Deep Learning Image Denoising Techniques: A Review

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Abstract- Restoration of image from degraded and noise corrupted signal is a major challenge. A lot of image restoration algorithm and method have been developed and available in literature on image processing. There have been several algorithm present and each has its advantage and disadvantage. But till date no single image restoration method is capable to address different type of challenges in different type of image modalities. Still the researcher and scientist are developing new and refining the previously available image restoration method and techniques. In this paper a comprehensive study is conducted of all the recent major image restoration method and algorithm available in literature and tried to find out the research gaps to provide the insight for further improvement in the existing state-of-art methods and to provide a new research paradigm to the research community and students.

Keywords- *Deep learning, image denoising, deep convolution, neural network, Non local filter.*

I. INTRODUCTION

Since the work on image denoising method have experienced lot of ups and downs, but always have been interest for researchers. Image denoising based method have been successfully applied to satellite imaging, remote sensing, weather forecasting etc. The latest advancement in the field of image denoising has been done with the development of deep learning. The key component of deep learning is multi-layered hierarchical representation of data using neural network that consist of more than two layers. Such method automatically allow to extract features of high level from low level. Though deep learning has been expired by neural networks there are some attempts to apply its ideas to other types of models. Here a survey of deep learning methods aimed at image denoising in images is represented.The relevant method under account to these problems is validated by the latest results of well-known competitions such as ImageNet, VCGNet etc. in the context of which the discovery or development in image denoising task has been recently made.

A. NOISE MODELS

Noise is unwanted source that is added in image and produce undesirable effect in image such as blind corner, blurred object, disturb background scene etc. To remove unwanted effect, learning of noise model is essential that lead to further processing of image. Noise come from different sources such as Charge Coupled Device (CCD) and Complementary Metal Oxide Semiconductor (CMOS) sensors.Probability density function (PDF) or Histogram is widely used to verify the noise model.Various types of noise are present such as Gaussian Noise known as electronic noise and caused by natural sources such as thermal vibration. But in digital image Gaussian noise is produce by disturbing gray-value. White Noise is identified by power noise. Noise power is infinity in white noise. In white noise relationbetween pixel value is not possible because each value different from other [1]. Brownian Noise is known as colour noise, flicker noise. It is caused by suspended particle in fluid and follow normal distribution. Salt and pepper Noise is known as drop noise and some pixel value is corrupted. This type of noise seen in data transmission.Periodic Noise is originate from electronic interference in power during image capturing. It appear in conjugate form in frequency domain. Quantization Noise present due to analog data that converted into digital form. In this noise model signal to noise ratio is min and max pixel value. Speckle Noise known as multiplicative noise and appear in laser beam, radar etc. and follow gamma distribution. Photon Noise present in X-ray visible light, gamma rays etc. that emit photon per unit time, known as quantum noise or shot term noise. In this paper various noise reductions methods have been reviewed to formulate a general consensus to formulate a image denoising method as a new one.

B. DENOISING PROBLEM

Image denoising problem require determining the noise it belongs to. The problem is complicated with the growth of noise, because several type of noise is present in image and is difficult to suspect which noise is present and need to determine the method required for removing noise from image. Image denoising is still a current issue that need to do more research.

C. DENOISING MODELS

Denoising is a method which reconstruct a signal from a noisy one. The main goal of denoising method is to remove noise and store useful information. But till now we don't get an efficient denoising method that improve the performance and functional analysis. There are various methods and algorithm available but till now no one is able to remove noise properlyfrom image. All algorithms perform well in image processing but still few percent of noise is present in image that lead to more refinement in image processing. Various type of methods are available, few of them are: Mean filter comes under linear filter and known as averaging filter. And used in region where noise of image need to be removed [2]. Median filter is nonlinear and used to find median value and replace each value with median value. The main disadvantage is complex computation and expensive and need to be arranged in sorting order and performance measurement is slow. Wiener Filter is used for filtering the image from noisy

corrupted image and based on statistical approach. It require accurate noisy model and is difficult to achieve and is also complicated in computation. LMS Adaptive filter is used when there is several changes in intensity value. It perform better job when compared with adaptive filter due to its simplicity and work well in salt and pepper type of noise. Various type of filters are available that help to remove noise. But these filters are outdated now because of their performance and are very slow.

a. IMAGE INPAINTING AND DENOISING

Image signal is distorted when we transfer data from one channel to another or while capturing data. Image denoising and inpainting are important image restoration problem and used in various application. Image denoising problem occur when image is distorted by noise mainly additive white Gaussian noise whereas Image Inpainting problem occur when some information about pixel is missing. Various method have been proposed. One approach is transferring image signal into another domain where noise can be easily removed [3, 4, 5]. Another approach is to capture image directly from image domain. The most important technique is sparse coding that drawn much attention [6, 7, 8, 9, 10, 11]. Image Inpainting can be divided into blind and non-blind. In non-blind, information about pixel value is provided that need to be filled whereas in blind no information about location of corrupted pixel and algorithm automatically identify pixel that require inpainting. We use Deep Autoencoder that use two layer network based on reconstruction of distorted image from which noise is removed to recover noise free data.

b. NON-LOCAL MEAN FILTER

Non-local means filtering perform by taking mean value of all pixel and weighted the pixel value to analyze how similar the pixel value target pixel value. The result provide much efficient and give clarity, and there is less loss of data in image when compared with local mean filter. Non-local mean filter are used in various applications such as de-interlacing and interpolation. When compared with otherdenoising techniques, non-local mean filter adds error in the denoising processs which is required because it effect less in disturbingthe denoised product. The non-local mean filter remove noise from image and clean the edges and there is less loss of structure. As noise is increased in image, the performance of local mean filter decrease and denoised image suffer from blurring and detail of image is lost.

c. IMAGE SUPER RESOLUTION

Single image super resolution are used to produce high resolution image from low resolution image. Image super resolution use deep learning method where mapping is performed between low and high resolution image. The mapping is performed in deep convolution neural network where low resolution image is taken as input and high resolution as output.

For code optimization, high resolution of image and video are produce by camera and mobile are significant in image processing. They need resources to run program and require experts. The performance is also increased when implemented the program [Hergarty et al. 2014; Mullapudi et al. 2016; RaganKelly et al. 2012] and these program increase runtime complexity.

II. DEEP MODELS

In this section, we explain the fundamental concepts of feed-forward neural networks and basic deep models in the literature. The contents are specifically focused on learning hierarchicalfeature representations from data. It is also described how to efficiently learn parameters of deep architecture by reducing overfitting.

A. FEED-FORWARD NEURAL NETWORK

Artificial neural network where connection between units are not formed and they don't create cycle.Different from recurrent model.First and simple type of neural network.Information moves in one direction forward from input node, through hidden node and output node.It is of two type single layer and multiple layer perceptron, in single layer consist of single output node in which input is directly connected to output node.While, in multiple perceptron multiple nodes are interconnected. It is used in back-propagation model.

B. BACK PROROGATION

Method used in artificial neural network to calculate error contribution of each neuron after batch of data is processed. Automatic diffraction is general technique that are used in back prorogation. It is supervised learning algorithm using gradient descent. The backward prorogation method used to calculate the last layer being first and first layer being calculated last. This technique used in speech recognition and image recognition. It is an efficient algorithm and help to increase implementation in GPU computing.

C. DEEP NEURAL NETWORK

Artificial neural network with multiple hidden layer between input and output and handle complex non linear relationship. Deep neural network is machine learning algorithm that consists of nonlinear processing units for feature extraction and transformation. Used in supervised and unsupervised classification and help in multiple level of representation. Deep neural network is feed forward model in which data flow from input to output without loop back.

D. RECURRENT NEURAL NETWORK

Recurrent neural network is a artificial neural network in which connection between units are used to form a graph. It use internal memory to process input. Used in handwriting recognition and speech recognition. It is directed acyclic graph that are used to replace with feed forward neural network. If there is time delay or storage problem then can be solved by

replacing with another graph. Recurrent network use two type of classes first finite impulse and second infinite impulse. Both network associative with dynamic behaviour.

E. CONVOLUTION NEURAL NETWORK

CNN or ConVnet is a class of deep feed-forward artificial neural network that has been used for visual imagery. CNN use variation of multiple perceptron and known as shift invariant, space invariant that are based on shared weight architecture. Used in natural language processing, image recognition and recomender system. CNN share weight that means same filters are used in each layer and help to improve performance and decrease time.

III. IMAGE DENOISING USING MACHINE LERNING

Analytical methods has been used to solve imaging problem such as image restoration, image inpainting. Machine learning and deep learning has been used to solve such imaging problem. The use of deep learning method for image processing took regression end to end learning approach in which specific inverse problem task has to be solved. The industrial world is moving into new area of smart sensing, the established area need to be developed for new opportunities and challenges. We use spatio-temporal data classification from raw sensor data without the need to reconstruct image. This is based on efficient used of machine learning methodology based on convolution neural network architecture for learning feature from end to end raw sensor data.

A. LEARNING SYSTEM

Lifelong learning is fundamental in autonomous for acquisition and fine tuning of knowledge through experience. Conventional deep neural network are used for action recognition from video that do not account for lifelong learning but learn a batch of data with already defined number of action, classes and sample. There is need to develop learning system with ability to develop incremental process.

Free energy based reinforcement learning are used to handle high dimensional state and action spaces. FERL is technique that work well with binary state input, where number of active state is lesser than non-active state. Elfwing et..al (2013) that The robustness and learning performance of FERL can be improved by scaling factor, Z (i.e Q=F/Z) that is related to size of network. Heess et..al (2012) proposed two energy based gradient algorithm and demonstrate that they are more effective and robust free than standard FERL in high dimensional tasks.

B. IMAGE CLASSIFICATION USING TEXTURE

Texture is key concept for object recognition task that are used to define texture based imagery data like Brodatz (WWW1,0000), VisTex (WWW2,0000). In Costa, Oliveria, Koerch and Gouyon (2013), a similar approach was used to find textural representation using Music Dataset (Sillia Jr., Koerich & Kaestner, 2008). Feature of Texture have been used to solve other object problem. Deep neural network have been used to learn data representation in both supervised and unsupervised setting. Deep neural network have achieved great performance in computer task include object recognition, detection and segmentation. The powerful technique is visualization that are used to understand how deep neural network work. Through visualization we see edges first, corner or shapes from second layer, object part from intermediate layer and object from last layer.

C. BIG DATA

Computer based simulation of difficult mathematical system are used to describe the feature of physical, chemical and mathematical model. These models are used to describe the computation complexity and with the usage of these models resources are also needed that lead to increase in cost value. These models are used in various scientific area such as weather forecasting, climate modelling, chemical transport. With the usage of these models lead to increase in usage of memory and need bulk of data to store i.e. Big Data. These model are used in neural network support, vector machine, kernel smoothing model and results are used in operational environment. Complex mathematical model are present in scientific area such as weather forecasting (Han & Pan, 2011; Lyunch, 2006), climate modelling (Flayo et al., 2013) and large eddy simulation (Sagaut, 2006). It is generic approach where problem of training dataset are created or resampled and combined with regression tool such as neural- networks, support-vector etc.

The word big is used with respect to data that are used in application domain and also need resources to execute application domain. Big data are collection of large processed information that cannot be processed using traditional approach. Big Data include cloud computing, online services, business and scientific data. These data also contain too much noise and some feature are related to target process. Many machine learning algorithm affected by noise and data must be processed feature extraction. The feature selector will help to reduce size of data that will also used to reduce execution time of algorithm and they provide efficient result.

D. PROBLEM RELATED TO PHASE RETRIEVAL

Phase retrieval problem occur when one want to recover input from only amplitude or intensity output of linear system.Phase retrieval problem refer to:

$$y = |Ax| + w \qquad (1)$$

Where measurement matrix A represent forward noise and w represent noise. prDeeep is flexible and can handle wide variety of measurement and we utilize convolution neural network . The existing PR algorithm lead to distortion of amplitude in the presence of noise that is not reliable in Gaussian and diffracted distribution measurement model and lead to slow the performance. To overcome these drawbacks, we use convolution neural network , a machine learning tool that help to boost the performance. prDeep is new technique that implemented in simulation and help to boost the

performance and used in high resolution applications .The main drawback of this model is it is restricted to amplitude.

E. LAYERED NEURAL NETWORK

Layered neural network are used to increase performance of various application such as image processing (Bengio, Courvellie, & Vincet 2013; LeCun, Bengio & Hinton , 2015), speech recognition (Krzhvesky, Sutskever, & Hinton , 2012; Tompson et. al, 2012) , natural language processing. They has simple layered structure of units and connections, they outperform other convolution model by their ability to learn non linear relation between input and output data.These parameters are optimized through training so that they extract important feature from input**.** Layered network used in three applications such as decomposition of layered network into small set of independent network which help to increase computation speed, the result can be applied to modularity index that help to increase the result efficiency and help to provide global relation structure that help to provide knowledge from trained network.

F. SEGMENTED ECHOGRAM DATA

The problem of segmented echogram data are collected from polar ice sheets, which is difficult to segment the data because of presence of noise. They propose a multitask spatio temporal network which is combination of 3D ConvNet and recurrent network to estimate surface from tomography radar image. The model outperform the existing model by providing hand tune information about parameters, extracting multiple surface of ice air and ice bed and need less non visual metadata and is 6ms time faster.

G. WAVELET TRANSFROM AND THRESHOLDING

An image can be effected while capturing and transmitting. Wavelet based noise reduction combined with thresholding and thresholding function is applied on thresholding neural network algorithm due to its continuity and non linearity .They provide higher PSNR value when compared with other existing method and provide 2.90 dB improvement when compared with other existing method.

H. HADOOP YARN

Hadoop based neural network used for parallel and distributeddata that are used to extract features. Artificial neural network embedded with hadoop are used to extract and compare multiple features.This allow the best and actual features to be selected and identified from large and high dimensional datatset that provide efficiency and flexibility of embedded binary associative memory using hadoop. Hadoop is open source java framework that support processing and large storage dataset in distributed compuitng environment. It's distributed file system facilitate rapid data transfer among nodes and allow the system to continue operating in case of node failure.

I. RESIDUAL LEARNING

Residual learning and batch normalization are used to increase the performance in denoising. The exiting model is additive Gaussian noise and trained to handle the Gaussian noise at certain noise level. But residual learning model is Gaussian denoiser with unknown level of noise that can handle blind Gaussian noise. With residual learning, DnCNN model remove the state of clean image from hidden layer. DnCNN model are used to increase the efficiency and increase performance and also used in GPU computing.

J. NON LOCAL SPARSITY REINFORCEMENT

It is combination of multiscale denoiser and nonlocal denoising based on non local filter that are used to show the similar features between two group of patches. The neural network use fix nonlocality with layered network but this model are implemented using modular structure with standard non local filter. And known as NN3D and use over large gray level image dataset. Nlf provide strong result where image has strong capability and use in edge preservation and detection and give disadvantage when there is weak similarity.

IV. LITERATURE REVIEW

Weio Hang Dong et al. [12] proposed a denoising based image Reconstruction that work on additive Gaussian Noise. They propose DCNN based model that exploit multiscale redundancies of natural image and they achieve competitive state-of -art on several IR task such as blurring, denoising, super resolution.

Junyan Xie, Linli Xu, Enhong Chen [13] that use stack sparse Decoding Auto-encoder that help to remove Gaussian and salt pepper noise. It help to improve performance in task of unsupervised learning and handle harder problem of blind inpainting of complex pattern. It can remove noise pattern and suitable where scope of denoising is narrow.

Chi Zhang et al. [14] proposed a model of ROMP,Yall1. ROMP is much faster than YALL1 which is important for ten thousand of CNN feature and there is same or similar structure of human and machine vision and stimuli was not used when decoded model.

Lovdeep Gondara [15] use convolutional denoising autoencoder and used to remove Gaussian and poison noise. They proposed denoising autoencoder constructed using convolution layer that can be efficiently used in medical image and achieve good performance by using small training dataset. But as noise level increase, this network trouble constructing original image.

Jo schlemper et al. [16] proposed a Dictionary learning based MRI using co-ordinate descent type algorithm. They proposed an algorithm that can reconstruct image in 23ms, which is fast enough to real time application. But in this dataset we first need to reconstruct image using sensor and then used for stimulus of acquisition process.

Hu Chen et al. [17] work on sonogram filtration technique that use special type of x-ray that visualize any abnormal opening in the body and are performed on either raw data or log

transformed data. It help to reduce poison noise that help in deep learning for noise reduction and help in preserve structural reservation and optimize RED-CNN and extend it to higher dimensional cases such as 3D reconstruction of dynamic spectral CT reconstruction Chao Dong et al. [18] use sparse coding based SR technique that work on Gaussian noise. SRCNN help in end to end mapping between low and high resolution and applied to other low level vision problem such as deblurring. SRCNN is small network that couldn't fit over all images. So need to develop large dataset.

Saikat Basu et al. [19] are used to investigate the use of deep neural network for classification of Texture dataset. They use Vapnik-Chervonokis (VC) dimension that used to show hand crafted feature extraction that work on Gaussian Noise. With VC dimension and establish relevance of handcrafted feature extraction. They define upper bound on VC dimension of convolution network and define dropout and drop connect network and relation of excess error rate. The feature extraction create lower level dimensional representation that enable DNN to achieve lower test error rate.

Kyong Hwan Jin et al. [20] explore relationship between CNN and iterative problem where normal operator associated with forward model. The balanced performance of SNR testing sonogram will decrease reconstruction performance and drop value by 50 dB and when noise level increase the performance gradually decline.

Shuhang Gu et al.[21] proposed JCAS model that adopt convolutional implementation for SSR part. The implementation avoid patch dividing issue and learn only several atom from input image that are used to model the complex texture. By comparing with other method it is able to generate high quality mapping result and less artefacts. And used in rain streak removal, cartoon texture, image tone mapping.

Victoria J. Hodge, Simon O' Keefe, Jim Austin [22] implement detail of five feature selector algorithm constructed using artificial neural network framework that are implemented in Handoop YARN. The feature selector are implemented by dividing the task into subtask and processed in parallel. The feature selector are implemented using large dimensional dataset that produce the efficiency and flexibility of binary associative memory and produce high sped searching application.

Jiwan Kim, Kwon Lee, Kyoung Mu Lee [23] proposed an image super resolution method using deeply recursive convolution neural network that is increased by recursion depth and used to improve performance without introducing new parameter for additional convolution. They produce sharp edge respective to pattern and outperform exiting method. We need to find an optimal number of recursion, if recursion is too deep then need to reduce number of recursion.

German I. Parisi et al. [24] proposed a self-organising neural network architecture for incrementally learning to classify human action from video sequences. Experimental result show that our model is competitive with batch learning and provide more flexible neural network model for learning robust, visual representation and perform well over time on the basis of visual experience.

Eunhee Kang, Junhong Min, Jong Chul Ye [25] proposed algorithm that remove complex noise pattern from CT image. And has greater denoising power for low dose and reconstruction time is faster than MBIR method. Texture of DNN different from MBIR method because texture is also important diagnostic feature.

Chihiro Watanabe, Kaoru Hiramatsu, Kunio Kashino [26] proposed simple structure from layered neural network. They decompose layered network into smaller independent network that divide problem and reduce time. The result can be measured using modularity index which measure effectiveness of community detection. The discovery or interpretation of knowledge using layered network is very difficult where its internal representation consist of nonlinear and complex parameter.

Noorbaksh Amiri Golilarz, Hasan Demirel [27] proposed a unique technique for noise removing in wavelet domain combined with thresholding function. This thresholding function is continuous and nonlinear, so applicable on thresholding neural network. Experimental result show superiority of proposed method over other available. It provide higher PSNR value and better visual inspection in comparison with other technique. Used for image denoising with wavelet transform, due to continuity and nonlinearity. Provide higher PSNR value and better visual inspection.

Feng Wang, Haijun Liu, Jian Cheng[28] proposed a visualization algorithm in which too small value of lambda lead to disordered image while too big lambda lead to image blurry. The algorithm can extract detail from image which usually filtered by previous method. This algorithm is used to extract feature from image and ensemble is powerful tool to improve performance and contain neuron of multiple instance which lead to compress data too much when compared with 1*1 layer.

Diego G. Loyola R et al. [29] present a systematic and compressive approach for optimally handling regression task with large dimensional data. Used for generic problem and used for problem where training pattern created or sampled. Speeding of such model is crucial in practical problem like weather forecasting, remote sensing etc.

Stefan Elfwing, Eiji Uchibe, Kenji Doya [30] proposed RBM function approximation that can be further improved by approximating value function by negative expected energy. It outperform FERL and NNRL in visual robust navigation task with raw and noisy RGB. Help in learning speed and final performance. Achieve new state-of -art result in stochastic SZ-Tetris in both model based and model free.

Mingze Xu et al. [31] propose multitask spatiotemporal neural network that is combination of 3D ConvNet and Recurrent Neural Network. It reconstruct and extract different material boundaries, avoid need of extra evidence, improve feasibility of analysing large dataset by significantly decreasing running time.

Michael Gharbi et al. [32] present a machine learning approach where input consume low resolution image, produce

changes in bilateral transformation space where edges are preserved using edge slicing and up sampled nodes are applied to high resolution image. The model doesn't require original data operator at run time and trained offline from data. The model implement complex scene dependent transformation for which no reference is needed.

Christopher A. Metzler et al. [33] proposed a prDeep simulation and demonstrate that it is robust to noise and can handle large variety of system model and operate fast enough for high resolution image. prDeep is able to handle wide range of measurement matrices, from intensity-only coded diffraction pattern to Fourier measurement.

Cristovao Guz et al. [34] introduce a paradigm that combine advantage of CNNF and of NLF through simple iterative framework called NN3D that use nonlocal self-similarity prior by mean of group wise filtering.

Omar Costilla. Reyes, Patricia Scully, Krikor B.Ozanyan [35] proposed learning architecture that is computationally efficient, and use low number of parameter and achieve reliable classification.

Kai Zhang et al. [36] demonstrate that prior based model suffer from two major drawbacks, first optimization problem cause time consuming and second computational efficiency. This model use batch normalization and residual learning to increase the speed and boost training performance. The model can handle blind Gaussian denoiser with unknown noise level. It also increase the efficiency of image denoising task using GPU computing.

V. CONCLUSION

Time averaging of image sequences aimed at improving the quality of image and increase performance and reduce temporal resolution. Therefore, denoising should be performed to improve image quality. There are several denoising techniques that has its advantages and disadvantages. The ultimate goal of denoising is to remove noise from image and produce better quality of image. However, no single method has shown to be superior to all other noise reduction, boundary preservation. Now denoising techniques and their types are upgraded day by day. The aim of this survey is to formulate a problem overview from the state-or-the-art available denoising methodologies and to prepare ground for initiating a study to provide an new analytical algorithm in terms of predictable accuracy of reconstruction methods.. This will help for the researchers who are willing to study the existing methods, analysis and develop a new denoising technique. Further the work can be extended for various interdependent tasks in this domain such as image segmentation, image classification and registration etc.

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