Enhancement of Low-Quality Underwater Images by using an Enhancement Algorithm

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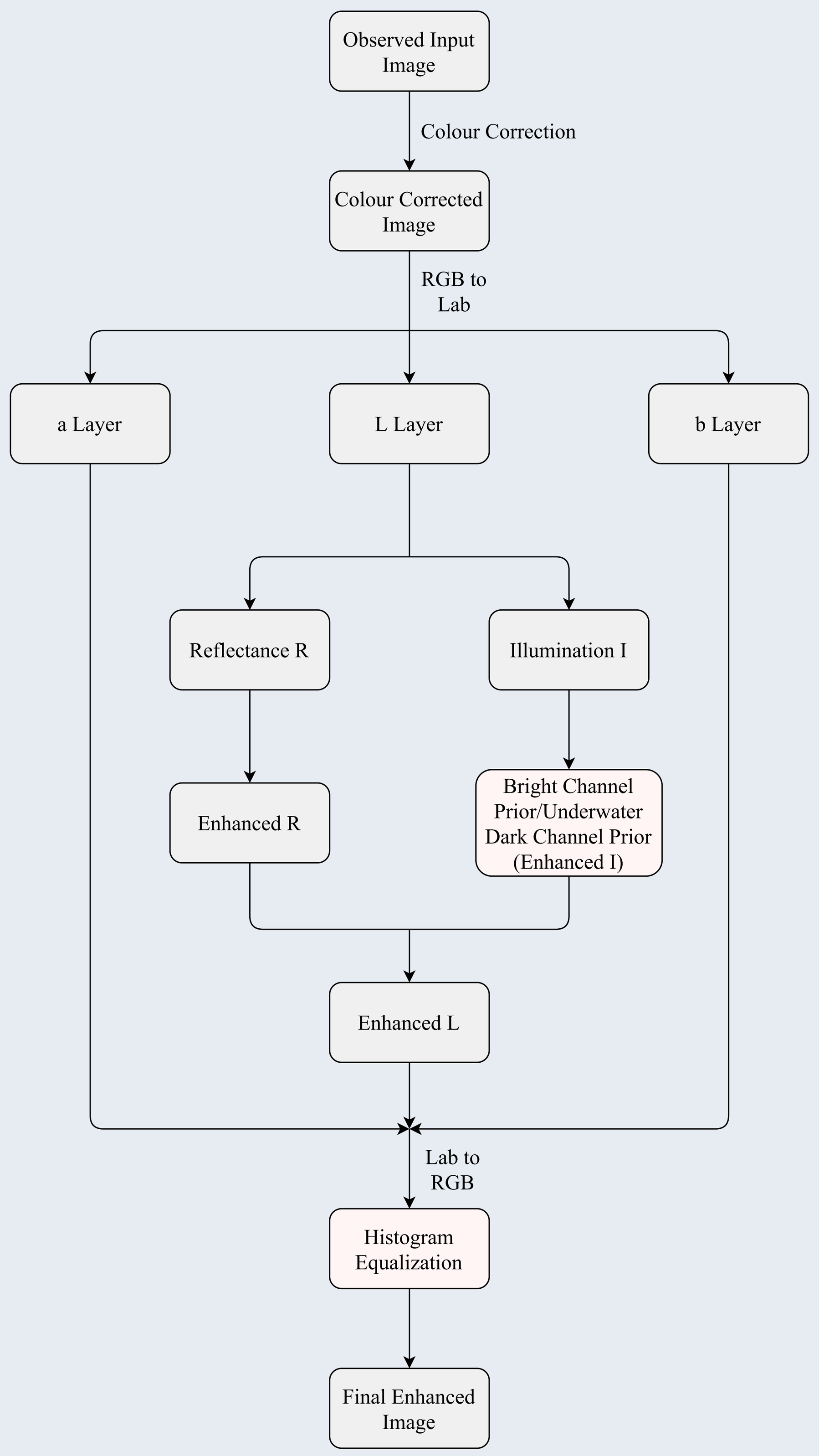
Introduction

Underwater images are of paramount importance in deep-sea scientific missions aimed at monitoring sea life and assessing the geological or biological environment. They are also used for the development and utilization of deep-sea resources. Having said that, images captured under water fall prey to the light absorption and scattering problem (a problem attributed to variable attenuation of light for different wavelengths with depth under water). This phenomenon is known to cause problems in images, like colour distortion, contrast reduction, fuzziness/haziness, underexposure and colour cast, all in all causing a loss of detail.

Thus, we attempted to overcome these limitations by devising a modified Retinex model where we incorporated Bright Channel and Underwater Dark Channel Prior algorithms to the Illumination component of images.

Method proposed



Principle

The working principle of our project is based on the Retinex-based model of image enhancement.

- To start with, colour correction is performed by means of histogram equalization to address colour cast in images. Following colour correction, the image is converted from RGB to Lab colour space. This is done because one entire channel in the Lab colour space is dedicated to luminosity; ergo, it can be kept separate from the colour channels. Also, the L component closely matches with the human visual systems perception of lightness.
- From the Lab colour space, the Luminance layer L is taken and the Illumination and Reflectance components of the image are extracted from it. In the Retinex model, the illumination component is found using low-pass Gaussian filters whereas the reflectance component is found by subtracting the illumination from the input image. However, the usage of Gaussian filters causes a halo effect at object edges which is undesirable. This is due to the illumination component of the image being continuous near object edges. To tackle this problem, pixel-wise bright channel prior and underwater dark channel prior algorithms are applied on the obtained illumination component. An enhanced illumination component results.
- The last step involves combining the enhanced illumination and reflectance components to get the L layer, i.e., the luminance layer. This, in turn, is merged with the a and b layers to get back the image in the Lab colour space. The Lab image is then converted back to RGB to give the enhanced underwater image. The intensity of colour in the resultant image may be high, causing a loss of realism. Applying Histogram Equalisation to that image normalizes the intensity of colour in the image. The image obtained after applying Histogram Equalization is the final enhanced image.

Implementation Results

Original Images

Single Scale Retinex

Multi Scale Retinex

Histogram Equalization

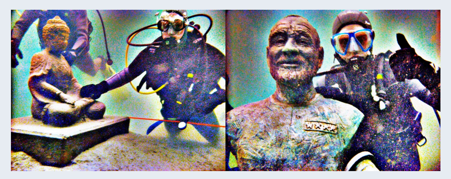
Rayleigh enhancement

ICM

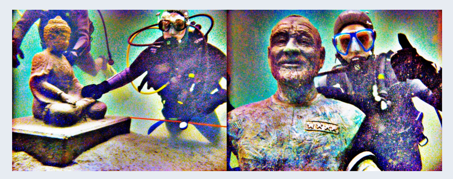
UCM

MSR + BCP

MSR + UDCP



MSR + BCP + HE



MSR + UDCP + HE

Metric Results

Technique	PSNR	UQI	SSIM	BRISQUE
SSR	11.26686	0.669303	0.1780818	25.9346
MSR	10.46132	0.651002	0.112845	32.12789
HE	10.63031	0.651046	0.1377284	25.17587
Rayleigh	10.84834	0.623186	0.1456407	23.7815
ICM	15.56018	0.791915	0.541476	35.71532
UCM	13.43738	0.683490	0.2724564	30.76935
MSR + BCP	10.50755	0.625243	0.117766	31.21352
MSR + UDCP	10.34061	0.593297	0.075834	29.81161
MSR + BCP + HE	9.71529	0.608994	0.0935275	31.09981
MSR + UDCP + HE	9.6645	0.605898	0.1212952	30.95051

Averaged Metric values for each Algorithm

Observations and Inferences

The table given depicts average values of metrics performed on images enhanced by different techniques. For every image metric, lower the value, better the enhancement technique used.

- PSNR presents the combination of MSR, UDCP and HE as the best solution. The combination of MSR, BCP and HE also performs reasonably well. The difference in performance between the two is because of UDCP being a component of the former, which gives an edge over BCP in the case of underwater images.
- According to the results obtained through the UQI metric, the combination of MSR and UDCP provide the best results. MSR + UDCP + HE and MSR + BCP + HE are also not far behind.
- The SSIM metric is in agreement with the UQI metric with regard to the combination of MSR and UDCP being the best technique. Following closely behind is combination of MSR, BCP and HE. However, the metric results show that the MSR + UDCP + HE combination is not up to the mark. This implies that the results of this combination may not conform with the subjective score given by human perception of images.
- According to BRISQUE, enhancement solely based on Rayleigh Distribution produces the best enhanced image. The proposed methods, i.e., MSR + BCP + HE and MSR + UDCP + HE yield slightly high values of BRISQUE metric. Nevertheless, the results are up to par.

Overall, It is evident that Retinex models involving UDCP generally perform better than ones with UDCP (with the exception of SSIM). This is obvious because the UDCP algorithm is tailor-made for underwater images. Also, the proposed methods are relatively successful in keeping detail loss to a minimum, when compared to the other pre-existing algorithms.

Conclusion

Owing to the light absorption and scattering problem, underwater images lose a considerable amount of detail. Our aim was to find an effective technique to remedy this.

Prior to testing the proposed method, a host of pre-existing algorithms were surveyed. Then, the proposed methods, i.e., MSR + BCP and MSR + UDCP were implemented. The output colour intensity was very high; ergo, HE was employed as a post-processing step to resolve this issue.

Four metrics were used to quantify the efficacy of each of the algorithms. The proposed techniques fared pretty well and our objective of minimising detail loss was fulfilled. The only unsatisfactory result was the SSIM metric result for the combination of MSR, UDCP and HE, which suggested that the technique needs to improve to make it more pleasing to the human eye.