A Novel Image Restoration Algorithm using Sliding Window and Neural Network

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Abstract. As images become one of the most significant information carriers in daily life, it is essential to transmit and store high quality images. In the case that original image is degraded, a method to extract information and restore the degraded image is needed. In this paper, a novel algorithm is proposed to restore degraded image by using sliding window and neural network. In our algorithm, first, we used the sliding window to sample the image, then put the sampled sequence into neural network for training, establishing a nonlinear mapping model between the target clear image and the blurred image. Finally, we put the degraded image into the well-trained network to restore. The simulation results and analysis of the restoration on MATLAB are also showed, it turns out the quality and clarity of the degraded image are well improved.

Introduction

Image processing plays an important role in the fields of scientific research, industrial production, medical care and communication [1]. But due to imperfect imaging systems, transmission media and equipment, etc. the image quality is degraded, such as blurred image, distorted, noisy, and the like [2]. In many fields, clear and high-quality images are required, so it is important to obtain images with less distortion.

The traditional image restoration methods can be roughly divided into inverse filtering method, algebraic method and spatial domain filtering method [3]. These methods are either faced with the assumption that the degraded image needs to satisfy the generalized stationary process, or face the problem of high dimension and complicated calculation, or without a complete theoretical guidance [4]; the image restoration problem has not been satisfactorily solved. In recent years, many new methods of image restoration, such as neural network computing, wavelet theory, graph cutting theory, etc. have injected new blood into the field of image restoration [5].

Neural network has the characteristics of strong nonlinear mapping ability, high fault tolerance and robustness, strong self-learning and self-adaptive ability, and the ability to apply learning results to new knowledge [6]. This paper briefly introduces the BP algorithm, about the design process and implementation method of image restoration, finally analyzes the simulation results of image restoration and evaluates the restoration effect.

Brief Review of BP

The BP algorithm consists of two processes: the forward propagation of the signal and the back propagation of the error [7]. The BP network adopts a guided learning approach, and its learning process is: signal is input from the input layer, passed to the output layer through the first or multilevel hidden layer, and the actual output is compared with the expected output, then reverse the error and adjust the weight of the network layer by layer until the error in the network output is reduced to an acceptable level, or until a predetermined number of learnings. BP algorithm can be summarized as the following steps:

1. Initialize, assign initial values to each weight and threshold with a small random number.
2. Read network parameters and training sample sets.
(3) Data normalization.
(4) Calculate each sample in the training set. Forward calculation of the output of each neuron in the hidden layer and output layer. Calculating the error between the desired output and the network output. Reversing calculation of modified network weights and thresholds.
(5) If the accuracy requirement or other exit conditions are met, the training ends, otherwise go to step (4) to continue.
(6) Results analysis and output.

Neural Network Image Restoration Design Process

Overall Design Structure

The neural network has three types of layers: input layer, hidden layer and output layer [8]. The number of nodes in each layer of the network is determined according to the input sequence of the network [9]. In this paper, the image is processed on the grayscale channel of the image, degraded image is used as the input data of the network training, the clear image is taken as the expected output data, and the restored image is taken as the actual output of the network. We do the size processing of the images input by the network, so the pixels of the clear image width and height are 130×130. The process of restoring degraded images in feedforward Neural networks Based on BP algorithm is shown in Figure 1

![Neural network model for image restoration.](image)

Figure 1. Neural network model for image restoration.

Input and Output Image Processing Method for Neural Network Training

Using a complete image as the input data of the network increases the number of nodes of the input neurons. To ensure the performance of the network, the number of nodes in the hidden layer should also increase accordingly. The complexity is increased, and the network training time will be longer, and the performance of the computer has higher requirements. In this paper, the training image is sampled by the sliding window of 3×3, so the number of input nodes of the network is 9.

A clear image has little difference between a pixel at a certain point and its neighborhood. It is assumed that the degraded input image is represented by \( P_{ij} \) (\( i=1,2,\ldots,128; \ j=1,2,\ldots,128 \)) at a certain point, and the pixel of the desired output image at a certain point is represented by \( T_{xy} \) (\( x=1,2,\ldots,128; \ y=1,2,\ldots,128 \)), and the original image is represented by pixel \( I_{mn} \) (\( m=1,2,\ldots,130; \ n=1,2,\ldots,130 \)) at a certain point. The pixels of the original image except the two rows and two columns of the edge are output as the desired image, that is \( T_{ij} = I_{mn} \) (\( i=1,2,\ldots,128; \ j=1,2,\ldots,128; \ m=2,3,\ldots,129; \ n=2,3,\ldots,129 \)), so the restored image pixel size of the network output is 128×128. Figure 2 is the process of selecting a block-degraded image through a sliding window., and Figure 3 is a process of selecting a target pixel by a sliding window.

![The process of selecting a target pixel by a sliding window.](image)

Figure 2. The process of selecting a target pixel by a sliding window.
Figure 3. The process of a sliding the window to select the target image.

**Designed Neural Network Structure**

Related experiments show that when the number of hidden layer nodes is 20, a smaller square error and faster convergence speed can be obtained [10]. According to Sections 3.1, 3.2 and 3.3, the number of neurons in the input layer, hidden layer and output layer we finally designed is 9, 20 and 1 respectively, and the input matrix and output matrix dimensions of the network are 9×16384 and 1×16384, respectively. The important parameters of the neural network BP algorithm are set to the maximum number of iterations 1000, using the unipolar logsig function as the node transfer function, the output function is the purelin linear function and the other parameters are the default values of the network. The threshold is set to 0.001 and the program terminates when the output objective function value is less than the threshold. When the network is trained, enter a new degraded image and you will get a clear image of the restoration.

**Simulation and Discussion**

There are many methods for judging image quality by calculating the deviation. Commonly evaluation criteria are square error (MSE), signal-to-noise ratio (SNR), and peak signal-to-noise ratio (PSNR). Wang et al. also proposed a method based on the Structural Similarity Index (SSIM) to evaluate the quality of images [1,5]. The range of PSNR is generally [20, 40]. The larger the value, the better the image quality. The SSIM value range is (0, 1), and the closer the value is to 1, the smaller the image distortion.

On the MATLAB simulation platform, we use the Wiener filtering method, sliding window and neural network method to simulate the image restoration. By comparing the two methods, we find that the method used in this paper has better effect on image restoration, both in terms of visual effect and statistical characteristics of histogram, as shown in Figure 4 and Figure 5.
Summary

This paper uses a 3x3 sliding window to sample the image, and trains the network in the MATLAB software environment. The network achieves the effect of restoring the degraded image. The visual effect is consistent with the restored image compared to the original clear image. In the next step of training, we will train the degraded image separately from the edge region and the smooth region, and further improve the neural network algorithm to make the image restoration effect closer to the real image.

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