20 Underwater Image Quality Enhancement using Locally Adaptive Color Correction (LACC) and Artificial Bee Colony (ABC) Optimization

Saorabh Kumar Mondal[1*], Manas Sarkar[1], Tanmay Sinha Roy[2], Arpitam Chatterjee[3], Bipan Tudu[3]

[1]Haldia Institute of Technology, Haldia, India
[2]Institute of Engineering and Management, Kolkata, India
[3]Jadavpur University, Kolkata, India

Abstract
Enhancing image quality is a crucial aspect of image processing. While low-quality images are often attributed to capturing devices or inadequate lighting conditions, the medium in which an image is taken also plays a significant role. In underwater environments, images frequently suffer from reduced contrast and color distortion due to the water's optical properties. Locally Adaptive Color Correction (LACC) is an effective method for restoring degraded underwater colors by minimizing color loss. Meanwhile, traditional histogram equalization (HE) and its improved variations are widely used for contrast enhancement in images captured in air. However, these methods may not be well-suited for underwater images, as they often result in over-enhancement, excessive whitening, or artificial contouring. Achieving balanced contrast enhancement while preserving brightness and sharpness remains a challenge in such scenarios. One possible solution is to optimize a well-defined objective function using computational intelligence (CI) techniques. Among these, Artificial Bee Colony (ABC) is an effective optimization algorithm for addressing contrast enhancement issues. This study introduces an ABC-based histogram equalization approach to enhance the contrast of underwater images while maintaining image quality. Three distinct image quality assessments (IQA) metrics are integrated into the objective function for refining the optimization process. The proposed approach is tested on various underwater images and compared with traditional and optimization-driven techniques. Both objective evaluations and visual assessments confirm the effectiveness of the proposed approach for underwater image enhancement.
Keywords: *Image Contrast enhancement; Histogram Equalization; Artificial Bee Colony (ABC)*

1. Introduction

Contrast of an image plays a crucial role in determining the eminence of an image, as it represents the perceptual difference between the lightest and darkest areas. The human eye is highly sensitive to contrast variations, making it an essential factor in visual perception. When an image has poor contrast, its visual appeal diminishes, and it becomes challenging to extract meaningful features for analysis using different image quality assessment (IQA) metrics [1]. Several factors contribute to low contrast in images, including transmission losses, limited sensitivity of optical sensors, noise introduced during image acquisition, and inadequate lighting conditions. Such images not only appear visually unappealing but also pose difficulties in feature extraction and further processing. As a result, contrast enhancement has remained a significant research topic for several years [2].

The primary aim of contrast enhancement is to improve the visual appearance of an image while preserving its crucial features. such as brightness and color, remain preserved. This is typically achieved by redistributing the intensity levels in an image. Low-contrast images often exhibit narrow histograms, where the pixel intensities are confined to a limited range instead of spanning the full intensity spectrum. Histogram Equalization (HE) is a commonly employed method for enhancing contrast [3], which works by spreading out pixel intensities across the entire intensity range. While HE effectively enhances contrast, it tends to introduce artifacts such as over-whitening, false contouring, and loss of original brightness. To address these limitations, various improved versions of HE have been developed, such as Brightness Preserving Bi-Histogram Equalization (BBHE) [4], Dual Sub-Image Histogram Equalization (DSIHE) [5], and Dynamic Fuzzy Histogram Equalization (DFHE) [6].

Apart from HE-based techniques, contrast enhancement has also been explored through mathematical modelling. Several studies have utilized mathematical formulations to evaluate image quality, often referred to as fitness functions, which are optimized using the algorithms of computational intelligence (CI) [7] to obtain enhanced images that meet desired quality standards. One such approach involves the Artificial Bee Colony (ABC) algorithm [8], where an incomplete beta function (IBF) is employed to construct a transfer function intended to