Swarm intelligence optimized piecewise gamma corrected histogram equalization for dark image enhancement

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ABSTRACT

In this paper, a highly adaptive swarm intelligence optimized dark image enhancement approach is proposed for remotely sensed satellite images. Here, a weighted summation framework is suggested for imparting “on-demand entropy restoration and contrast enhancement”. This approach utilizes the benefits of both gamma correction and histogram equalization; and hence, overall image enhancement can be appropriately imposed without losing original image features, especially for dark satellite images. For further improvement, gamma correction is also employed in a piecewise manner, separately for dark as well as light pixel values, so that over-saturation and other related unnatural artifacts can be avoided. A suitable entropy and contrast based cost function is utilized, and its maximization is done by employing particle swarm optimization over a three-dimensional search space. The proposed approach is found to be highly appreciable for overall enhancement, preserving all the intrinsic visual details for a wide range of dark image database covering satellite as well as general images.

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1. Introduction

Information gathering through digital imagery is an indispensable basis for various kinds of applications these days. Quality enhancement for various kinds of images is highly desired for exact and reliable information gathering. Image capturing feature is obligatory in most of the hand-held consumer electronic devices now-a-days; and hence, an intelligent image acquisition feature is highly desired in them [1]. In various domains of engineering and technology, image processing is in very high demand, both from human vision as well as machine vision perspective. Restoration for already captured degraded low quality images, and extraction of high quality images out of them; is a highly desired and not so simple task. In general, the degradations arise from imperfect image acquisition circumstances. Remotely sensed images of the earth’s surface and its atmosphere, captured from long distance by using various sensors mounted over the satellites or aircrafts, are widely used these days for various geological surveys and geographical information systems. Quality of any captured image is restricted by full dynamic range of the sensor, which had been used at the time of capturing [2]. Also, non-uniform environmental il-

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Please cite this article as: H. Singh et al., Swarm intelligence optimized piecewise gamma corrected histogram equalization for dark image enhancement, Computers and Electrical Engineering (2017), http://dx.doi.org/10.1016/j.compeleceng.2017.06.029
lumination due to variation in sunlight contributes as uncontrollable artifacts. Hence, contrast separation between the bright and dark areas for fine details is very poor, and such images may be classified as low contrast dark satellite images. Highly concentrated information in any image may get lost when contrast is restricted to a specific range which is very common in dark satellite images. Hence, proper contrast as well as entropy enhancement for overall quality enhancement for dark satellite images is of prime importance.

Various kinds of histogram-based as well as transform-based techniques have been proposed for contrast enhancement [3–5]. Histogram based enhancement techniques fascinate researchers very well due to their well organized and systematic processing behavior, and those can be classified as global as well as local histogram modification approaches. Local or piecewise histogram based enhancement approaches excel over global histogram based enhancement approaches, due to their locally focused and more adaptive processing behavior [6]. Hence, histogram division based image enhancement came into trend. But simple and straightforward statistical parameters based histogram processing again leads to typical unbalanced and non-uniform enhancement, which leads to unnatural artifacts. These shortcomings have been avoided up to certain extent by using adaptive kind of thresholding for histogram sub-division as in brightness preserving bi-histogram equalization (BBHE) [7], which has been proposed for mean brightness preservation along with contrast improvement. Likewise, dualistic sub-image histogram equalization (DSIHE) [8] method, which excels over BBHE in terms of brightness preservation and entropy of an image as it divides the main histogram into two sub-histograms each containing equal number of bins based on median value instead of mean brightness has been reported.

Recursive mean-separate histogram equalization (RMSHE) has been also proposed where recursive separation is imparted. A similar algorithm, recursive sub-image histogram equalization (RSIHE) [9] divides the histogram based on median, instead of its mean value. Finding optimal level for recursive histogram-division is a major challenge for achieving the desired improvement in RMSHE and RSIHE methods. Brightness preserving dynamic histogram equalization (BPDHE) [10], an extension of dynamic histogram equalization (DHE) has been proposed with Gaussian-smoothing filtering before histogram division using local maxima for better mean intensity preservation. Applying fuzzy histogram computation along with it, brightness preserving dynamic fuzzy histogram equalization (BPFHE) was proposed for histogram smoothing before its partitioning into the sub-histograms [11]. Above methods are highly fruitful for the images with significant peaks in their histograms. For further improvement, Ooi and Isa have proposed the quadrants dynamic histogram equalization (QDHE) [12] where main histogram is partitioned into four sub-histograms based on its mean value, and then clipped according to mean intensity occurrence before equalizing the sub-histograms locally. Exposure based sub-image histogram equalization (EISIHE) [13] has been introduced for low exposure images where threshold based on image exposure is utilized for image sub-division. Some authors have proposed another robust algorithm termed as median-mean based sub-image-clipped histogram equalization (MMSIHE) [14] where histogram clipping is performed, using threshold based on median along with bisecting each section, to obtain four sub-images so that they can be equalized locally.

It is well clear from the above mentioned methodologies that researchers are utilizing core concept of histogram equalization everywhere, either in one form or the other: where dynamic intensity range redistribution is common without specifying any adaptive closed form expression for overall entropy as well as contrast enhancement. This is the core reason behind the lack of obvious blind-reliability over histogram equalization (local and global both) based enhancement approaches; and hence, gamma correction was suggested by various researchers for contrast enhancement. Gamma correction was initially applied directly on image pixels in its original domain [15]. Afterwards, transform domain gamma correction based on DCT and DWT [16,17] was suggested with a common problem of manual tuning for the desired and relevant gamma value which is a very tedious and a trivial kind of task. It was found that applying gamma correction over a histogram is easier and quite efficient rather than applying gamma correction on the corresponding image itself. Later on, adaptive gamma correction with weighting distribution (AGCWD) [18] and its improved versions like [19]; were highly appreciated for this objective, where desired contrast enhancement is imparted by utilizing a gamma value-set of size $2^{l-1}$ for a corresponding $l$ bit image, which itself is derived by using cumulative distribution of the intensity values present in low contrast input image. Image enhancement using the averaging histogram equalization (AVGHEQ) approach [1] was also proposed comprising a pipelined approach including color channel stretching, histogram averaging, and re-mapping. Later on, histogram equalization and optimal profile compression (HEOPC) [20] based color image enhancement was introduced which is a parallel programming approach comprising linear stretching, equalization along with intensity profile compression, and saturation maximization. Recently, a computationally efficient approach, named as intensity and edge based adaptive unsharp masking filter (IEUMF) [21] based color image enhancement was reported utilizing the unsharp masking filter for edge augmentation.

Most of the pre-existing closed form algorithms may not serve the purpose for quality enhancement of poorly illuminated dark satellite images (especially for real-time image processing applications), and consequently the necessity for blending of swarm intelligence with classical approaches arises. This motivation leads many researchers to introduce particle swarm optimization (PSO) [22] for quality enhancement of general images. Also, conventional gamma correction [15] has been combined with PSO for simultaneous brightness and entropy enhancement of general images. Still, simultaneous contrast as well as entropy enhancement for dark images adaptively is a very challenging task.

In this context, a novel and highly adaptive weighted summation framework, collectively inspired by the exponential as well as linear behavior of pixel intensities, by taking the benefits of both partial uniform equalization as well as piecewise gamma correction is designed here, and hence optimally leads to overall enhancement in terms of information content, sharpness and contrast, somehow irrespective of nature and domain of the image. Piecewise gamma correction (PGC) is employed through a novel concept of constructive involvement of both kinds of gamma values ($\gamma_1 = \gamma \text{ and } \gamma_2 = 1/\gamma, \forall \gamma > 1$).

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