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Enhancement Techniques for Underwater Images

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***Abstract*—In this paper we present techniques for enhancement of underwater images that have been degraded because of scattering and absorption in the medium. These require only image processing software Without the use of any specialized hardware. The scene's organizational pattern or the situation under the sea changes as we go deeper into the waters. Merging two images that are at once created from the same source version of the image that has been contrast corrected and white balanced is performed on the original image. The two images are produced by the fusion process, in addition to the weightsthat are associated with them. The aim of using maps is to improve the way the colours and borders are transferred to the enhanced image. A detailed weight map is used to avoid thelow-frequency components, transitions, and variations which may cause artifacts.**

In addition to this, the paper makes use of a multi-scale fusion approach and uses the images when they were recreated. The comprehensive approach to qualitative and the result of the quantitative study also presented. Images with dark components have improved visibility, the overall contrast has been enhanced, and the edges now have a greater degree of sharpness. Our investigation has also shown that proves that our method was designed correctly. It is not very unaffected by the settings of the camera and improves several aspects of the precision of the picture processing program. For example, in a picture,two strategies that can be used are segmentation and key point matching. It has the potential to enhance the image's current quality. In confirming the order to get these improved outcomes, we have employed PSNR, Mean Squared Error(MSE), as well as the Structural Similarity Index (SSIM), in addition to the histogram analysis as quantitative metrics

***Index Terms*— Image Processing, White Balance, Gamma Cor- rection, Multi-scale Fusion, Normalization, Contrast Limited Adaptive Histogram Equalization (CLAHE).**

I. INTRODUCTION

Due to poor visibility, not much is known about ocean ecosystems throughout the world. To know more about ocean, use of underwater image enhancement techniques are nec- essary. This is because water covers more than 70% of the Earth's surface and underwater images have become more significant in the study of marine life, underwater mountains, flora, and fauna. Due to this increased interest in what lies under the surface and for further exploration, we need High- Quality under water images. But due to the Light reflection, scattering the light penetration is hindered. The quality of the image depends heavily on the structure of the water (i.e., the medium in which the image is taken) and the water's properties, such as dust sprinkling and distorting and refracting light. As you go inside waters in sea, the reflections are polarised horizontally while some are polarised vertically. With vertical polarisation, objects seem darker and more subdued, making it feasible to capture richer tones that could otherwise be lost in the mix. Seawater is 800 times denser than air [5], making it a common problem for

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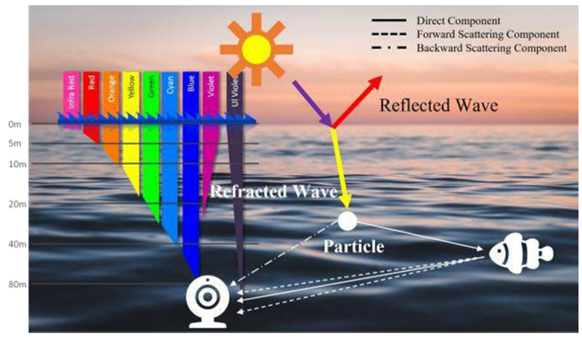

Fig. 1. Schematic Of Underwater Image

underwater photography. Thus, light beams from the air are partially reflected and partially absorbed [3] as they travel to the water. As you get further into the ocean, the amount of light entering the water decreases. Similarly, water molecules are capable of absorbing part of light. As a result, the underwater sights get darker and darker as the ocean depth increases. The quantity of light beams decreases as we travel deeper, but the colours likewise do so one by one, as their wavelengths decrease. For example, a depth of 3 meters causes first, the colour red to disappear from the sky. Second, the orange hue gradually fades away. The orange colour disappears about 5 meters below the surface. Similarly, the majority of the colours get absorbed leaving behind Blue and Green colours as shown in Figure 1. Lastly, the yellow fades away completely at a depth of
10 meters [3]. To counteract the blue color's dominance, anything submerged changes its natural hue. As a result, blue dominates underwater photographs. Brightness, contrast, and other factors abound in those fuzzy images with lots of blue hues. The two-step image enhancing-improving method for underwater photography combines white balancing and fusion to enhance the images without explicitly inverting the optical model. Color casts induced by selective absorption of colours with depth and back-scattering are compensated for using white balance and image fusion techniques, respectively inour method of image processing.

II. Enhancement of Under Water Images

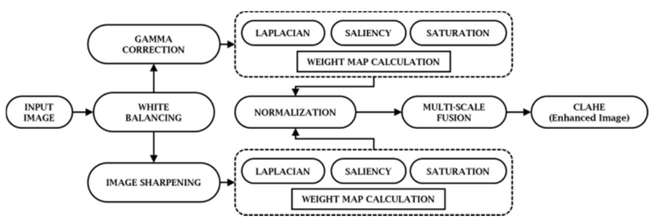

Fig. 2. Block Diagram

To overcome the hazing effect in underwater images, a fu- sion, white balancing techniques can also be effectively used. Colour casts generated by varying illumination or medium at- tenuation can be eliminated by the process of white balancing. Seeing green or blue underwater is a genuine issue that must be addressed addressed since it affects images at depth as shown in Figure 1.

The wavelength spectrum is selectively affected by the attenuation process as light travels through water, which affects both the intensity and looks of a coloured surface. Because long-wavelength light is less susceptible to scattering than short-wavelength light, our ability to discern colour varies as we dive deeper into the water.

In reality, the amount of separation between the observer and the scene affects how much colour is attenuated and lost in the image (Figure 1). Many current white balancing techniques have been examined, and some of them are found to be successful and suited for the above enhancement. After that, going through these approaches [15] and there is still a need for enhancement of undersea image processing approaches are to be improved. Based on a predetermined assumption, these methods estimate the light source colour and then use the normalized light source intensity to ensure colour constancy. As an example, the Gray-world method [15] assumes that the scene's average reluctance is colourless. Each channel may be averaged to decide how much illumination is being dispersed. A two-step procedure, as indicated, is used to improve underwater images

without explicitly inverting the optical model. The white balancing method that is being employed looks to correct the colour cast those results from the selective absorption of colours with depth, while the fusion method we use aims to improve the scene's edges and details while reducing the loss of contrast caused by back-scattering. The Detailed flow of the enhancement technique can be seen in
Figure 2.

White Balancing is the main emphasis for image enhance- ment. Cutting the unwanted colour casts caused by different lighting or medium attenuation qualities attempts to improve the image's aspect. A major challenge in underwater colour feeling is a green-bluish look that needs to be corrected. The attenuation process alters the hue and intensity of a colourful surface by selectively altering the wavelength spectrum when light passes through water.

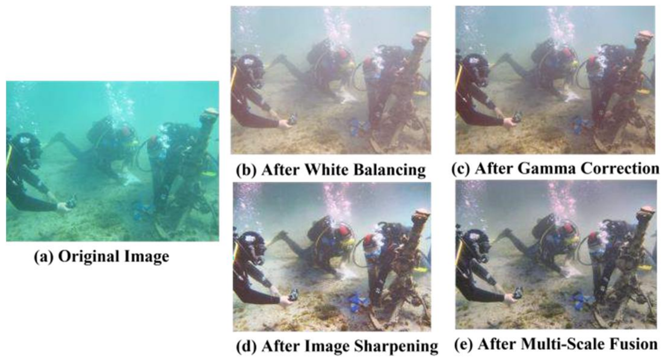

Fig. 3. Different techniques for dehazing of images

While traveling deeper into the water, the ability to see colour changes because the scattering weakens long wave- lengths more than short ones. Attenuation and loss of colour are also affected by how far away the observer is from the scene they are looking at. So have a look at a wide range of white balance approaches [15], and it found that some are both successful and appropriate for our situation. The new solution for underwater scenes is based on the following ideas:

For underwater scenarios, it found that the well-known Gray- World method [11] performs well in terms of visualquality. When it comes to significantly damaged underwater scenarios, typical solutions fail miserably. However, the hue shift stays, and as a result, it seems blue. Although the Gray- World approach cuts the blue tone best, we see strong red artifacts when using it. A low mean value for the red colour channel causes overcompensation in areas where the red colouris present (since the Gray-world separates each channel byits mean value). As a result, compensating for the loss ofthe red channel is our primary goal. As determined by prior underwater study. Gray World will be used in the second stageto compute the white balance picture.

To compensate for the lack of red channel, the following two observations and concepts are used:

- The green channel is considerably better preserved in water compared to the red and blue channels.
- The green channel carries opposite colour information to the red channel.

So it is more important to compensate for the large attenu- ation caused by red compared to green when moving through the clear water. As a result, a small part of the green channel is mixed with the red channel to compensate for red attenuation. Initially, using the ratio of green to blue was thought to be the most efficient way to compensate for the loss of colour information in the red channel, It allows better restoration of the full-colour spectrum using only the green channel information while preserving the natural appearance of the background (water area).

Red channel information should not be sent where the green channel information is still relevant. Therefore, we want to avoid the reddish colour of the Gray-world method in the overexposed parts of the image. The red channel should only be corrected in areas where the red channel is significantly attenuated (see Figure 2). Pixels with significant values in all three channels show that they are in regions close to the observer or artificially illuminated and do not need to be reconstructed. This argument follows statement in [11] [8] [10].

To represent the adjusted red channel $I_{rc}(x)$ at each pixel position (x) as per the observations [1] given below:

$$I_{rc}(x) = I_r(x) + [\alpha(\bar{I}_g - \bar{I}_r)(1 - I_r(x)) I_g(x)] \quad (1)$$

Colour channels of image I's red and green colour channels are represented by $I_g(x)$ and I_r and I_g, respectively. A constant parameter is used in Equation 2 to show that each element in the second term is a direct outcome of one of the observations listed above. For varied lighting circumstances and acquisition settings, we've found that $\alpha = 1$ value works well. The unsharp masking notion is employed, therefore. Similarly for the Blue channel,

$$I_{bc}(x) = I_b(x) + [\alpha(\bar{I}_g - \bar{I}_b)(1 - I_b(x))I_g(x)] \quad (2)$$

III. MULTI-SCALE FUSION

Here, Figure 3 shows how dehazing can be performed uisng a technique based on multi-scale fusion. Authors in [6] have discussed color restoration of under water images. Image fusion has been proved to be very much useful ina variety of applications, including vision compositing [7], multi- spectral video enhancement [9], defogging [4], [1], and HDR photography [2].

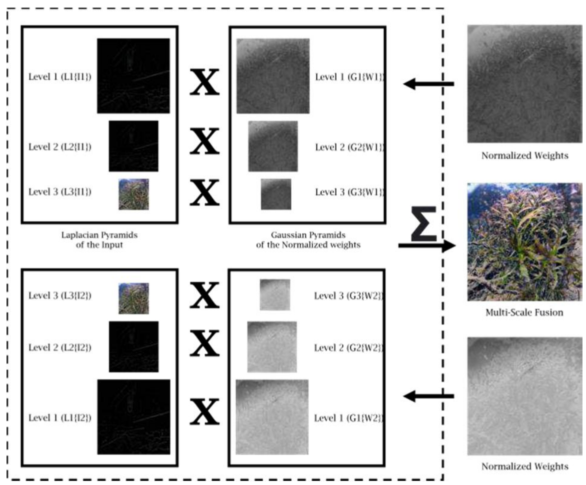

Fig. 4. Schematic Of Multi-Scale Fusion

The main focus of this paper is to obtain a quick solution that can improve scene visibility in a variety of underwater images. This work, like those of [4] and [1], is based ona collection of inputs, produced from a sole source picture. However, unlike
[4] and [1], those two were picked especially,to get the most out of the white balancing strategy described in the preceding section. A pair of inputs are included to improvethe colour contrast and edge sharpness of a white-balanced image, respectively.

A. Inputs of the Fusion Process

By applying the **White balancing** approach to the input images because colour correction is very important under- water, This phase seeks to improve the image quality look by removing colour casts created by different illumination components. White balance suffers from obvious impacts at water deeper than 10 feet since the absorbed colours are difficult to restore.(Refer Figure 3 (b))
As a consequence, its necessary to perform a **Gamma correction** on the white balanced image version to produce required initial input. It is important since white-balanced underwater images tends to seem overly bright in general. This adjustment enhances the contrast between darker andbrighter areas at the expense of features in the underwaterand overexposed areas. This requires a secondary input that relates to a sharper variant of the white balanced image tocompensate for this loss. (Refer Figure 3 (c))
As a result of this, emulating the reversal of Laplacianin the second input, the disparity between a white-balanced picture and its Gaussian filtration counterpart causes undesired artifacts [13]. The **Multi-scale fusion** approach will help to keep the final blended image free of these artifacts.(Refer Figure 3 (e))

B. CLAHE [16]

Histogram Equalization (HE), an antiquated contrast en- hancement technique, performs well in typical images like human representations or everyday photographs. By spreading out the most regular power values, this technique develops a picture's universal distinction. In any event, it endures more commotion in confined spaces. The HE has been reduced to a nearby histogram levelling, or "variable histogram levelling". CLAHE depends on HE, the flexible approach that creates each histogram of a sub-picture to reposition the beautifulupsides of the images.

The CLAHE computation differs from traditional HE in that it uses tiny regions of the image called tiles and calculates several histograms, each of which is compared to a distinct section of the image and is used to reorder the image's softer edges.

The CLAHE enhancement computation may be performed in a variety of different spaces, including the RGB, YIQ, and HSI spaces. A variety space is defined by red (R), green (G), and blue (B) elements in the RGB variety model. These three segments are power images in monochrome.

In this sense, the RGB model is an ideal tool for different age groups when images are captured by various camcorders or displayed on various displays. CLAHE may be used oneach of the three components separately in the RGB variety model. The R, G, and B separate portions can be combinedto provide the result of a full-variety RGB image.

Before Applying a Histogram to an Underwater image, The RGB colours are not Uniformly Distributed over Image pixels. So, the Quality and the Contrast in the Image become poor. So, Applying CLAHE to an Image result in the Uniform Distribution of RGB Colour patterns over the entire Image. It is possible to improve the final image based on the improved image results using the HE adjusted contrast limit. If the contrast that its photograph captures is really dark, the contrast value on the final image will be lighter. On the other hand, if the image that was caught was exceptionally bright, the contrast value would have decreased and the image would have became darker.

IV. Subjective Measurements

A. Red Channel and Blue channel correction

As said earlier we perform the color correction by keeping the value of correction factor-alpha in the range of [0,1]. By this, we can achieve the enhancement of the red channel and the blue channel as shown in Fig 1(b).

B. Evaluation of white balance & Gamma Correction

As said earlier in the paper to perform the color correction by keeping the value of correction factor-alpha in the range of [0,1]. By this, one can achieve the enhancement of the red channel and the blue channel as shown in Figure 6.

C. Evaluation of white balance & Gamma Correction

In white balance, we concatenate the corrected or enhanced RGB channels and we Linearize gamma-corrected RGB values i.e., the gamma correction of the sRGB values in input so that output contains linear RGB values. Then we estimate the illumination using the Gray-world algorithm afterward we adjust the color balance of the RGB image with chromatic adaption finally once again we Adjust image intensity values or color map to get the white balanced image which is depicted in Figure 3b and Figure 3c

D. Evaluation of Image Sharpening

Here we perform 2- D Gaussian filtering of images by filtering input image witha 2-D Gaussian smoothing kernel with a standard deviationof

0.5 and return the filtered image then we do Normalization and Histogram Equalization This process is done to enhance the contrast of the image. This series of processes is termed Image sharpening and this can be seen in Figure 3d.

E. Evaluation of Multi-Scale Fusion

By using the Gaus- sian Pyramid and the Laplacian Pyramid. An image processing technique known as the Gaussian pyramid breaks an image into smaller and smaller groups of pixels to blur it. The name was inspired by German mathematician Johann Carl Friederich Gauss.

Using the Laplacian pyramid, we may assess the degree to which the low-pass filtered image differs from the original MR image. A Laplacian filter is used to calculate a picture's second derivatives, which gauges how quickly the image's first deriva- tives change. If the values of neighboring pixels are changing, it's because of an edge, but if they're not, it's because of a gradual progression. During the pyramid reconstruction, both Gaussian and Laplacian pyramids contribute to Multi-Scale fusion. In Figure Figure 4, this may be observed.

F. Evaluation of CLAHE

In contrast to Contrast-Limited Histogram Equalization (CLAHE), which decreases noise by lowering local histogram Equalization(HE), which distin- guishes between the two, splits the images into neighbour- hoods and applies neighbourhood. Bi linear insertion is used to conceal district borders. In a trial of improvement in Contrast, A function now uses a scalar quantity in the range [0, 1] as existing with the Contrast upgrade limit. If the traits that follow the cut-off are superior, we want to introduce more differentiation. The contrast Limit function has a difference that helps to preserve the over saturation of the image [16]. The overall processing of underwater image enhancement is summarized in Figure 5.

V. OBJECTIVE MEASUREMENTS

This section provides the objective evaluation after the enhancement techniques applied on the underwater images. These metrics are available as provided in [12]

Image Quality Original White Gamma

A. Peak Signal to Noise Ratio: PSNR

Using image as a reference, calculates the peak signal-to- noise ratio (PSNR) for image. Better image quality is indicated by a higher PSNR value [12].

B. Structural similarity index: SSIM

To assess image quality, SSIM computes the structural similarity index (SSIM) for gray-scale image.A value near one suggests higher image quality [12].

C. Mean-squared error: MSE

It computes the mean-squared error (MSE) between the arrays X and Y to assess image quality. A lower MSE score shows that X and Y are more comparable [12].

D. BRISQUE

Blind/Reference less Image Spatial Quality Evaluator (BRISQUE) no-reference image quality score is used to compute the no-reference image quality score for image. It contrasts A with a default model built from images of natural situations with comparable aberrations. A lower score suggests improved perceptul quality [12].

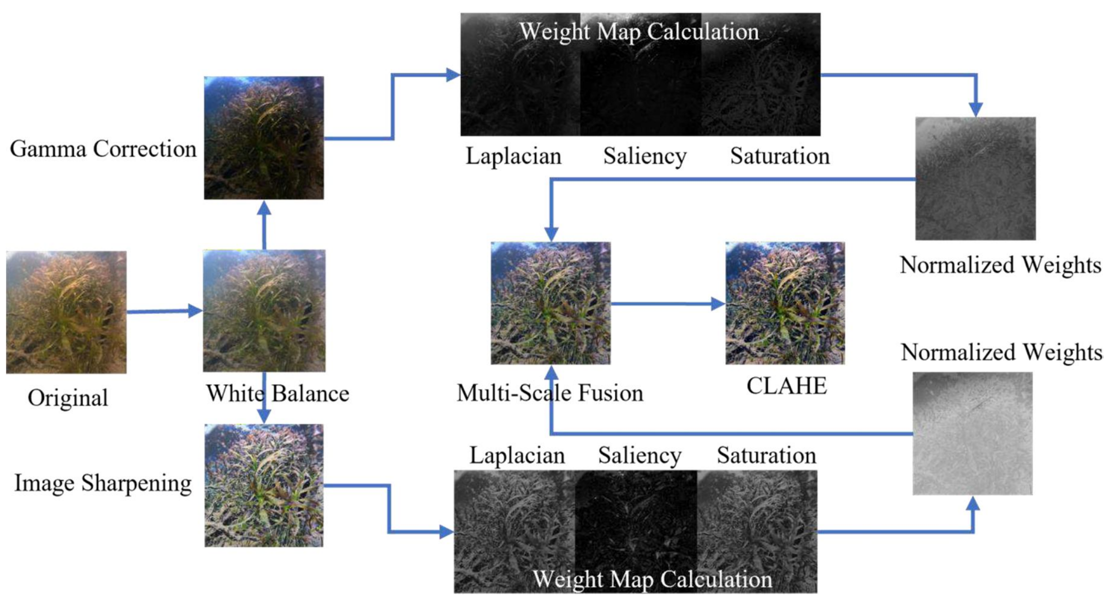

Fig. 5. Summary of under water image enhancement. Using Gamma correction and edge sharpening, the (too pale) white- balanced picture is split into two separate images, Input 1 and Input 2. Two images are supplied into the fusion process,which creates weight maps based on normalization and mixes the inputs using a multi-scale method. Multi-scale fusion is demonstrated using only three layers of Laplacian and Gaussian pyramids

E. NIQE

Naturalness Image Quality Evaluator no-reference image quality score: Using the Naturalness Image Quality Evaluator, compute the no-reference image quality score for image A. NIQE compares to a standard model built from images of natural settings. A lower score suggests improved perceptual quality . [12].

VI. RESULTS

This paper discuss the various methods for enhancing under- water images. The single original image is all that is needed for this method, which is based on the fusion principle. With the ability to recover significant faded details and edges. During trials our approach can enhance a wide variety of underwater images with excellent accuracy. This paper describes howthe suggested image enhancement approaches work for a variety of difficult underwater computer vision applications. The results are shown in Figure 6.

Figure (5a & 5f) are obtained from [2] where as Figure 5b, 5c, 5d & 5e are captured with the help of Insta 360 camera with specifications wide angle 5.7k panoramic video capturingwith 4k resolution which improves the image quality. [14] From figure 6, one can observe the enhancement of underwaterimage by reducing the haziness and removal of noise in the images with the series of processing. The Image quality can be observed objectively in the table 1. It compares the different image quality matrix with the different enhancement techniques.

VII. CONCLUSION

Innovation in image processing extracts data from images and uses it in a variety of applications. Here, this paper highlights the most important applications for image handling that could offer important benefits. The advancement of under- water robotics has made underwater exploration much simpler and less difficult. However, the reason these robots are so expensive is primarily due to the sophisticated cameras that are attached on them. in order to develop more effective, reliable, and camera-independent algorithms with more study in this area. When these algorithms are built into the robots, they will not only help obtain better, enhanced underwater exploration images but also dramatically lower the cost of these robots.

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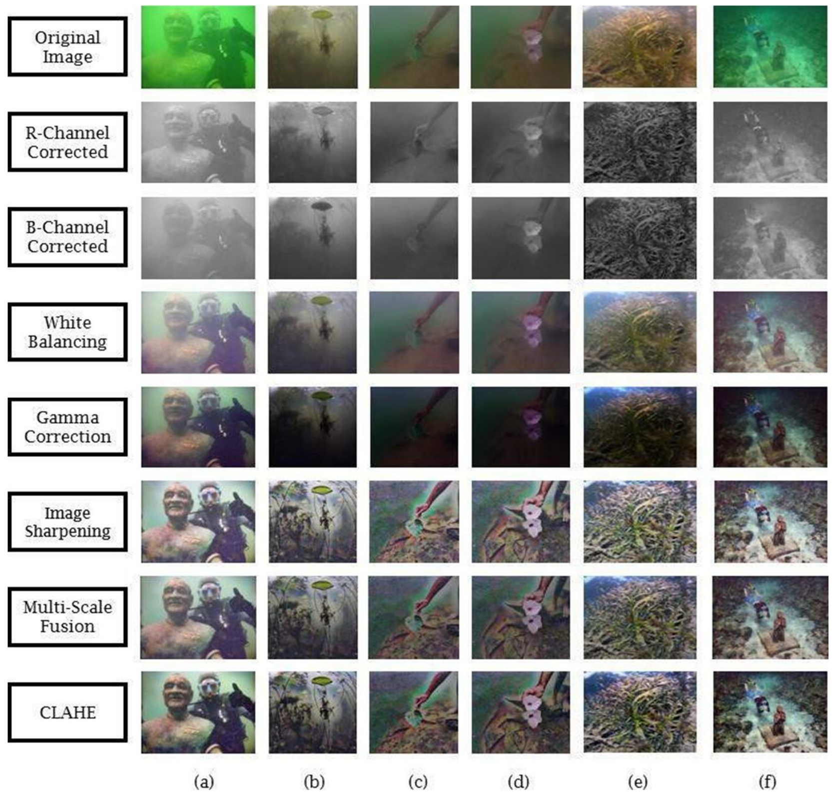

Fig. 6. Comparison over different enhancement Techniques

TABLE I. EDGE AND PIXEL-BASED IMAGE QUALITY ASSESSMENT

Image Quality Matrix [Accepted Range]	Enhancement Techniques					
	Original Image	*White Balancing*	*Gamma Correction*	*Image Sharpening*	*Multi-Scale Fusion*	*CLAHE*
Red Channel Mean (≤ 0.5)	0.1753	0.4962	0.2585	0.5002	0.4226	0.3826
Green Channel Mean (≤0.5)	0.5064	0.4886	0.2562	0.4963	0.4191	0.3992
Blue Channel Mean (≤0.5)	0.3092	0.4952	0.2559	0.4996	0.4215	0.3898
PSNR (in dB) (¿30)	–	61.4986	64.2340	60.4674	62.9768	63.2066
Average SNR (in dB) ($\geq 4dB$)	–	4.8356	7.5710	3.8044	6.3139	6.6854
Structural Similarity (SSIM) Index Value (∼ 1)	1	0.9724	0.9947	0.9667	0.9785	0.2038
Mean Squared Error (MSE) (∼ 0)	0	0.2743	0.1480	0.3319	0.2496	0.0301
No Reference Image Quality Score (BRISQUE) (≤ 30)	45.1850	45.0421	44.4191	48.4987	45.9127	28.3506
Naturalness Image Quality Evaluator (NIQE) (≤ 2.5)	2.5815	2.5022	2.6058	2.5487	2.4522	2.6267