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Optimum wavelet based masking for the contrast enhancement of medical images using enhanced cuckoo search algorithm

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ABSTRACT

Unsharp masking techniques are a prominent approach in contrast enhancement. Generalized masking formulation has static scale value selection, which limits the gain of contrast. In this paper, we propose an Optimum Wavelet Based Masking (OWBM) using Enhanced Cuckoo Search Algorithm (ECSA) for the contrast improvement of medical images. The ECSA can automatically adjust the ratio of nest rebuilding, using genetic operators such as adaptive crossover and mutation. First, the proposed contrast enhancement approach is validated quantitatively using Brain Web and MIAS database images. Later, the conventional nest rebuilding of cuckoo search optimization is modified using Adaptive Rebuilding of Worst Nests (ARWN). Experimental results are analyzed using various performance matrices, and our OWBM shows improved results as compared with other reported literature.

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1. Introduction

Contrast enhancement is a technique which improves the image quality for various applications. In medical image analysis, contrast enhancement algorithms are used as a preprocessing module. Medical image analysis mainly helps in improving the clarity of diagnosis. Generally, contrast enhancement is classified as example based [1] and intensity based [2]. Intensity based enhancement is broadly classified as the histogram based, transform domain, filter based and masking based approaches. Histogram based approach is a conventional contrast manipulation technique [3]. Akila et al. [4] performed a comparative study on different histogram based techniques for mammogram image enhancement. Improved histogram techniques are modified for better enhancement; such as automatic exact histogram specification [5], segments dependent dynamic multi histogram equalization [6] and threshold optimized histogram equalization [7] etc. Wavelet transform techniques have a greater role in image processing such as compression [8], segmentation [9], enhancement [10] etc. Lie et al. [11] developed a Stationary Wavelet Transform (SWT) based enhancement for finding the de bonding defects in solid rocket motors. Feng et al. [12] developed a contourlet transform based technique for retinal image enhancement. Liao et al. [13] proposed multi scale top hat transform based enhancement technique for retinal vessel enhancement; quality of enhancement is analyzed using extracted blood vessels and the available ground truth vessels. Fourier domain is a very conventional approach in transform based signal processing. Rallabandi and Roy [14] proposed a Fourier based image enhancement approach for Magnetic Resonance (MR) images. Anand et al. [15] proposed directional transform based enhancement algorithm for mammographic X-ray images. Filtering is the process of selecting a desired band of signal. In image communication, filter based techniques are mainly used for restoration [16–18] and enhancement. Paul et al. [17] proposed a neighborhood filter for MR image enhancement. Unsharp masking is an enhancement approach, in which scale value is used for mask formulation. Depending on the scale value, mask is classified as unsharp mask and high boost mask. Conventional masking techniques use static scale value, which is based on random selection [19–20]. Polesel et al. [19] proposed an adaptive unsharp masking technique for image enhancement. Optimum scale value selection can dynamically adjust the scale value using an optimization algorithm. There are various optimization algorithms applied in image processing applications, such as Genetic Algorithm (GA) [21,22], Particle Swarm Optimization (PSO) [23–25], Ant Colony Optimization (ACO) [26,27], Cuckoo Search Algorithm (CSA) [28,29] etc., which are some examples. Enhanced Genetic Algorithm (EGA) is a modified technique, in which crossover ratio and mutation ratio are selected based on the threshold value [30]. Conventional cuckoo search algorithm is modified for the performance

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improvement based on genetic operators and adaptive parameters [31–33].

The organization of this paper is as follows. Section 2 describes the generalized unsharp masking and the need of optimum scale value. Section 3 presents the proposed optimum wavelet based masking in detail. Section 4 discusses the conventional cuckoo search algorithm, need of the proposed adaptive rebuild of worst nest and enhanced cuckoo search algorithm in detail. Section 5 discusses the results and discussion. Lastly, Section 6 presents the conclusions.

2. Generalized unsharp masking and need of optimum scale value

Unsharp masking is a reliable contrast enhancement technique [34] in which, the filtered version of an original image is scaled with a fixed value and the resultant is subtracted from the original image, which is called a mask and is added with the original image as shown in Fig. 1. The main difficulty of this scheme is, fixed scale value irrespective of input images, in which scale values are selected randomly.

3. Proposed optimum wavelet based masking

Our proposed technique is a dynamic unsharp masking, in which scale selection is performed using an optimization algorithm. Original image is decomposed as approximation coefficients and high pass filter using Discrete Wavelet Transform (DWT) given by Eq. (1). The approximated coefficients reconstructed using Inverse Discrete Wavelet Transformation (IDWT) is given by Eq. (2).

$$W_{\varphi}(j_0,m,n)=\frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}f(x,y)\varphi_{j_0,m,n}(x,y) \quad (1)$$

$$f^{A}_{(x,y)}=\frac{1}{\sqrt{MN}}\sum_{m}\sum_{n}W_{\varphi}(j_0,m,n)\varphi_{j_0,m,n}(x,y) \quad (2)$$

Where, $W_{\varphi}(j_0,m,n)$ is the approximation coefficients, φ represents the scale coefficients, j_0 is the arbitrary initial scale value, $m,n$is the wavelet domain discrete variables. In which, $f(x,y)$ is the input time domain image with discrete variables x,y with size $M\times N$, here $j_0=0$, $\varphi_{j_0,m,n}(x,y)$ is the scale function and $f^{A}_{(x,y)}$ is the reconstructed approximation coefficients [35].

The reconstructed approximation coefficients consist of wavelet low pass filtered image. In our approach instead of the original image, wavelet approximated image is considered for masking formulation. Reconstructed low pass signal is optimum scaled using an enhanced cuckoo search algorithm. The mask formulated is optimum wavelet mask, which can dynamically improve the contrast of the image. Optimum wavelet mask is added to the original image and an intensity improved image is obtained as output image as shown in Fig. 2. The proposed technique can be used as preprocessing technique; here it is tested for brain MRI, face XR, MRI and ribs from Brain Web data base and various mammogram images from MIAS data base.

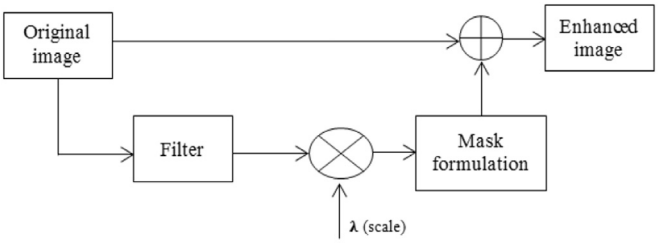

Fig. 1. Block diagram of generalized enhancement technique.

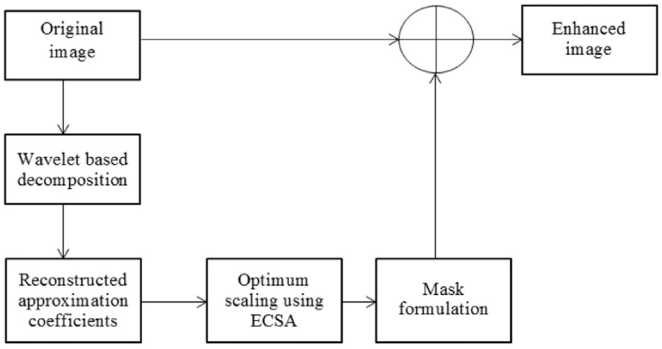

Fig. 2. Block diagram of proposed enhancement technique.

Algorithm for proposed OWBM

Input: Original medical image
Output: Enhanced medical image
Step 1: Read the input image
Step 2: Perform DWT (db4) decomposition as frequency sub bands [LL, LH, HL, HH]
Step3: Reconstruct approximation coefficients LL
Step 4: Select the optimum scale value using ECSA
Step 5: Perform product of scale value and approximated image
Step 6: Subtract the product from original image [mask]
Step 7: Add the mask with original image

4. Cuckoo search algorithm

This section is divided into 3 subsections as follows,

1. Conventional cuckoo search algorithm.
2. Need of adaptive nest rebuilding.
3. Proposed enhanced cuckoo search algorithm.

4.1. Conventional cuckoo search algorithm

Yang and Deb [29] proposed a biological inspired optimization technique called cuckoo search algorithm (CSA) based on brood parasites of bird cuckoo. Usually cuckoo does not construct nests but lay their eggs in some host bird nests. If it identifies that the eggs are not their own, host bird either rebuild their nest or they will abandon their eggs. Egg contained in a nest is considered as a solution and cuckoo egg considered as a new solution. In cuckoo search, generation of new solutions $x^{(t+1)}$ is performed using levy fight.

$$x_i^{t+1}=x_i^t+\alpha\otimes Levy(\lambda) \quad (3)$$

In Eq. (3) step size (α) is related to the scales of the problem of interests. The product $\otimes$ represents entry wise multiplications. The Levy flight essentially provides a random walk while the random step length is drawn from a Levy distribution.

$$Levy\sim u=t^{-\lambda},(1<\lambda\leq 3) \quad (4)$$

The objective of this technique is to replace the not so good egg by the new solution. In the conventional form, each nest has one egg. Nevertheless, the simplest algorithm can be extended to multiple solution applications [36].

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