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Dynamic Stochastic Resonance for Low Contrast Image Enhancement

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Abstract: *This paper presents a technique for enhancement of low contrast images using dynamic stochastic resonance(DSR) technique. Stochastic resonance is a technique in which noise signal is used to enhance the system performance. The noise can be added externally or internal noise of image can be used .However, in the proposed technique, internal noise is used for enhancement. Number of methods have been established for image enhancement but none of the methods used noise signal. In this paper, the performance of the proposed technique is also compared with the performance of the other existing techniques.*
Keywords: *Contrast enhancement, Non-linear system, Stochastic resonance.*

I. Introduction

Image enhancement is an approach to improve the quality of images in terms of human visual perception. It is the process of manipulating an image so that the result is more suitable than the original for a specific application [7]. It is one of the most important area of digital image processing. Large number of techniques are used for enhancement of images in the spatial domain. Dynamic stochastic resonance (DSR) technique can also be used for image enhancement in spatial domain.

Noise is generally considered as nuisance i.e. it is unwanted signal. In past, the emphasis was how to reduce or eliminate noise .Some researchers recently discovered that there exists a potential function when extracting useful signal from noise which increases the signal intensity ratio significantly. This is stochastic resonance [1]. It is a phenomenon in which noise can be used to enhance rather than hinder the system performance. Therefore, noise can play a constructive role in enhancing weak signals. In the proposed work, the internal noise of an image has been utilized to produce a noise-induced transition of an image from a state of low contrast to that of high contrast. Dynamic Stochastic Resonance (DSR) has been used for enhancement of dark images previously [2]. However, in this paper, Dynamic Stochastic Resonance (DSR) is used for enhancement of both dark as well as bright images.

II. Dynamic Stochastic Resonance(Dsr)

Stochastic resonance was first presented by Benzi in 1981[3].According to stochastic resonance theory, in a non liner system, the partial noise energy can be transformed into signal energy if input signal power keeps invariant while noise intensity changes. SR occurs if the SNR, input/output correlation has a well marked maximum at a certain noise level [4], [5]. It has been observed from the working of SR mechanism that the weak signal is unable to cross the threshold at lower noise intensities giving a very low SNR. The output is dominated by the noise for large noise intensities which leads to a low SNR. However, the noise allows the signal to cross the threshold for moderate noise intensities giving maximum SNR at some optimum noise level. For low contrast image, the pixel is initially in a weak signal state, addition of optimum amount of noise causes its transition to strong signal state.

Mathematically it has been proved that if the Signal -to- Noise Ratio (SNR) is maximized, it enhances the signal. Benzi's double well theory suggests two states of image contrast, i.e. low and high also it is assumed that the particles are analogous to state of coefficient magnitude and particle's oscillation corresponds to number of iterations applied on DSR equation which is described as following [2][3] ,

$X(n + 1) = X(n) + \Delta t\,[aX(n) – bX^3(n) + \text{Input}]$
(1)
where input = $B \sin(\omega t)+ \sqrt{D}\xi(t)$
$\sqrt{D}\xi(t)$ represent the internal or externally added noise function,
B and ω are the amplitude and frequency of the periodic signal
n – number if iterations
$a = 26_0{}^2$ and $b < (4a3)/27$

6_0 is standard deviation of the image

The values of a and b are obtained by differentiating the maximization of SNR signal [2].
The equation for SNR is as follows-

$$\mathrm{SNR} = \left[\frac{4\mathrm{a}}{\sqrt{2}(6_0\, 6_1)^2}\right] \exp\left(-\frac{\mathrm{a}}{26_0{}^2}\right) \tag{2}$$

III. Performance Parameters

Performance parameters such as peak signal-to-noise-ratio (PSNR), mean-square-error (MSE), quality index etc. are not suitable for our purpose. These parameters require distortion-free image or reference image. Since we want to measure the performance of our technique in terms of contrast as well as perceptual quality, we have chosen two metrics, relative contrast enhancement factor (F) and perceptual quality metric (PQM), respectively, to characterize each of them. The parametric metrics are Color Enhancement Factor (F), Contrast Enhancement Factor (CEF) and Perceptual Quality Measure (PQM) described by [2], [6].

1. An estimate of relative contrast enhancement factor (F) can be obtained by computing ratio of values of quality index post-enhancement (QB) and pre-enhancement (QA). Therefore

$$\mathrm{F} = \frac{\mathrm{Q_B}}{\mathrm{Q_A}} \tag{3}$$

2. Perceptual quality metric (PQM) –

$$\mathrm{PQM} = \alpha + \beta \mathrm{B}^{\gamma_1} \mathrm{A}^{\gamma_2} \mathrm{Z}^{\gamma_3} \tag{4}$$

where α, β, γ1, γ2 and γ3 are model parameters that were estimated with the subjective test data [6]
B is the average blockiness, estimated as the average differences across block boundaries for horizontally and vertically.
A and Z constitute the activity of the signal.

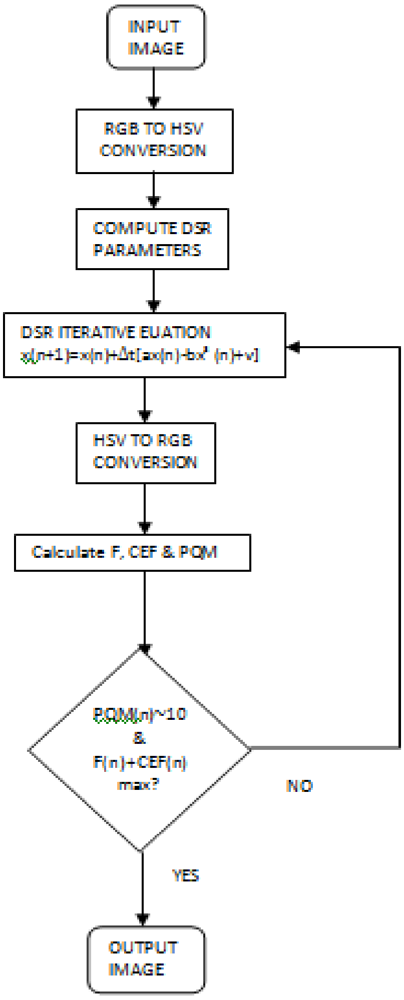
3. Color enhancement factor (CEF) is defined as the ratio of colorfulness of enhanced image to that of original image.

IV. Proposed Algorithm

The proposed algorithm performs contrast enhancement on images by applying Dynamic Stochastic resonance (DSR) iteratively [2].

Step1:- Convert RGB image to HSV color space
Step2:- Apply DSR
Step3:- Compute RGB image after each iteration
Step4:- Calculate the performance metrics F(n), PQM(n) and CEF(n) after each iteration. The iterative process is
continued till F (n) + CEF (n) becomes maximum within the constraint that PQM is as close as possible to value 10.

In case the input is a grayscale image, omit the steps of color conversion, remaining steps are same for grayscale image. However this algorithm does not enhance bright image so it needs to be modify to enhance bright image by incorporating adaptive local neighborhood processing.



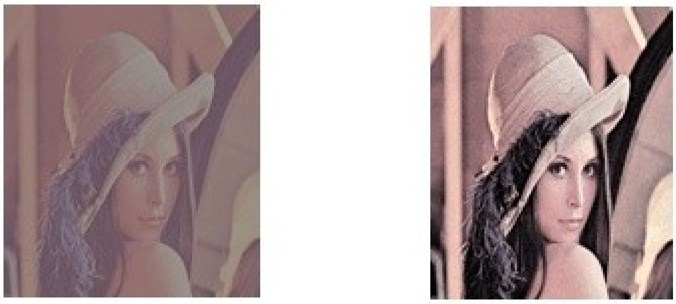
Block diagram of algorithm

V. Experimental Results

To verify the performance of the proposed technique, Dynamic Stochastic Resonance (DSR) is applied on some low contrast images. Fig. 1(a) shows original dark input image on which Dynamic Stochastic Resonance (DSR) is applied to enhance it and resultant enhanced output is shown in fig. 1(b). Similarly, Fig. 1(c) shows original low contrast input image on which Dynamic Stochastic Resonance (DSR) is applied to enhance it and resultant enhanced output is shown in fig. 1(d). In fig. 2(a), one color image is taken on which Dynamic Stochastic Resonance (DSR) is applied and its enhanced output is shown in fig. 2(b). In this paper, the proposed technique is also applied on bright images. Fig. 3(a) and fig. 3(c) show bright images and fig. 3(b) and fig. 3(d) show respective enhanced output.

(a) Input Image (b) DSR enhanced output (c) Input Image (d) DSR enhanced output

Fig. 1 shows original image and its DSR enhanced output



(a) Input Image (b) DSR enhanced output

Fig. 2 shows original color image and its DSR enhanced output

(a) Input Image (b) DSR enhanced output (c) Input Image (d)DSR enhanced output

Fig. 3 shows original bright images and its DSR enhanced output

VI. Comparative Analysis

The performance of the proposed technique is compared with other existing techniques like histogram equalization and adaptive histogram equalization. Fig. 4 shows comparison of the proposed technique with other techniques. Table I & II shows values of performance parameters using proposed technique against other existing techniques.

Original Image (b) Histogram Equalization (c) Adaptive Histogram Equalization (d) DSR

Fig. 4 shows enhancement results on input image using proposed DSR-based technique and other existing enhancement techniques

Table 1 Comparative performance of the proposed technique with various existing techniques using two performance metrics F and PQM on two grayscale input images

	Fig. 1(a)		**Fig. 1(c)**	
methods	F	PQM	F	PQM
Histogram Equalization	1.4889	7.2026	3.4143	9.3564
Adaptive Histogram Equalization	3.2288	8.7374	4.7172	10.2693
DSR	4.8053	8.0348	4.8030	9.2366

Table 2 Comparative performance of the proposed technique with various existing techniques using three performance metrics F, CEF and PQM on one color input image

	Fig. 2(a)		
methods	F	PQM	CEF
Histogram Equalization	3.3333	15.0970	0.9725
Adaptive Histogram Equalization	0.4848	15.0000	0.8805
DSR	5	13.5066	1.3029

VII. Conclusion:

In this paper, an image enhancement technique using DSR is presented. The dark as well as bright images are enhanced using DSR. The results of the proposed technique are quite satisfactory as compared to other techniques in terms of enhancement and visual information.

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