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Application of Neural Networks for Noise and Filter Classification to enhance the Image Quality

Dr. T. Santhanam[1], S. Radhika[2]

[1]Assoc. Prof.& Head, PG & Research Department of Computer Science
D. G. Vaishnav College, Chennai, India

[2]Assoc. Prof., Department of Computer Applications
R. M. K. Engineering College, Tiruvallur Dt., TN, India

Abstract

Image processing operations can be categorized into three major categories: image enhancement, image compression and image restoration. The objective of image enhancement is to improve the insight of the information in images for human viewing or to be used as a preprocessing tool for other image processing techniques. Filtering techniques play a crucial role in enhancing the quality of an image. This article explores the possibility of using an Artificial Neural Network for image noise classification followed by the suitable filter classification. Probabilistic Neural Network strikes a superior performance in identifying the noise as well as the suitable filter for the removal of a specific type of noise.

Keywords: *Image enhancement, Noise and Filter classification, neural networks.*

1. Introduction

Image enhancement aims in improving the quality of a digital image needed for visual inspection or for automated image processing operations. The main objective of image enhancement is to process an image so that the result is more suitable than the original image for a specific application. Image enhancement approaches fall in to two broader categories namely spatial domain methods and frequency domain methods. The approaches in the spatial domain are based on direct manipulation of pixels in an image and the approaches in the frequency domain refer to the modification of the Fourier transform of an image. When image enhancement techniques are used as pre-processing tools for other image processing techniques, then quantitative measures can determine which techniques are most appropriate.

1.1. Spatial Domain methods

The value of a pixel with coordinates (x,y) in the enhanced image F is the result of performing some operation on the pixels in the neighborhood of (x,y) in the input image, F. Neighborhoods can be any shape, but usually they are rectangular. Gray level transformations, Histogram processing, Enhancement using Arithmetic/Logic operations, Smoothing filters and Sharpening filters are some of the methods used in the spatial domain for image enhancement.

1.2. Frequency domain methods

Image enhancement in the frequency domain is straightforward. The Fourier transform of the image to be enhanced is computed, multiply the result by a filter and take the inverse transform to produce the enhanced image. Ideal filters, Butterworth filters, Gaussian filters, Laplacian filters and Homomorphic filters are used in the frequency domain for image enhancement.

In Information Technology, biometric authentication refers to technologies that measure and analyzes human physical and behavioural characteristics. Physical characteristics such as fingerprints, irises and facial patterns when captured, as raw images requires some image processing techniques to get the exact image so that the individual's identity is established. Filters are widely employed in the field of biometrics for improving the quality of images before extracting the features for identification/recognition.

2. Artificial Neural Network

An Artificial Neural Network (ANN), usually called "Neural Network" (NN), is a mathematical model or computational model that tries to simulate the structure and/or functional aspects of biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. Neural networks can be used to model complex relationships between inputs and outputs or to find patterns in data.

Classification is one of the major research areas of neural networks and many neural networks have emerged as an important tool for classification. The recent research has established that neural networks are a promising alternative to various conventional classification methods. The advantage of neural networks is that it makes use of self-adaptive methods to adjust to the data without any explicit specification. Fabio Roli and G N Marcialis used a single layer perceptron with a class-separation loss function for classifying individuals based on their fingerprints. [2]

Image denoising is an important image processing task, both as a process itself, and as a component in other processes. Very many ways to denoise an image or a set of data exists. The main properties of a good image denoising model are that it will remove noise while preserving the fine details of the image. Many image denoising algorithms were prevalent in the past, but they weren't successful when it comes to automatic image restoration. [3][4][5][6] Identification of the noise is crucial for an image denoising model to be accurate.

The use of a Multi Layer Perceptron (MLP) [7], Back Propagation Network (BPN) [7] and Probabilistic Neural Network (PNN) [8] to classify the image noise, based on the statistical features like skewness and kurtosis is available in the literature. Noise identification is vital for determining the denoising procedure for an image, which leads to image enhancement for further processing.

2.1 Back Propagation Network (BPN)

Back Propagation Network is a multilayer feedforward network employing back propagation algorithm. As the name implies, the errors propagate backwards from the output nodes to the inner nodes.

The steps in the BPN algorithm are [9]

1. Select a pattern X_k from the training set T, and present it to the network.
2. Compute activations and signals of input, hidden and output neurons in that sequence.
3. Find the error over the output neurons by comparing the generated outputs with the desired outputs.
4. Use the error calculated in step 3 to compute the change in the hidden to output layer weights, and the change in input to hidden layer weights (including all bias weights), such that a global error measure gets reduced.
5. Update all weights of the network in accordance with the changes computed in step 4.

   Hidden to output layer weights

   $$W_{hj}^{k+1} = W_{hj}^{k} + \Delta W_{hj}^{k} \quad (1)$$

   Input to hidden layer weights

   $$W_{ih}^{k+1} = W_{ih}^{k} + \Delta W_{ih}^{k} \quad (2)$$

   where ΔW_{hj}^{k} and ΔW_{ih}^{k} are weight changes computed in step 4.
6. Repeat steps 1 through 5 until the global error falls below a predefined threshold.

T. Kalpalatha Reddy and N. Kumaravel have used BPN for classification of bone samples at different locations of the jawbone region [12] and Graham Kendall *et al.* have used it to classify document zone content in technical document images. [13]

2.2 Multilayer Perceptron (MLP)

The most common neural network model is the multilayer perceptron (MLP). This type of neural network is known as a supervised network because it requires a desired output in order to learn. The goal of this type of network is to create a model that correctly maps the input to the output using historical data so that the model can then be used to produce the output when the desired output is unknown.

The inputs are fed into the input layer and get multiplied by interconnection weights as they are passed from the input layer to the first hidden layer. Within the first hidden layer, they get summed then processed by a nonlinear function. As the processed data leaves the first hidden layer, again it gets multiplied by interconnection weights, then summed and processed by the second hidden layer. Finally the data is multiplied by interconnection weights then processed one last time within the output layer to produce the neural network output.

Real-world task like the classification of hand-written numerals may be efficiently and economically accomplished by means of a general-purpose Multi Layer Perceptron. [1]

2.3 Probabilistic Neural Network (PNN)

Probabilistic neural networks are forward feed networks built with three layers. They are derived from Bayes Decision Networks. They train quickly since the training is done in one pass of each training vector, rather than several. Probabilistic neural networks estimate the probability density function for each class based on the training samples.

There is an input unit for each dimension in the vector. The input layer is fully connected to the hidden layer. The hidden layer has a node for each classification. Each hidden node calculates the dot product of the input vector with a test vector subtracts 1 from it and divides the result by the standard deviation squared. The output layer has a node for each pattern classification. The sum for each hidden node is sent to the output layer and the highest values wins.

The Probabilistic neural network trains immediately and is used for classifying data. Probabilistic neural networks handle data that has spikes and points outside the norm better than other neural nets. PNN is used in classifying cancer data. [10][11]

3.Methodology

Step 1: The noises in an image are classified as non-gaussian white, gaussian white and salt and pepper noise by the PNN as given in [8] and the performance of the network is above 90%.

Step 2: The classified noises are given as input to BPN, MLP and PNN networks which identifies the suitable filters for noise removal. The filters that are classified by the neural network are Wiener filter (Non gaussian white) [14], Infinte Impulse Response filter (Gaussian white) [15] and Median filter (Salt and pepper noise) [16] . The performance of BPN, MLP and PNN networks are given in Table-1.

A k-fold cross-validation is used. i.e. the images are partitioned in to k (say 10) partitions at random. Training is carried out with k-1 partitions and testing is carried out with the left out partition. The cross validation process is then repeated k times, with each of the k partition being used exactly once for testing. The k results are averaged to determine the resulting accuracy.

Table 1: Performance analysis of PNN, MLP and BPN network

	Wiener filter	***IIR filter***	***Median filter***
PNN	93.33%	96.67%	93.27%
MLP	96.67%	86.67%	90%
BPN	93.33%	93.33%	86.67%

The entries in the table give the correct % of filters classified for a specific type of noise. The performance of PNN in classifying the filter for noise removal is greater than 90% and is superior to MLP and BPN network.

4.Conclusion

The use of Neural Network for classification of noise followed by classification of filter is explored in this article. CASIA-Irisv3 database have been used to test the performance of the network and the experiments have been carried out in MATLAB. The results show that PNN proves to be a better network in classifying the noises as well as filters than the MLP and BPN models. The results obtained can be used in employing the suitable filter for noise removal, thus enhancing the image for further processing.

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Dr. T. Santhanam is working as Associate Professor and Head in D. G. Vaishnav College, Chennai. He is having over 20 years of experience in teaching and has many research publications in international journals and conferences. His areas of interest are Biometrics, Image Processing, Neural Networks and Data mining.

S. Radhika is working as Associate Professor in R. M. K. Engineering College and is pursuing her research in D. G. Vaishnav College affiliated to University of Madras, under the supervision of Dr. T. Santhanam. Her research interests are Image Processing and Artificial Neural Networks.