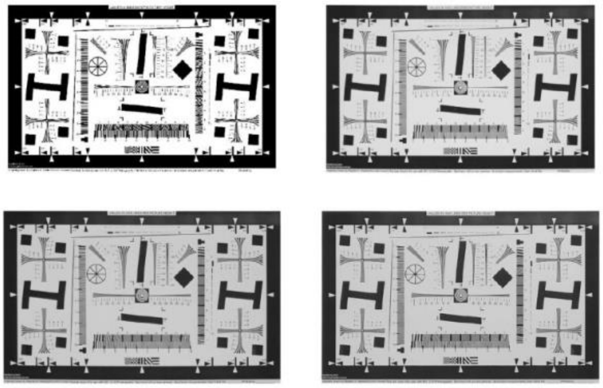

Fig. 8 From left to right, top to bottom: original image, Samsung A5 with natural light, Samsung A5 without natural light and Redmi Note7 with natural light

Table 1. Computed PSNR and SSIM of mobile devices considered

Mobile Device	Samsung A5	Samsung A5	Redmi Note7
Natural Light	No	Yes	Yes
PSNR	11.2341	11.2612	11.3728
SSIM	0.5018	0.4960	0.5007

Table 2. PSNR and SSIM of image corrected by a Gaussian filter with different variance values

Variance	Original	0.5(default)	5	10	15
PSNR	11.261	11.2633	11.38	11.42	11.33
SSIM	0.4960	0.4961	0.503	0.512	0.517

4. Results and Discussion

4.1. Comparison between different Setups

We applied this method to three photos resulting from different situations: one with a mobile device Samsung A5 with natural light (next to a window during daytime), one "without" natural light (behind a desk) with the same mobile device, and one with mobile device Redmi Note7 with natural light (see Appendix). The resulting images are presented in Figure 7. The results of the three configurations seem to be equivalent; the main differences are the shades of grey resulting from the black and white part of the original image. However, the levels of detail are almost equal. An equalisation of histograms will be performed later to correct this issue of colour shades. We now compute the PSNR and SSIM for each of those images. The results are as follows:

We find near results for the different devices. Especially for the two different cases using Samsung A5, the results are too near to determine a better situation. Different causes could explain this; we cannot control the number of light sources, their angle and intensity, precision in the choice of the points used for the restoration method, and the parameters of the camera's focus. We could try with more important differences of light exposition to compare the impact, but in our case, the test is inconclusive. [26-28] The higher PSNR and SSIM values obtained for the mobile device Redmi Note7 confirm the better specifications of the phone (Appendix), even if the impact seems limited, according to the two criteria.

4.2. Sharpening

In image processing, sharpening is the process of emphasising the image's texture to unblur images and make them clearer. It consists of modifying some pixels' intensity to increase the gradient and delimitating more precisely the image's different objects. To see if the camera has applied to sharpen, we analyse illumination levels based on the pixel values of a short section of the image (horizontal pixels from 1 to 3000, at vertical level y = 850), as shown in Figure 8. We can see that some pixels have values higher or lower when passing from a dark to a light zone and vice-versa. Those are the effects of the sharpening applied by the camera to enhance the precision of delimitations.

4.3. Noise Reduction

When we restore the image, the limited values of PSNR and SSIM show that degradation of the image happened. [24-25] One cause, as we can see in the previous figure, is the fact that white and black are not exactly restored by the camera but become light and dark shades of grey. Moreover, some noise could have been included during the recuperation of the image. Indeed, the rotation and the rise of the size (number of pixels) applied to the object generated a loss of precision in the forms. [29-30]

4.4. Noise Filters

4.4.1. Gaussian Filter

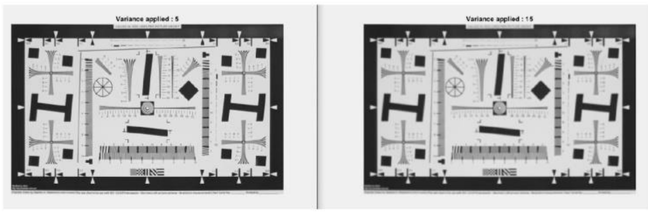

Fig. 9 Comparison between the visual aspects obtained for variances of 5 and 15 with Gaussian filter

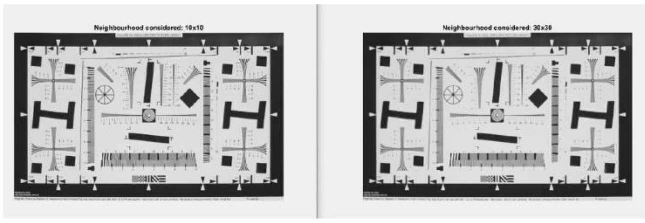

Fig. 10 Images obtained by applying a median filter with 10x10 and 30x30 neighborhoods

First, we try the Gaussian filter on the acquired image. The Gaussian filter [20-21] used with different variances shows that the PSNR and SSIM increase when variance increases until a value of around 20 (PSNR decreasing but SSIM still increasing until a variance value of 50), but the visual aspect of the image is blurred when the variance becomes taller than 10. So, an equilibrium must be found between the indicators' value and the visual aspect of the image. Nevertheless, the changes in indicators value are minor.

Table 3. PSNR and SSIM of image corrected by a median filter with different neighborhood size values

Neighbourhood	Original	3*3	10*10	20*20	30*30
PSNR	11.261	11.263	11.312	11.375	11.401
SSIM	0.4960	0.4966	0.5008	0.5090	0.5151

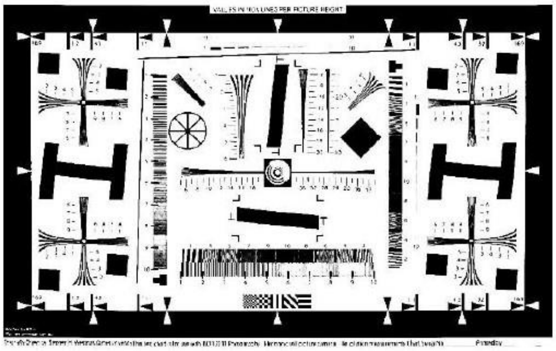

Fig. 11 Image corrected to have the same histogram as the original one

4.4.2. Median Filter

Then we apply some median filters to the image with squared neighborhoods of different sizes. In this method, we find the median of the pixel and replace the pixel with the median of the gray levels of the neighborhood pixels. [19-20] We observe the same evolution than with the Gaussian filter. An increase in the parameters produces a minor increase in the values of PSNR and SSIM. [22-23] Nevertheless, a too-big parameter reduces the visual precision of the image. The tiniest details form a large zone of uniform color due to the filter's process–the pixel's intensity becomes the mean of its intensity and those of its neighborhood, as shown in Table 3.

4.5 Histogram Equalization

Finally, we consider histogram equalisation to correct the fact that the black and white colors of the original image, with the intensity of 0 and 255, do not have the same intensity on the restored image as depicted in Figure 11. The differences between values explain the low SSIM obtained. So, to correct it, we apply the "imhistmatch" Matlab function to modify the restored image until its histogram is the same as the original one. Compared to the original image, the image obtained has a PSNR value of 10.294 and an SSIM value of 0.7985. There is a significant increase in the SSIM due to the correspondence of the majority of pixels, but the PSNR decreased, cause of a loss of quality for the characters or tiniest elements.

5. Conclusion

Finally, we considered a method of image restoration to extract a wanted object from a picture taken by a camera. We used the Peak Signal Noise Ratio and Structural Similarity Index to estimate restoration quality. We saw that different setups finally led to images with similar qualities. Then we applied to the restored image different filters to remove the degradation of the image of the rotation and extension applied during the restoration process and to increase its similarity with the original one. We observed that Gaussian and Median filter allows for softly increased SSIM and PSNR but could also cause a blurred effect or a loss of the tiniest details. Finally, we tried a method of equalisation of histograms that greatly increased the SSIM but hurt the PSNR. This lab work allowed us to handle image restoration and to become aware.

Appendix

The mobile devices used in this project have cameras with the complexity of the subject following specifications:

Table 4. Mobile Specifications

Mobile Device	Samsung A5	Redmi Note 7
Resolution	4608 * 3456 pixel	4608 * 3456 pixel
F-Number	1.9	2.2
Focal Length	3.60 mm	3.84 mm
ISO	40	400
Exposure	1/33 s	1/50 s

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