A Comparative Study of Image Enhancement Methods: A Literature Review

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Abstract – Image enhancement in computer vision and image processing problems is routinely used to improve performance by sharpening the image content, increasing contrast or rectifying aesthetic failures. The current paper examines some common techniques used, including black balance correction, dehazing, sharpening, histogram equalization, and CLAHE (Contrast Limited Adaptive Histogram Equalization) considering their applicability in both underwater and medical imagery. The comparison discussion entraps the main literature, using the standard measures like: Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM). Also, the white balance always ranks the best, providing the 54.8672 dB and SSIM value 0.9991, which significantly underlines the ability to maintain structural integrity and color true-to-life. New real-time-potential deep-learning models, e.g. U-Net, require significant computational power, though. The review was summarized by stating the advantages and drawbacks of each of the methods and concluding on the worthiness of the hybrid designs that integrate multiple methods, the need to adhere to the requirements in the specific domains and how AI features are becoming increasingly important in shaping versatility and automation. Future work must thus be directed to real-time and adaptive enhancement architecture so as to meet the requirements of underwater robotics, medical imaging, and autonomous navigation.

Keywords: Image Enhancement, White Balance, Dehazing, CLAHE, PSNR, SSIM.

1. INTRODUCTION

Talking about digital image enhancement, one will actually speak about the increase of the appealingness of a photo as well as its applicability to people and/or machines. Visual information is currently used in such a variety of fields as marine exploration, medical diagnostics, surveillance, or autonomous navigation, which is why the demand in quality enhancement techniques is currently skyrocketing. The thing is, the shots in the tricky conditions (the examples can be the deep-sea zones or internal body) might be of low contrast, cluttered, and color shifted. It is the water downside that compels us to plunge into more powerful upgrading gimmicks so as to salvage the picture. Learning computer vision, you understand immediately that, widely used techniques (histogram equalization, CLAHE) usually act as default option to increase contrast and enhance facial details in pictures of poor quality or in the dark. In addition, the correction of white-balances and de-hazing algorithms are really efficient in color recuperation and edge enhancement of the picture, especially underwater shots. There was then deep-learning revolution. Buttoned neural networks (CNNs) have opened a new place of image enhancement by making global parameters learnable and adaptive features. Given sufficient information, these models keep learning what counts as something that looks good and are yielding results that clearly look better than their hand-made analogues. Encouraging developments in imaging enhancement have widened the scopes of possible solutions but every technique introduces its own limits based on the circumstances.

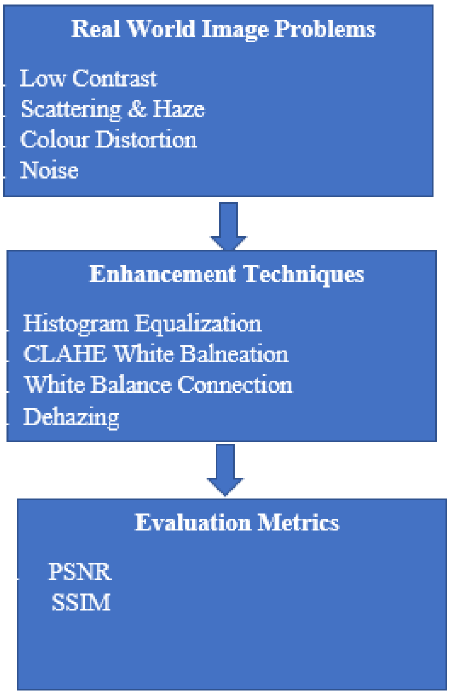

Fig -1: Overview of Image Enhancement Workflow and Challenges

The models presented in the choose-workflows with white-balance approaches are more likely to present a better color fidelity, and the deep-learning networks also have the capacity of producing significant improvements, but usually require intensive computational resources. Since there is no unified criterion of assessing performance or choosing a technique, the ability to apply this in a broad sense is challenging. The general aim of the current paper is to conduct a broad literature review of the most notable image-enhancement methods, describing their principles of operation, practical applications, limitations, and benefits. The study allows one to get a clear picture of the current trends in the research on the one hand, and on the other hand, to define the primary issues in which the research needs to be filled, because of which, in the future, hybrid and intelligent systems will be able to work with image enhancement more efficiently.

2. LITERATURE REVIEW

[1].Kobra et al. (2025) presented an interrelated system of improvements that combine correction of the white balance in their paper on Advanced Underwater Image Restoration, dehazing, sharpening and the enhancement of the contrast of underwater images. Their performance found white balance correction, to be the best among others since it had PSNR of 54.8672 dB and SSIM of 0.9991.

Merits

1. Better color restoration;
2. Good structural maintenance;
3. Good comprehensive analysis based on PSNR and SSIM;

4. Increased clarity under water;
5. Robotic design.

Demerits

1. Only suitable to underwater shots;
2. Real time usage is expensive to compute;
3. there were sometimes visible distortions in the structures as a result of dehazing;
4. The operations involved sharpening which added appreciable noise;
5. Under furnished system in terms of medical images.

[2].Shoffan et al. (2024) under the title Comparative Analysis of Enhancement Techniques for Brain Tumor Segmentation scrutinized CLAHE, HE, their hybrids in the context of the CNN-based performance in these segmentation operations. The hybrid model CLAHE-HE did better in terms of accuracy of segmentation compared to independent methods.

Merits

1. Excellent Dice rolls;
2. Better surge delineation of the tumor;
3. Good training on U-Net;
4. local contrast was maintained with CLAHE;
5. Suitable generalisation over MRI information.

Demerits

1. Must have annotated data;
2. Computer-intensive requirements;
3. Inappropriate to use with non-medical pictures;
4. Tunings needed parameter;
5. Low interpretability.

[3].He et al., 2010, He et al. started a discussion on the way to dehaze a given image. They derived their key concept based on the nature of the outside sky that, given any scene, the scene is guaranteed to appear in at least one low intensity color channel.

Merits

1. It works well in removing haze.
2. It does not need any form of training to run which is a good thing to any busy body working on projects.
3. It serves outdoor photographing very good.
4. It is (easy to) implement.
5. It increases visibility in real sense.

Demerits

1. The images may turn out to be darker than they are supposed to be.
2. There may be distortion of color in the bright areas.
3. The processing of pictures with high-resolution is time-consuming.
4. It is not flexible, it does not observe any difference in any scene.

5. Performances are poor under water.

[4].Garg et al. (2018) in their work introduce simple CLAHE-based enhancement model to highlight underwater images using combination of percentile methods. This model is desirable on many grounds:

Merits
1. It is very easy to apply;
2. It increases the visibility of features;
3. It is fast;
4. It copes very well with uniform improvement;
5. It finds usefulness in edge detection.

Demerits
1. It is subject to introducing artifacts;
2. Bright areas could turn out to be over-emphasized;
3. Pointing mural, without colouring;
4. It also reduces in performance when in turbid water;
5. It does not have adaptive abilities.

[5].Liu et al. (2020) suggested a real-time pipeline of CNN-based restoration of an image in terms of color and visibility enhancement underwater.

Merits
1. Adaptive enhancement
2. Adaptive enhancement
3. Uses big data to learn
4. Deals with various degradations
5. Combines color and contrast
6. In dynamic scenes it is effective.

Demerits
1. Requires a lot of computation
2. Must have a lot of training data
3. Poor interpretability
4. Misinterpretation
5. The danger of over fitting
6. Not easy to be implemented on edge devices.

3. CONCLUSION

As a part of this literature review, I examine fundamental approaches to image enhancement and their comparison in case of implementing them into the practical environment, including underwater and medical imaging. White balance correction is the most reliable one because we work with color accuracy and structural integrity. CLAHE and HE, among other approaches, can provide good results, when the preference is to increase local contrast and image detail. Although dehazing works well to corral atmospheric haze, it nevertheless creates imperfect results in the form of visible artifacts. Conversely, deep-learning-based methods are flexible to treat a large array of image formats but at the cost of high compute requirements and inability to provide answers in a way that is readily understandable. Combining the conventional and learning-driven approaches (hybrid structures) are of actual value to future studies. To ease the provision of comparison, I will postulate an easier assessment scheme that will unite the measures such as PSNR and SSIM. In the future, enhancement methods in the form of real-time domain-aware should become the focus.

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