UNDERWATER IMAGE ENHANCEMENT USING DISTANCE FACTOR ESTIMATION AND WAVELENGTH COMPENSATION

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Abstract:-

The earth is an aquatic planet as its 70% surface is covered by water. For investigate condition of our oceans, underwater mountain and plants, monitor marine species; we need clear underwater images. Captured underwater image is fuzzy due to degradation phenomenon such as absorption, scattering and attenuation. To overcome those problems, we propose a new underwater image enhancement method, which is composed of two successive processing: distance factor estimation and wavelength compensation. First we apply white balancing and contrast stretching to capture image. Then we apply different weight maps and pyramids to generate enhanced image. Our result is better than existing methods.

Keywords:-*Underwater image enhancement, distance factor, white balance, contrast stretching, weight maps, pyramids*.

1. Introduction:-

Underwater image enhancement is very important in present day for ocean applications such as seafloor survey, ocean sampling network, fish pond monitoring, biological monitoring, etc. [7]. Underwater image usually suffers from poor visibility, lack of contrast and color casting, mainly due to light absorption and scattering [2].When the light wave propagates through the water the different frequency components of light wave produce different absorption profile as shown in fig.1. The absorption of light wave depends on following factor such as velocity of water, amount of suspended particle in water, turbidity of water, salinity of water etc. [7]. When camera light incident on objects then it get reflected and deflected number of times by particles present in the water before reaching the camera, this phenomenon is known as a light scattering which results in a poor visibility and low contrast in the underwater image [8].

Following figure 1 shows absorption profile of different color components. Blue color has short wavelength so it travels long distance in water and red color has long wavelength so it travels short distance in water [8].

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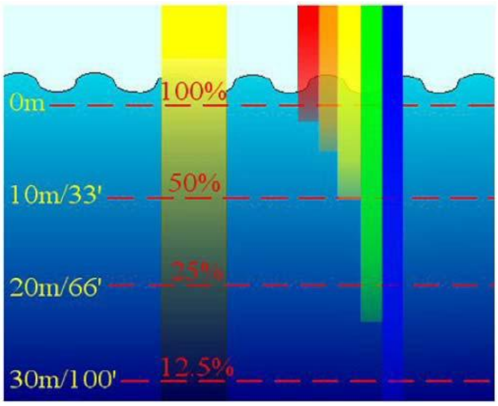

Image enhancement improves perception of image information for image viewer or to provide better input for image processing techniques. Following table shows summary of different approaches for image enhancement techniques in terms of their author, approach and their results.

Fig.1: Absorption profile of different color components of light in water

Year	Author	Title	Approach	Result
2016	Xiu Li, Zhixiong Yang, Min Shang, Jing Hao	Underwater Image Enhancement via Dark Channel Prior and Luminance Adjustment	Dark Channel Method	Decrease in implementation time
2015	P.K.Dwiwedi,Biswajit Paul, DibyenduGhoshal	Underwater Image Enhancement using Distance Factor Estimation	Distance Factor Estimation	Improve visual quality of underwater image
2014	J.Y.Chiang, Ying-Ching Chen, Yung-Fu Chen	Underwater Image Enhancement by Wavelength Compensation & Dehazing	Wavelength Compensation and Dehazing	Dehazing and improvement in quality in deep water
2010	Iqbal K., Odetayo, M.; James, A., Salam, R.A., Talib, A.Z.H.	Enhancing the low quality images using Unsupervised Color Correction Method	Unsupervised Color Correction Method (UCM)	Enhanced illumination and contrast.

Table1: Summary of image enhancement techniques

2. Underwater Image Mode:-

Underwater image can be resembled with the haze image in free space. The free space haze image is modeled as a combination of two parts, viz. i) direct attenuation and ii) scattering part. Mathematical derivation of free space haze image is given as follows:

Haze image ($I_z(x)$) = Attenuation component + Scattering component

= Scene radiance * transmission +Atmospheric light*(1- transmission)

= $J(x)*\Gamma(x) + A(1-\Gamma(x))$ ……….. (1) The term transmission is factor derived as,

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$\Gamma(x) = e^{-\beta d(x)} = \frac{Eo\ (\lambda, d(x))}{EI\ (\lambda, 0)} = (Rer\ (\lambda))^{\ d(x)}$ .... (2)

Where, β = attenuation constant,

d(x) = distance of object from the scene point i.e. Camera lens

J(x) = the reflected light that is directly transmitted, $I_z(x)$ = Image captured by camera

λ = wavelength of light

x = point in the image.

The residual energy ratio (*Rer*) indicates the ratio of residual energy to initial energy for every unit of distance.

3. Proposed Method for Underwater Image Enhancement:-

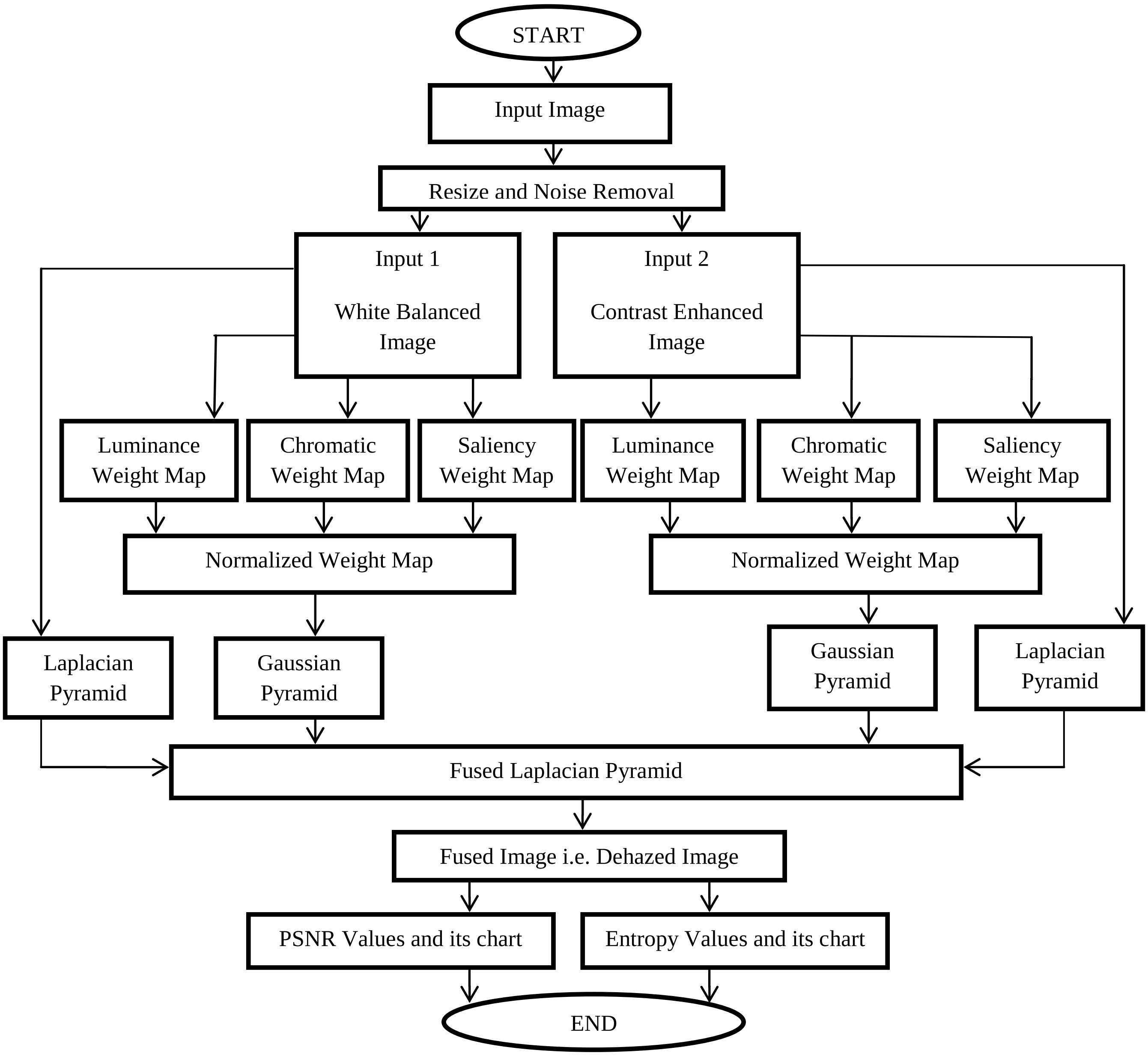

Fig.2: Flowchart of proposed method

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3.1 Input Image:-The images are acquired from different sources like research papers, internet, etc.

3.2. Resize and Noise Remove:-The acquired image has different noise such as salt and pepper noise, motion blur noise. These noises are removed by using different filters.

3.3. White Balance:-This is used for enhancing the image appearance by discarding unwanted color cast. It consists of following steps:

3.3.1. Compute average value of R, G, and B components.Gray value is the average of R, G, and B average.

3.3.2. Calculate scale value for each component using equations:

R_Scale value= Gray value/ R_Avg

G_Scale value= Gray value/ G_Avg

B_Scale value= Gray value/ B_Avg

3.3.3. Estimate white balance R, G, and B component using equations:

WhiteBalance_R= R_Scale value* im(R)

WhiteBalance_G= G_Scale value* im(G)

WiteBalanceh_B= B_Scale value* im(B).

3.4. **Contrast Enhance:-**To enhance the image we use histogram stretching to increase the contrast. This amplifies the visibility in the region of haze but yielding some degradation in the rest of the image. We calculate luminance as:

Luminance = 0.2989* red channel + 0.5870* green channel + 0.1140 * blue channel …… (3)

3.5. Weight Maps:-

3.5.1. Luminance Weight Maps:-This map explains the standard deviation between every R, G, B color channel and each pixel luminance L of the input. . Luminance measures the visibility at each pixel by assigning low values to regions with low visibility and high values to regions with good visibility. This weight map is given as:

$$W_l = \sqrt{1/3[(R-L)^2 + (G-L)^2 + (B-L)^2]} \quad \text{.... (4)}$$

HereR, G, B represents the color channels of the derived inputs and L represents the luminance.However, this map reduces the color information and the global contrast which is why two more weight maps are assigned which are chromatic (colorfulness) and saliency (global contrast).

3.5.2. Saliency Weight Maps:-The main aim of the saliency weight map is identifies the property with respect to the neighborhood regions. This map reflects the distinction between a particular region and its neighboring area. Saliency map can make the edge of the original image to be highlighted.

The equation for the saliency weight map is given as:

$$W_s^{\,k}(x) = \left\| I_k^{whc}(x) - I_k^{\mu} \right\| \quad \text{.......... (5)}$$

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Where I_k^{μ} represents the arithmetic mean pixel value of the input and I_k^{whc} is the blurred input image excluding the high frequency noise and textures. I_k^{whc} is obtained by employing a small 5x5 ($\frac{1}{16}[1, 4, 6, 4, 1]$) separable binomial kernel with the high frequency cut-off value *whc* $=\frac{\pi}{2.75}$.

3.5.3. Chromatic Weight Maps:-Chromatic weight map controls the saturation gain in the output image and thus increase its colorfulness. The higher saturation means more realistic the color. The chromatic weight map is given as:

$$d = \exp\left(\frac{-(S-S_{max})^2}{2\sigma^2}\right) \quad \ldots\ldots\ldots (6)$$

With standard deviation $\sigma = 0.3$.

3.6. Pyramids of Image:-The image pyramid is a data structure designed to support efficient scaled convolution through reduced image representation. It consists of sequence of copies of an original image in which both sample density and resolution are decreased in regular steps.

3.6.1. Gaussian Pyramid:-The main objective of Gaussian Pyramid is to decompose the images in order to obtain the information at multi-scale, to extract the characteristics or structures of interest, in order to attenuate noise:

3.6.1.1. Initiate with the original input image, g0.

3.6.1.2. In order to reduce the noise from the images i.e. to obtain “reduced” image, low pass filter is applied.

3.6.1.3. By “reduced” image, we mean that the resolution and spatial density have ben decreased.

3.6.1.4. Apply the operations in order to obtain to the series of images g0, g1……gn that form the pyramid image construction.

3.6.2. Generating Kernel:-The 5-by-5 pattern of weights w is used to generate each pyramid array from its predecessor. This weighting pattern, called the generating kernel. For simplicity we make w separable:

$w(m, n) = \hat{w}(m)\hat{w}(n)$ ………(7)

The one-dimensional, length 5, function $\hat{w}$ is normalized:

$\sum_{m=-2}^{2} \hat{w}(m) = 1$

And symmetric

$\hat{w}(i) = \hat{w}(-i)$ for i = 0,1,2

all nodes at a given level must contribute the same total weight (=1/4) to nodes at the next higher level. Let $\hat{w}(0) = a$, $\hat{w}(-1) = \hat{w}(1) = b$, and $\hat{w}(-2) = \hat{w}(2) = c$. Here equal contribution requires that $a+2c = 2b$. These three constraints are satisfied when:

$\hat{w}(0) = a$

$\hat{w}(-1) = \hat{w}(1) = 1/4$

$\hat{w}(-2) = \hat{w}(2) = 1/4 - a/2$. ……. (8)

3.6.3. Laplacian Pyramid:-A series of error images L0, L1 ….. Ln such that each image with error is the variation among the two levels of Gaussian Pyramid, is the Laplacian Pyramid. Following are the ways given to obtain this:

3.6.3.1. Develop the top level of Laplacian Pyramid, Ln.

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3.6.3.2. Add the developed edition level Ln to Ln-1, in order to obtain gn-1.

3.6.3.3. Keep repeating the same operation till we arrive at the base level of pyramid, so that we can obtain fully recovered image. No error image exist for the top level of pyramid, therefore we can treat the image at the top as error image i.e. L_n, g_n=L_n.

3.6.4. Laplacian Pyramid Generation:- The Laplacian Pyramid is a sequence of error images L_0, L_1,….., L_N. Each is difference between two levels of the Gaussian Pyramid. Thus, for $0 \leq l \leq N$,

$$L_l = g_l - \mathrm{EXPAND}(g_{l+1})$$

$$= g_l - g_{l+1,\,1} \ \ldots\ldots\ldots\ldots\ldots\ldots\ (9)$$

Since there is no image g_{N+1} to serve as the prediction image for g_N, we say $L_N = g_N$.

3.6.5. Decoding:- The original image can be recovered by summing all the levels of the Laplacian pyramid:

$$g_0 = \sum_{l=0}^{N} L_{l,l} \qquad \ldots\ldots\ldots\ldots\ (10)$$

A more efficient procedure is to expand L_N once and add it to L_{N-1}, then expand this image once and add it to $L_{N-2,}$ and so on until level 0 is reached and g_0 is recovered. This procedure simply reverses the steps in Laplacian Pyramid generation. $g_N = L_N$ and for l = N-1, N-2, …..,0.

$g_l = L_l + \mathrm{EXPAND}\ (g_{l+1})$. ……… (11)

3.7. Performance Parameter:-

3.7.1. Mean Square Error(MSE):- It is quantitative metrics used to compare the improved image and original image. It is used as signal fidelity measure. I_1(m, n) and I_2(m, n) represents the intensity value of original and improved images respectively. The lower the value of MSE shows the lower the error or noise. It calculated as

$$\mathrm{MSE}= \frac{1}{MxN}\left(\sum_{M,N}[I_1(m,n) - I_2(m,n)]^2\right) \ldots\ldots\ (12)$$

3.7.2. PSNR:-PSNR indicates the ratio of the maximum possible signal and the noise that affect the image representation. PSNR value is calculated as:

$$\mathrm{PSNR}= 10*\log\left(\frac{255*255}{MSE}\right)\ldots\ldots\ldots\ (13)$$

3.7.3. Entropy:-Entropy is statistical measure of randomness. Entropy is a measure of image information content, which is interpreted as the average uncertainty of information source. Entropy is calculated as the summation of product of the probability of outcome multiplied by the log of the inverse of the outcome probability as

$$E= -\sum_{x=1}^{k} p(x)\log_2 p(x) \ \ldots\ldots\ldots\ldots\ (14)$$

Where p(x) is equal to p which represent the probability distribution function of the image at the state x(pixel). K is total number of intensity levels.

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4. Experimental Results:-

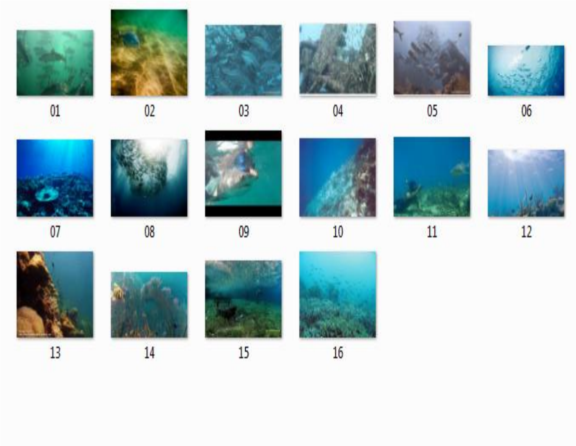

Fig.3 :- Database images

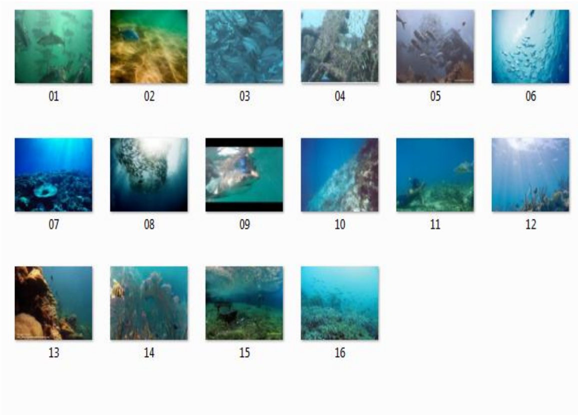

Fig.4:- Resized database Images

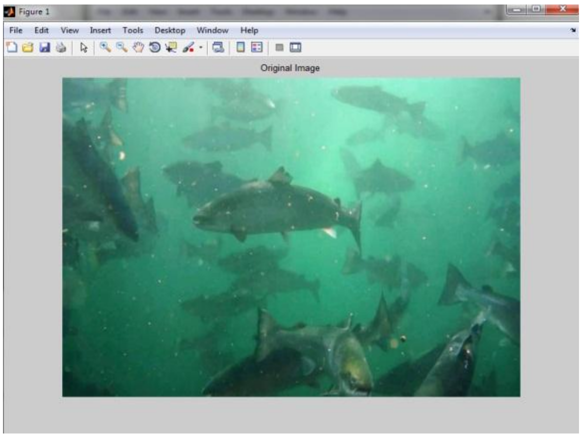

Fig.5:- First image as Input Image

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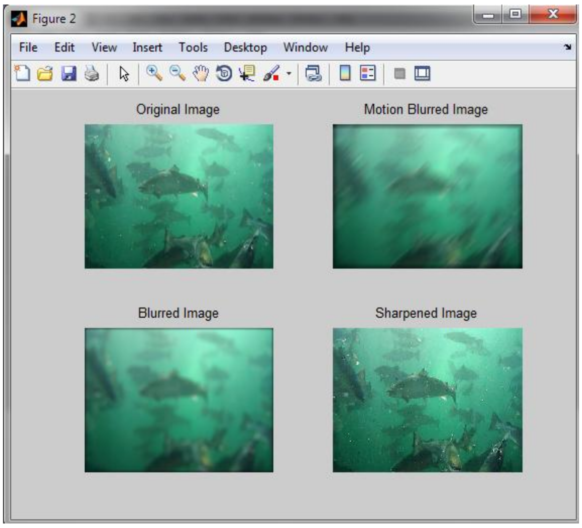

Fig.6:- Preprocessing output

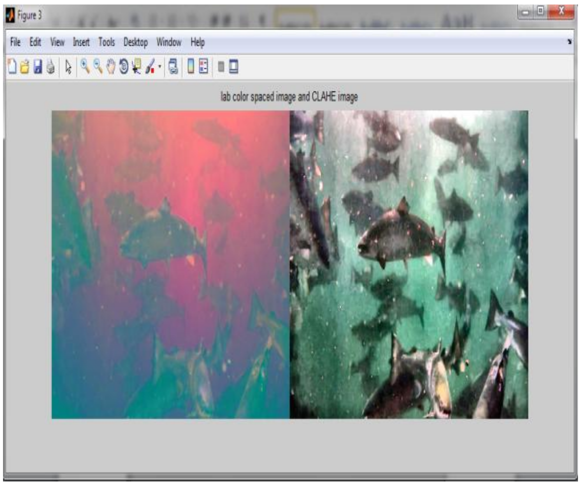

Fig.7:- lab color space and CLAHED image

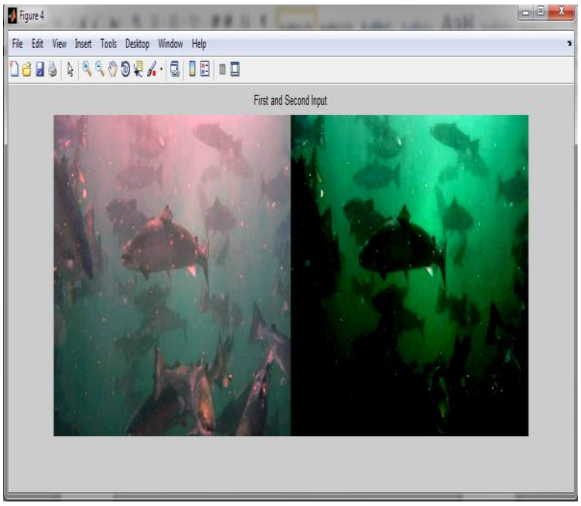

Fig.8:-White balanced image and enhanced contrast image as first and second input for weight map generation

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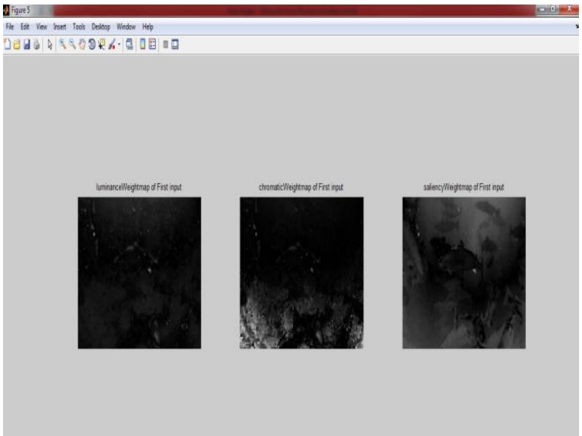

Fig.9:-luminance, Chromatic and Saliency weight maps of first input

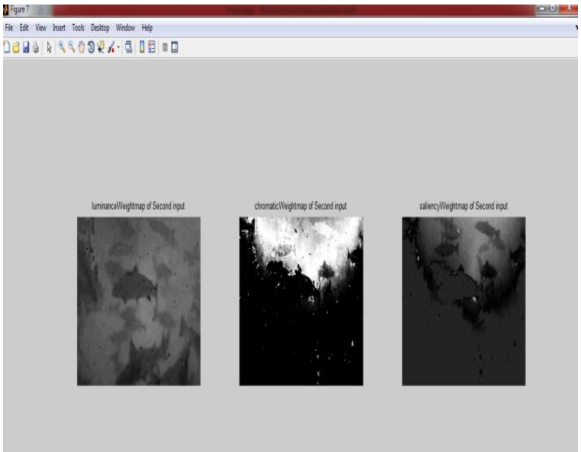

Fig.10:- Luminance, Chromatic and Saliency weight map of second input

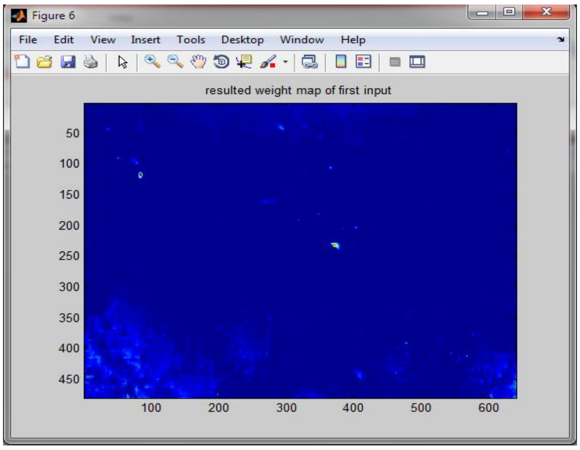

Fig.11:- Normalized weight map of first input

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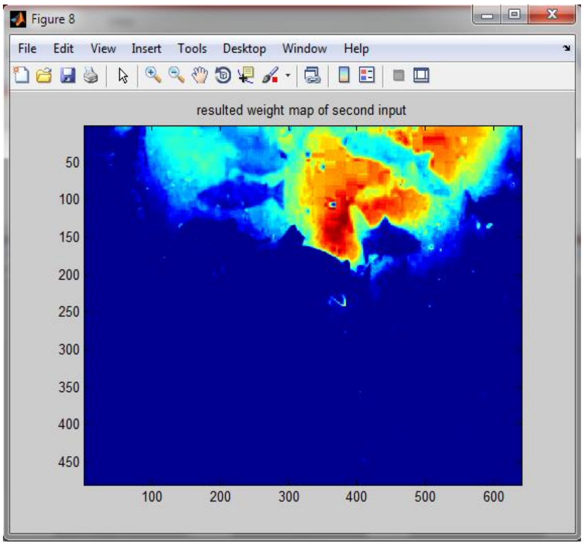

Fig.12:- Normalized weight map of second input

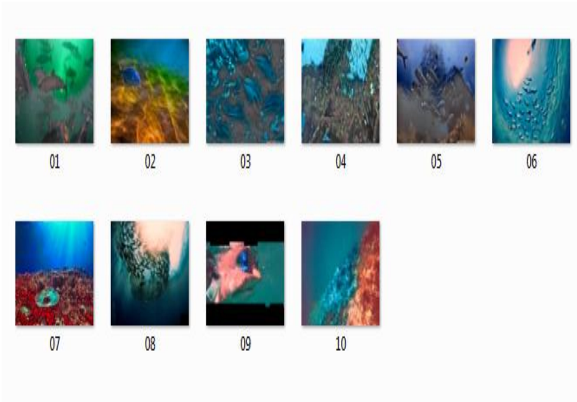

Fig.13:- Dehazed i.e. enhanced database images

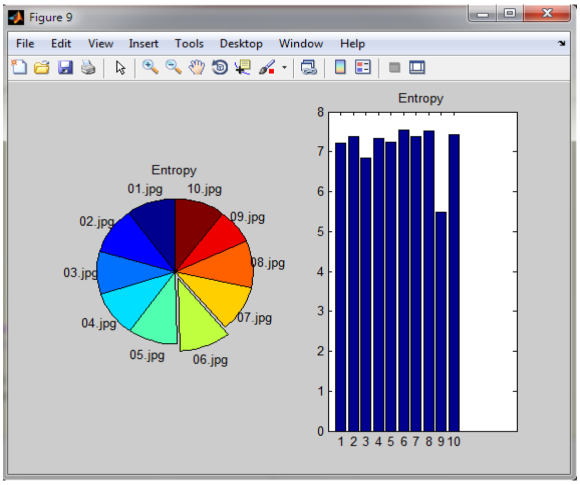

Fig.14:- Entropy of our Images

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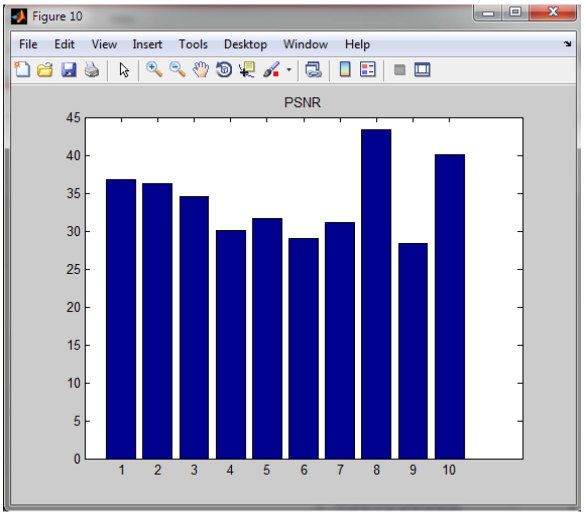

Fig.15:- PSNR of images

Following table shows Entropy and PSNR values of our images:

Database image number	Entropy	PSNR
01	7.2262	36.7320
02	7.3915	36.2042
03	6.8340	34.5756
04	7.3217	30.1009
05	7.2392	31.6384
06	7.558	29.0216
07	7.3758	31.0626
08	7.5304	43.3998
09	5.4799	28.3171
10	7.4175	40.0544

Table2:- Entropy and PSNR of our images

5. Conclusion:-

The proposed algorithm effectively restores images and removes haze. The different algorithm for underwater image enhancement is developed. Our proposed algorithm combines distance factor estimation approach and wavelength compensation approach to get better result. The low value of entropy and high value of PSNRshows enhanced image has very less error.

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