Study of Deep Learning Techniques on Image Denoising

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Abstract. With the advancement in the area of Artificial Intelligence, the technology of deep learning is widely used in the field of Digital Image Processing and it is showing good results in the domain of Image denoising. To understand the area and progress of the field of deep learning in the domain of denoising, the research work is to be reviewed on various techniques, so that research scholars, academicians and industry professionals can take benefits out of this. The three models are introduced in this paper, such as wavelet neural network, pulse coupled neural network and convolutional neural network which are typically used in the field of noise reduction i.e. image denoising. The method of reduction in noise which is nonlocal in nature is considered as the heart of this technique. The aim of this paper is to better understand the recent developments in the field of machine learning and deep learning with the domain of reduction in noise of digital images.

1. Introduction

With the recent advancements, several traditional denoising methods and algorithms have been introduced and well applied in various applications. There are several methods like median [1], Gaussian [2], mean [3] and non-local mean [4]. These methods are used in many applications but still challenges are involved in preserving the clarity of image structure, more research on the techniques of image denoising is needed. There are several mathematical theories are involved in the creation of different methods. The algorithm enters into a new stage, when some new mathematical theory knowledge is applied to the algorithm of denoising. In recent years, the technology which is introduced in the field of Image denoising is neural network which is having very good advantage in producing the results. With many developments in the field of artificial intelligence, neural network deep learning techniques have been used popularly in several applications and with the application of this, image denoising technology has been further enhanced.

Several methods of denoising have been evolved with time using the technology of deep learning. For example, [5] Zhang Wenxing's literature in image denoising methods using deep neural network, [6] Li Chuanpeng's literature in image denoising methods using pulse-coupled neural network, and various PCNN based algorithms by Wenjie in the literature [7]. Research work carried out on several methods of image denoising algorithms is applicable in networks.

2. Noise Models in Image Processing

The component which interfere with a clean signal, that is known as Noise. It occurs in various types of images due to different phenomenon which are physical in nature. Large amounts of noise not only affect the origin of images but also degrades the quality of various image recognition algorithms. In this section, we discuss about various noise models which are used in image processing domain.
2.1 Gaussian Noise

Gaussian noise is the most commonly type of noise model which are basically used to show distortions which are thermal in nature. Distribution defines the probability density of Gaussian noise, \( \sigma^2 \) its variance, and \( -\infty < x < \infty \).

2.2 Quantization Noise

When analog signal is to be converted into digital signal, then the noise that we encounter is Quantization noise and it also results in quality drop. It can be seen as noise which is sampled uniformly with the range specified 0 to q.

2.3 Salt and Pepper noise

This type of noise can be used to handle distortions simultaneously while data transmission is taking place through channel which is noisy in nature and it results in the loss of information which are to be measured in the number of pixels.

3. Neural Networks used in Image Denoising

There are some types of Neural Networks used in Image denoising are:

3.1 Convolutional neural network (CNN)

CNN consists of acquisition of feature and its corresponding structure of feature with the use of sigmoid colon as its activation function. The operation of convolution is to be applied on the sample input image and then its offset is used to generate four feature maps correspondingly and its four pixels are summed up for mapping with it, requires sums and weights. The activation function ReLu is used to get the four layers feature operational map and they are rasterized into vector input corresponding to its pixel values. The output result value can be obtained from neural network. In [8], Jing discussed about deep network which worked on CNN in various algorithms of image denoising which are based on basic CNN. The resultant network is very much differentiated from traditional network of neural networks which comprises of four sub-networks. The image which is used as input is applied to several convolution functions and the image is going to be filtered many times to get the feature map of the network. Furthermore, obtained feature operational maps are connected completely to retrieve the output image. Jing discussed innovative framework [9] for noisy images. The structure that she gave consists of convolutional layer and it is not containing the sample layer as described in figure 1. It comprises of four types of layers which are :-i) Input layer ii) Convolutional layer iii) Pooling layer iv) Output layer. The process of denoising consists of three steps: a) Extraction of block image b) Nonlinear mapping c) Reconstruction of image. These steps directly map the noisy images to noiseless images. The real scene CNN is discussed by Wang Chun [10] which uses deconvolution algorithm. This method suggested to map denoised images data set to be applied to convolutional neural network. The algorithm of simulated annealing improves the rate of training and try to establish the model of denoising to have image denoising of real scene. Junfeng [11] tried to work upon the noise removal algorithm which is based on image mixing using the concept of convolutional neural network. In this, he discussed about convolutional network of 9 layers which uses nonlinear mapping, dimensional contraction, image feature extraction, magnification of the dimensions of the image. To get the final model, noisy image is to be trained.
by reconstruction. In [12], Yungang discussed the method of image denoising which used CNN for the computed tomography images which are having poor visual effect. The CNN given us batch normalization and learned images. The two uses the mapping function which is a function of cavity convolution which results in the increase of receptive fields.

Figure 1. Structure of Convolutional Neural Network

3.2 Pulse coupled neural network (PCNN)

Pulse-coupled neural network was proposed by Eckhorn [13] whose network structure is based on the principle of cat’s view. As compared to traditional neural networks, there is a lot of difference.

This type of neural networks retrieves information which is valid from different backgrounds with the traits like entire join and sync pulse and it is somewhat similar to human visual systems. In pulse coupled neural network, the neuron output has only two states i.e. misfire and ignition [14]. The pixel which is affected by noise will make to pass through this type of neural network, the actual output varies from the surrounding pixel output to actually determine whether the point is of category noiseless or noisy. Furthermore, when some neuron ignites and its adjacent neurons don’t respond to the ignition, indicates that it has been affected by noise. If most of the neurons which are adjacent in nature does not respond to ignition, then their resultant gray value is lower than the standardized value and the resultant pixel is not affected by noise.

A new method of image denoising was proposed by Xiadong which used this type of neural network for binary images [15]. The combination of pulse coupled neural network and time sharing matrix is used to get new method of denoising which is split in nature making use of time-sharing matrix and it was proposed by Liu et al. [16]. Furthermore, an enhanced PCNN method of denoising is proposed by Wenjie [17] which worked on the previous problem and only the usage of CNN removed only binary noise and the gray image cannot be removed. All the traits of PCNN with morphology of mathematics in combination with impulse noise was summarized by Ma Yide and invent the new method of image denoising with gray morphology. The synchronization pulse of this neural network is utilized by this method. To know the source of the noise, a feature is issued that is to be used with shape filtering mathematically which reduced the noise. For different noise models, different types of PCNN algorithms of denoising are proposed. For effective removal of salt and pepper noise, Yuanmin et al. discussed a new and strong method of denoising [18] which is based on pulse coupled neural network that is adaptive in nature. The mechanism of noise transition is introduced in this method which became its special feature. For better preservation of details, the area of the noise is to kept noise free. For medical images [19], the method of denoising which is used was
also based on this type of neural networks that used wavelet denoising which is a wide application of wavelet algorithms i.e. proposed by Yecai. In this method, the wavelet coefficients are first processed and then algorithm of PCNN will be applied and it also modify the wavelet coefficients automatically. The underlying structure of this type of network is given in figure 2. This consists of Input layer, pulse generator, connection node and output layer. The main characteristics of PCNN and median filtering which is adaptive in nature was also analysed by Liu et al. [20] which results into the formation of method of denoising which is PCNN-based median filtering that is adaptive in nature.

![Figure 2. Structure of Pulse coupled Neural Network](image)

### 3.3 Wavelet neural network (WNN)

This type of neural network works with the replacement of nonlinear activation function of normal neuron with the nonlinear base wavelet. The entire structure of this network and primitives are to be studied on the underlying basis and analysis of wavelet which can cover the deficiencies of design. These types of networks have also some type of disadvantages. As the dimensions of the network increases, in case of multi-dimensional input system, it results in the exponential growth of samples and the structure of the network becomes more complex, that results in less convergence speed.

![Figure 3. Structure of Wavelet Neural Network](image)

To select the correct wavelet base on the basis of actual conditions is not possible adaptively. Another method which used this type of neural network was proposed by Deng for the problem statement of denoising of impulse noise [21]. This method is a combination of median filtering and WNN to perform various operations on noisy pixels. It divides the pixel into non-noisy pixel and
noisy pixel and then the assignment of coefficient scale values to different noise pixels according to the value of their domain and finally gets the output by the combination of median filter. This type of neural network can also be applied to biomedical images by Nian [22] and better reduction in noise is achieved which results in increasing efficiency of the workers. In the field of laser images, this type of neural networks was also proposed by Tang which results into the denoising technique, obtained better effects of denoising and efficiently preserving the image details.

The structure of wavelet neural network is described in figure 3. It consists of three types of layers i.e. input layer, hidden layer and output layer. The input layer consists of many states which are applied to hidden layer with its own bias and weights applied finally to output layer creating final results which can be calculated by taking the previous layer results.

4. Results and Discussion

By using the five layer-neural network, non-local mean filtering method, block construction of learning filtering process and the by the usage of activation function i.e. ReLu function with mean square loss function, the optimization function of Adam is used.

To get better effect of noise reduction, utilized the small batch processing model on the framework of keras. The framework is described in figure 4 which after applying noisy image through various layers, it is converted into image which is free of noise.

In the process of actual denoising, the denoised image needs to be divided into several image blocks of fixed size and then the technique of machine learning learns various mapping functions between different blocks of image. In the process of denoising. All the blocks of image are become noise free by the usage of mapping function and then the images of block are combined to form an entire noise-free image.

Figure 4. Framework of Neural Network Denoising

Steps of simulation of binary images using deep neural networks for specific case of “Cameraman” image:

a. If we have deep learning toolbox, then clean image B is to be differentiated from noisy image A by using keyword “net”.

b. If we have pretrained neural network, which is convolutional in nature, we can use the keyword” DcNN”
c. In workspace, load the gray image and we have to create version of the image which is noisy in nature.

d. Display the two images as montage

e. The noise is to be removed from the noisy image and then the result will be displayed.

The results can be showed in figure 5 and figure 6. Figure 5 represents the noisy version of the image and figure 6 represents denoised version of the image after simulation.

![Figure 5. Noisy version of Image “Cameraman”](image1)

![Figure 6. Denoised Image “Cameraman”](image2)

5. Conclusion

Various models of neural networks have been introduced in this paper which achieved better results in the denoising of various types of images but the challenges of setting of parameters and size of data set are also faced. There are no fixed criteria for the parameter setting in the model as they are experimentally achieved to obtain the best suited parameters. There is a need of further research on this problem. Mixed noise is achieved in some images. Most methods of denoising can only work for a single type of noise. Therefore, for removal of combined noise by the application of deep learning technology is what we aim to study further.
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