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# Neuro-Fuzzy Approach: A Robust Way to Restore Degraded Documents

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***Abstract*— Document binarization is one of active research area in image processing domain in which wide varieties of techniques are proposed so far. But when it comes to document restoration only few algorithms are only marginally satisfactory. As documents are degraded by several factors like Paper aging effects, Contrast variation, Smearing and Smudging of text, Shadow through, Ink bleeding etc which impose tough scenarios for any method. The Degraded documents may contain vital information, so efficiency and accuracy is must required while restoring it. In this paper a new perspective of Neuro-Fuzzy restoration is presented and compared with other existing techniques both qualitatively (visual inspection) and quantitatively (Accuracy, NRM, MSE, PSNR).**

***Keywords*— Accuracy, Hybrid, MSE, Neuro-Fuzzy, NRM, PSNR, Restoration.***

## I. INTRODUCTION

Binarization is common image processing technique used in variety of applications i.e. image segmentation, Document restoration, character recognition, Edge detection etc. It is used to convert pixels values into two classes of foreground and background [1]. The Document Restoration is a method in which document is digitize by setting all information pixels to 0 and background to 1.The performance and efficiency of any algorithm is truly depends upon degrading factors.

Historical or Ancient documents may contain vital information which needs to be preserve for future. The Restoration of these documents are very cumbersome task as it is effected by many non-linear factors i.e. paper aging effects, contrast variation, smearing and smudging of text, shadow through, ink bleeding etc [2][3].

The Artificial Neural Network (ANN) is a system of parallel operating neurons that approximates the function of the biological Neural Network. The architecture of Neural Network is formed by three layers i.e. Input, Hidden and Output [4]. The input and output layer are connected to outside world with multiple hidden layers arranged between them in such a way that they forms mesh type of network. The neurons have associated Biases and all neurons links are characterized by some weight value [5]. These Weights and biases are updated during learning process. On the other hand Fuzzy algorithm is a system which accepts analog input scaled between 0 &1 and depending upon some if-else rules it generates true (1) and false (0) values. These if-else rules are logical statements written to fulfill specific task [6]. Both ANN and Fuzzy controller have capability to map nonlinear or random variables.

This paper is organized in following subsections. An introduction to existing techniques is described in Section II. The proposed Neuro-Fuzzy technique is described in Section III. In next section results of various existing techniques along with proposed is presented and at the end valid conclusion of this paper is drawn.

## II. LITERATURE SURVEY

In literature, all the existing techniques can be categorized into two types i.e. retrieval and recovering methods. The Retrieval methods are basically binarization methods which are used to extract the useful information from degraded documents by calculating appropriate threshold value. Based upon the nature of threshold calculation the binarization methods are subdivided in three classes namely Local, Global and Hybrid [7] [8].

The local binarization method is generally slow and gives noisy response as it is based on estimating local parameters of every individual pixel[9][10]. Whereas Global thresholding is single thresholding method which is generally fast but performs inefficiently in degraded scenarios. As segmentation of information is done by considering all pixels of image [11][12][13]. Apart from this, Hybrid adaptive class of Binarization combines the advantage of both Global and Local technique but becomes messy in operation. The results of these binarization methods are not up to the mark in degraded images.

The Recovering methods are different from Retrieval class in the sense that they not only filter the informative pixels but also recovered the lost information. These techniques are based on complex computation which makes them resource inefficient but they give much better results in case of highly degraded ancient document. The common methods used are generally based upon Artificial Neural Network (ANN), Particle swarm optimization (PSO), Edge Continuity Relation and Probalistic Generative approach[14][15][16][17].

## III. PROPOSED ALGORITHM

In this section, proposed Neuro-Fuzzy technique is presented for recovering textual information from degraded documents. The Artificial Neural Network (ANN) and fuzzy algorithm are combined together to map different degrading factors as shown below

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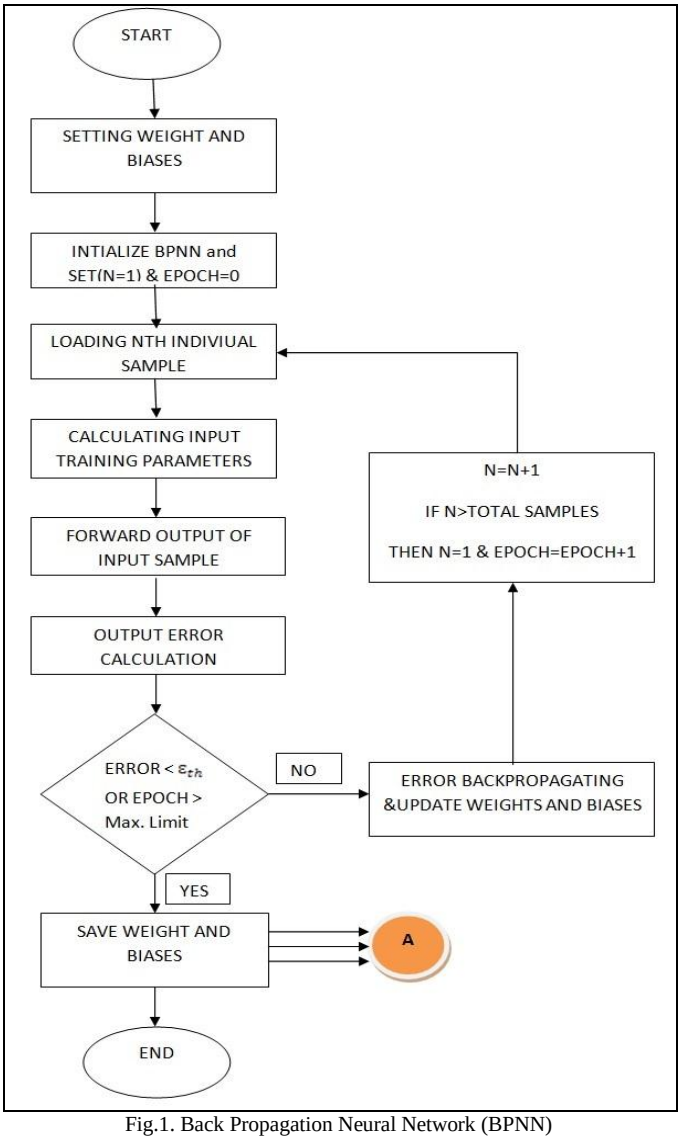


Fig.1. Back Propagation Neural Network (BPNN)

The whole proposed technique is divided into two phases. In first phase, Back Propagation Neural Network (BPNN) is trained to N samples as explained in figure 1. Accordingly, BPNN network is defined and initializes using some preset values of weights and biases. Then outputs of all training samples are defined and input parameters (Global, Local &Hybrid) are calculated for every individual sample. Next the output generated by BPNN is compared using the desired output of sample and by subtraction error term is calculated. This error term is propagated back and weights &biases of whole Neural Network are updated using delta rule. Now next sample is given to the Neural Network, as indicated by incrementing N by 1. If value of N reaches max value of samples then variable N is set to 1 and consequently epoch is incremented. This process continues until either the error is decreases beyond some specific value or epoch reaches max limit. If any of these two conditions prevails, then the neural network is said to be trained and its weight and biases is saved in some variable say A.

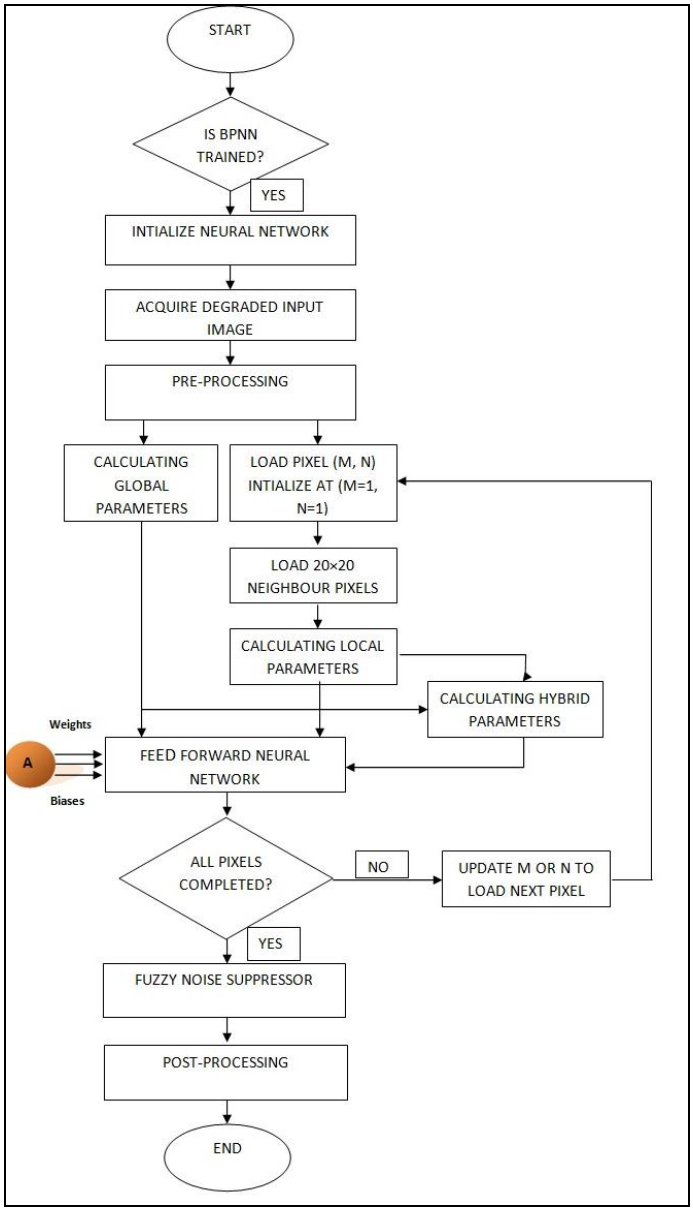


Fig.2. Proposed Algorithm using Neuro-Fuzzy Approach

In second phase, Document Restoring is performed as described in figure 2.This phase is only initiated after completion of first phase. The degraded document is acquired by using digital cameras but in this paper images from DIBCO datasets are used. The acquired images are pre-processed by converting to grayscale if required. The next step is to calculate the input parameters i.e. Global, Local & Hybrid.

The global parameters (Otsu threshold, Mean & standard deviation) are calculated using properties of whole image. The local parameters (21×21Mean, 21×21 standard deviation, 21×21 Otsu threshold level, 9×9 Mean, 5×5 Mean, 3×3 Mean) are calculated by generating variable window sizes around every individual pixel. And lastly Hybrid parameters i.e. (Mean, Standard deviation and Otsu threshold) are estimated by using both global and local values.

These input parameters are different for every individual image pixel and given to Feed-Forward Neural Network. The Feed-Forward Neural Network restoring the informative pixels by using learning of BPNN stored in variable A. Once all the pixels are being processed, Fuzzy Noise Suppressor is

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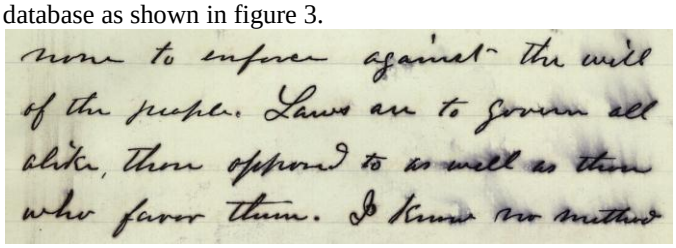
implemented to clear all the spurious responses of neural network. And finally, output of Fuzzy controller is post processed by thresholding using appropriate threshold level.

## IV. RESULTS

In this section, results of proposed technique are compared with existing techniques (Otsu, Sauvola) both qualitatively and quantitatively. The test images are taken from DIBCO database as shown in figure 3.

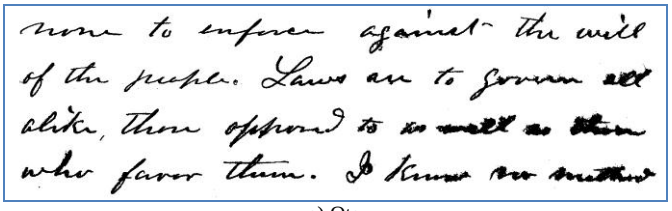


(a)

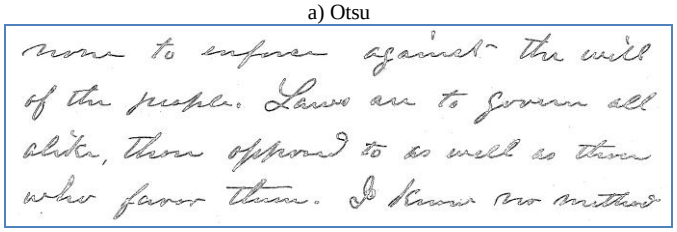

(b)

Fig.3. Test Degraded Images

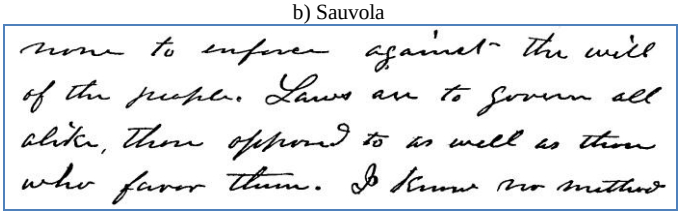
The Quantitative analysis is done by visual inspecting the output images of various techniques. The restored output images of different existing techniques include proposed for both test images are shown in figure4.



a) Otsu

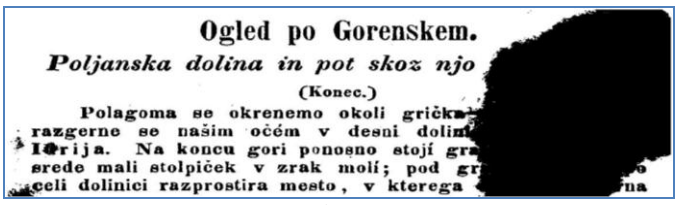


b) Sauvola



c) Proposed

Fig.4. Qualitative Analysis of Test Image 1 by various restoring techniques




a) Otsu

a) Sauvola


c) Proposed

Fig.5. Qualitative Analysis of Test Image 2 by various restoring techniques

The Acquired test images deteriorated by different nonlinear factors like ink smudge, ink stain, ink bleeding, paper aging effects and broken pixels as shown in figure 3a & 3b. The Restored test images, by various existing techniques shown in fig 4(a-c) & 5(a-c) reveals their limiting performance to different degrading factors. The Global thresholding techniques like Otsu are unable to recover information out of deteriorated documents. And local thresholding techniques like Sauvola unable to detect and restore informative pixels. But results shown by proposed Neuro- Fuzzy techniques are remarkably superior as shown in fig. 4 (c) and 5 (c). Also, the proposed technique minimizes different degrading factors and recovered all valuable information out of the uneven & noisy background.

TABLE I. Quantitative Analysis of various techniques for Test Image 1

| METRICS | PROPOSED | OTSU | SAUVOLA |
|---|---|---|---|
| Accuracy | 0.9928 | 0.979 | 0.9654 |
| NRM | 0.0235 | 0.0251 | 0.2421 |
| PSNR | 21.41 | 16.7842 | 14.6139 |
| MSE | 0.0072 | 0.021 | 0.0346 |

TABLE II. Quantitative Analysis of various techniques for Test Image 2

| METRICS | PROPOSED | OTSU | SAUVOLA |
|---|---|---|---|
| Accuracy | 0.9826 | 0.7638 | 0.8763 |
| NRM | 0.0631 | 0.1444 | 0.4983 |
| PSNR | 17.5957 | 6.2678 | 9.076 |
| MSE | 0.0174 | 0.2362 | 0.1237 |

The Quantitative Analysis includes four parameters Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Accuracy and Negative Rate *Metric (*NRM). The PSNR reveals amount of information in comparison to noise in any image and MSE signifies average of difference between Output and Ground Truth image. Whereas Accuracy reveals number of output image pixels exactly matches Ground Truth image pixels. Apart from this, NRM is based on pixel wise mismatch values from both ground truth and output image. Out of these four performance metrics, PSNR and Accuracy are directly relates to quality of output image by various techniques.

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In Figure 6, proposed Neuro-Fuzzy approach has highest (PSNR & Accuracy) and lowest (MSE & NRM), which are necessary conditions for any optimally performing technique. So, this signifies the efficiency of proposed method to restore degraded document over other existing techniques.

## CONCLUSION

In this paper, a novel Neuro-Fuzzy algorithm is put forward for restoration of degraded documents to preserve crucial textual information. There are numerous techniques existing in literature but they are not up to the mark. The qualitatively and quantitatively comparison presented in last section clearly demonstrated that proposed novel Neuro-fuzzy technique outperforms other popular methods in textual restoration.

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