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Water cycle algorithm based multi-objective contrast enhancement approach

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ABSTRACT

Enhancement of hazy images or video is challenging task because of low contrast exhibited in them. Global contrast stretching methods have been successful in restoring contrasts but problems like overcompensation, truncation of pixel values amounting to loss of information tends to creep in. Artifacts may be introduced and images may loose its colorfulness. This paper presents an evolutionary enhancement method for restoring contrast in images or videos while preserving its colorfulness and brightness. The study proposes a novel histogram equalization method inspired by principles of water cycle algorithm. The proposed method first smoothes Y channel of YCbCr color space and divides input frame into two components using Otsu's 2D thresholding. A set of weighing constraints have been formulated and applied to both components individually in a controlled manner. Water cycle algorithm has been employed to exploit an optimal value of weighing factors for enforcement of constraints on individual components. A three dimension objective function has been designed to suitably perform equalization and control enhancement process. Experimental results show that proposed method is effective in removing haze like patterns in images and videos.

1. Introduction

A number of applications like object detection and tracking, anomaly detection are governed by amount of information that could be captured by cameras. Although some success has been attained with invent of sophisticated cameras but constraints imposed by weather like low illumination, fog and haze have not been still completely overpowered. It makes the task of enhancing and sharpening images or videos a challenging and an evergreen problem. An image or video captured in bad weather is bound to have low contrast that can attenuate performance of various computer vision tasks. Most of image enhancement methods tend to improve contrast and highlight details by processing individual pixel level values either locally or globally. Out of these, histogram equalization (HE) is one of the most commonly implemented strategies amongst all because of its simplicity. In methods like HE, enhancement is obtained by redistribution of pixel intensities over a dynamic range. Dynamic range of histogram is stretched by histogram equalization in order to provide contrast improvement. Histogram equalization can be performed either globally or locally. The major difference between the two is that global HE methods use histogram of entire image as compared to local methods which divide image into sub-blocks

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and use histogram of sub-blocks independently [1]. The final enhanced image is obtained by fusing together sub-blocks using bilinear interpolation method. Local methods suffer from check board effect introduced near boundaries of blocks. Some authors have also tried to extend principles of histogram equalization to color images while working in RGB space or in non linear color space like YCbCr or HSI. Few of these approaches are available at [2–4]. One of the most famous approaches for this is 3-D histogram equalization [2] proposed by P.E. Trahanias and A.N. Venetsanopoulos. A 3-D cumulative distribution function (CDF) was proposed by authors to measure correlation among R, G and B components. Another method that uses multiple 2-D histograms rather than single 3-D histogram has been given by Menotti et al. [3]. The method looks for correlation of color channels among two different histograms and performs equalization thereafter. Han et al. [4] has tried to compromise over enhancement of 3-D histogram technique and low contrast of 2-D histogram ignoring correlation between R, G and B channels. HE is commonly implemented strategy but enhanced image using HE tends to have unnatural enhancement, introduction of washed-out effect and intensity saturation artifacts due to error in brightness because of mean-shifting.

This paper proposes a modified histogram equalization approach that not only tends to enhance contrast of image or frame but also aims to preserve its colourfulness and brightness. The input frame is converted to YCbCr domain and its Y channel is extracted. The Y channel of input frame is smoothened using Gaussian low pass filter to suppress useless information. The frame is then portioned into background and foreground frames using Otsu's 2D thresholding principle. The foreground and background are then subjected to suitably designed constraints. Intensity is manipulated using an improved form of histogram equalization which tends to enhance frame preserving its other details with help of water cycle algorithm (WCA). WCA helps to select an optimal value of parameters based on combination of three objective functions that has been suitably framed such that over enhancement can be negated and loss of colourfulness of image or frame could be mitigated. The approach is novel as it works on YCbCr space and a novel objective function for evaluation of image quality has been carefully designed for preservation of color and naturalness. This multi objective function has been utilized in water cycle optimization (WCA) algorithm for enhancement of images or videos. The desired values obtained using WCA are used to control the contrast enhancement process. This paper is organized as follows: after the introduction part, some important studies in the present field have been discussed. Section 3 provides introduction to water cycle algorithm and introduces proposed system. The formal algorithm of water cycle based histogram equalization method is also part of this section. Experimental results and discussions are provided in Section 4 and Section 5 provides summarization of proposed approach.

2. Related work

Consider an input image I of size $M \times N$ with intensity in the range of $[X_{low}\ X_{high}]$, the probability density function $P(r_k)$ for any level is given as:

$$P(r_k) = f(k)/M \times N \quad k = X_{low}, 1, 2 \ldots X_{high} \tag{1}$$

where $f(k)$ represents frequency of occurrence of level r_k in image, $M \times N$ defines the total number of pixels in image and L is total number of gray levels in image. The CDF (cumulative density function) is given as

$$C(r_k) = \sum_{i=0}^{k} P(r_k) \tag{2}$$

Histogram equalization maps an image from narrow range to entire intensity range of $[X_{low}\ X_{high}]$ using CDF

$$h(X) = X_{low} + (X_{high} - X_{low}) \times C(X) \tag{3}$$

HE is a traditional contrast enhancement approach that flattens histogram and imposes a noteworthy modification in brightness of image. This section discusses several methods used by researchers to overcome limitations of HE. Kim [5] proposed brightness preservation method known as Brightness Preserving Bi-Histogram Equalization (BBHE) which performs segmentation of input image into two parts on the basis of mean and performs equalization of both components individually. Another variant of BBHE that segments image on the basis of median was proposed by Wan et al. [6] known as equal area Dualistic Sub-Image Histogram Equalization (DSIHE). Another extension of BBHE known as Minimum Mean Brightness Error Bi-Histogram Equalization (MMBEBHE) was proposed by Chen and Ramli [7]. These methods were found to be suitable to images having uniform intensity distribution. Chen and Ramli [8] proposed Recursive Mean Separate Histogram Equalization (RMSHE) method which partitions histogram of source image recursively [8] and performs enhancement of all segments independently. Computational cost was clearly a disadvantage of this method. Few weight based equalization methods like weighted threshold HE (WTHE) [9] had also been proposed to add adaptivity and ease of control to enhancement process. These methods tend to modify probability density function by suitable weights before equalization and performed normalization afterwards with addition of some adjustment factor. Weight Clustering HE (WCHE) [10] was also developed which had its basis on adaptive change of weights.

There had been attempts by researchers to utilize use of soft computing techniques for controlling enhancement process. Few of these have been summarized in this section. Sheet et al. [11] proposed modified version of HE based on fuzzy statistics of digital images known as Brightness Preserving Dynamic Fuzzy Histogram Equalization (BPDFHE) to handle inexactness of