A Review on Image Denoising Filtering Techniques Using Deep Learning

Garima Sharma[1], Dr. Kishori Lal Bansal[2], Sunil Kumar[3]
[1, 3] Dept of Computer Science
[2]Professor, Dept of Computer Science
[1, 2, 3] Himachal Pradesh University, Summerhill

Abstract- *Image de-noising is a fundamental task in image processing that aims to remove noise from images while preserving their visual quality. Noise can be introduced into images due to various factors such as low-light conditions, sensor limitations and compression artifacts. De-noising filtering techniques are used to remove noise from images and improves their quality. In recent years, deep learning based de-noising techniques have shown promising results and have become popular due to their ability to learn complex features from data. These techniques are deep neural network to learn the mapping between noisy and clean images and can effectively remove noise from images. This paper provides a comprehensive review of deep learning based de-noising filtering techniques and analyses their performance on different types of noise. The paper categorized different De-noisers into dictionary learning models such as CNN-based models and GAN-based models. The comparative analysis helps in identifying the most effective technique for a particular type of noise and applications. The study compares various techniques based on their effectiveness and provides insights into their advantages and limitations.*

Keywords- Deep learning, De-Noising, GAN, CNN, RNN, Auto-Encoders.

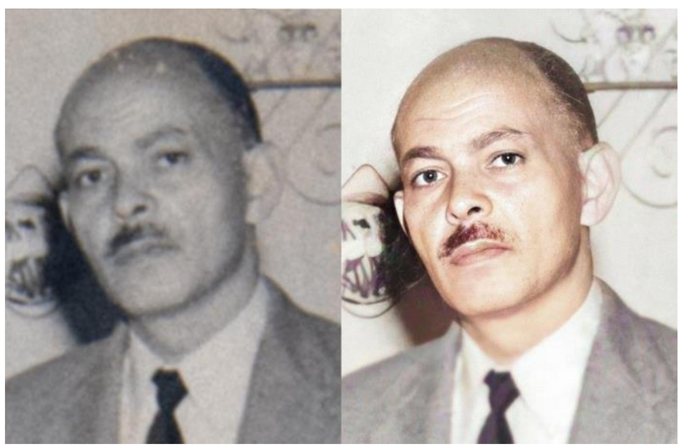
I. INTRODUCTION

In today's world, pictures are everywhere and play important roles in many things, like in medicine, security cameras, taking photos, and teaching computers to see. But sometimes these pictures aren't perfect because they can get messy or unclear due to problems when they were taken or saved. That's where the combination of deep learning and image cleaning techniques comes in handy. It's like having a smart tool to make these pictures look better and easier to understand.

Deep learning is like a super-smart tool in the world of computers. It's a part of machine learning, and it has become important recently. It uses something called "neural networks," which are inspired by how our brains work. These networks are like layers of problem-solving units that are good at finding patterns and details in lots of information [3].

People use deep learning in all sorts of computer tasks. For example, it helps computers understand and talk in human languages, recognize our voices, and do amazing things with pictures. So, it's like a big brain for computers that makes them super smart at understanding and working with data.

Image de-noising is a computer vision task that removes noise from an image. Noise can be introduced into an image during acquisition or processing and can degrade image quality and make interpretation difficult. Image de-noising techniques aim to restore the original quality of an image by reducing or removing noise while preserving the important features of the image.



Images are susceptible to various types of noise that distort the image information stored in the images. Image de-noising has become an integral part of the image processing workflow. It is used to mitigate the noise and highlight the specific image information stored in it. Machine learning is an important tool for image de-noising workflow due to its robustness, accuracy, and time requirement [5] [6].

TYPES OF DEEP LEARNING NETWORKS

FEED-FORWARD-NEURAL NETWORK

A forward neural network is nothing but an artificial neural network that ensures that the nodes do not form a cycle. In such a neural network, all the perceptron is arranged in layers such that the input layer takes the input, and the output layer produces the output. Since the hidden layers are not connected to the outside world, it is called hidden layers. Each perceptron in one layer is connected to each node in the next layer. It can be concluded that all nodes are fully connected. It contains no visible or invisible connection between nodes of the same layer. There are no return loops in the forward network. A back propagation algorithm can be used to update the weight values to minimize the prediction error [11].

RECURRENT NEURAL NETWORK

Recurrent neural networks are another variant of feed forward networks. Here, each neuron in the hidden layers receives an input with a certain delay. A recurrent neural network mainly uses the previous information of existing iterations. For example, to guess the next word in a sentence, you need to know the words used before. It not only processes inputs but also distributes height and weight over time. This does not allow the model size to increase as the input size increases. But the only problem with this recurrent neural network is that its calculation speed is slow, and it does not consider the future input of the current state. There are problems with remembering previous information.

CONVOLUTIONAL NEURAL NETWORK

Convolutional neural networks are a special type of neural network that are mostly used for image classification, image clustering, and object detection. DNNs enable the unsupervised construction of hierarchical image representations. Deep convolutional neural networks are preferred over other neural networks for best accuracy.

AUTO-ENCODERS

An auto-encoding neural network is another type of unsupervised machine learning algorithm. Here, the number of secreted cells is small compared to the number of mast cells. But the number of feeder cells equals the number of output cells. The auto-encoder network is trained to display an output similar to the supplied input to force AEs to find common patterns and generalize the data. Auto-encoders are mostly used for a smaller representation of the input. It helps to recover original data from compressed data. This algorithm is relatively simple because it only requires that the output be identical to the input.

II. CLASSIFICATION TECHNIQUES

Classification techniques in denoising deep learning are essential for evaluating the performance of denoising algorithms or models in removing noise from images [1]. These methods help categorize and assess how well a denoising approach works. Here are some common classification techniques used in denoising deep learning:

1. Peak Signal-to-Noise Ratio (PSNR):

PSNR measures denoised image quality by comparing it to the original noisy image. Higher PSNR values indicate better denoising performance.

2. Structural Similarity Index (SSI):

SSI assesses how similar the denoised image is to the clean (noise-free) image. A higher SSI score means better denoising.

3. Mean Squared Error (MSE):

MSE calculates the average squared difference between the denoised and clean images. Smaller MSE values indicate better denoising.

4. Peak Signal-to-Noise Ratio in dB (PSNR-dB):

PSNR-dB measures denoised image quality in decibels, making it easier to understand. Higher values suggest better quality.

5. Root Mean Square Error (RMSE):

RMSE computes the square root of the MSE, representing the average error between the denoised and clean images.

6. Structural Dissimilarity Index (DSSIM):

DSSIM, an extension of SSI, quantifies structural differences between the denoised and clean images. Lower DSSIM values indicate better denoising.

7. Mean Absolute Error (MAE):

MAE calculates the average absolute difference between pixel values of the denoised and clean images. Smaller MAE values imply better denoising.

8. Classification Accuracy:

In some cases, denoising effectiveness is assessed using classification accuracy when distinguishing between noisy and clean images.

III. LITERATURE REVIEW

The literature review has been done by studying various research papers. Many researchers are using classification techniques on the different datasets and analyzing their results. A detailed literature review of existing deep learning techniques is given below:

In 2017, Nikita Narayan et al. [19] explored the application of Deep Learning in image classification, a field aiming to make machines recognize images as humans do. They introduced a system called Image Classification with deep learning, which uses classifiers like neural networks to classify images. Their system was developed using Python and TensorFlow, utilizing GPU (NVIDIA) and CPU for performance evaluation. They found that Convolutional Neural Networks (CNNs) provide high accuracy compared to other classifiers, making them a suitable choice for image classification.

In 2018, Venu Gopala Rao Matcha et al. [20] explored the concept of Image Classification using Deep Learning, focusing on the Alex Net architecture with convolutional neural networks. They conducted experiments with four images selected from the ImageNet database, observing that Alex Net effectively classified images, even in testing scenarios, demonstrating the power of deep learning in image classification.

In 2019, Mohd Azlan Abu et al. [21] studied Image Classification based on Deep Learning and TensorFlow, particularly focusing on a deep neural network (DNN) for categorizing five species of flowers. They found that DNNs provided high accuracy, achieving over 90% for roses and the second flower type.

In 2020, Shivam Singh [19] explored Image Classification Using Deep Learning, emphasizing the benefits of deep learning in improving image classification accuracy compared to traditional methods. The article discussed various deep learning algorithms, their advantages, and applications.

In 2022, Suzhen Zhang et al. [1] proposed a Deep Learning Model for Image Classification Using Machine Learning. They introduced an advanced convolutional neural network structure for image classification, outperforming other models in terms of classification accuracy after optimization.

In 2013, Manpreet Kaur et al. [22] addressed the significant problem of image noise reduction, especially impulsive noise. They highlighted the importance of noise removal for preserving image information and provided an overview of various noise reduction algorithms.

In 2015, Juhi Mishra et al. [11] conducted a review on Image De-Noising Techniques, emphasizing the importance of noise reduction in various fields. They discussed different noise models, including Gaussian, salt and pepper, speckle, and more, and examined noise reduction methods such as filter-based and wavelet-based approaches.

In 2015, M.A. Shahid et al. [23] focused on blurring images in the non-linear domain and discussed methods related to different types of noise, including Gaussian, salt and pepper, and comma noise.

In 2016, Alisha PB et al. [22] provided an Overview of Image De-Noising Techniques, highlighting the effectiveness of wavelet filters compared to standard spatial filters. They evaluated various techniques, including thresholding methods, and concluded that Bayesian shrinkage showed promising results.

In 2017, Shumaila Solangi et al. [23] presented a literature review on Image De-Noising methods, summarizing different techniques and categorizing them into local and non-local, spatial and frequency domain methods. They also discussed low-rank and low-value methods for de-noising.

In 2017, Mukesh C. Motwani et al. [5] conducted a survey on Image De-Noising Techniques, providing an overview of notable works in the field. They emphasized the importance of understanding noise models and selecting appropriate noise reduction techniques based on the specific noise behavior.

In 2017, Neetu Mittal et al. [24] analyzed different filters for noise reduction in images, evaluating the performance of Median, Median, and Wiener filtering techniques on images with various types of noise.

In 2019, Mohammed Otari et al. [25] conducted a comparative analysis of Image Noise removal techniques, focusing on the performance of different filters, including the median filter and Weiner filter, in eliminating various types of noise.

In 2020, Y. Srinivas et al. [26] discussed image processing using deep learning techniques, covering topics related to medical imaging, image mining, content-based image retrieval, and gap detection in medical images.

In 2019, Chinwe Tian et al. [27] provided a comparative study of deep image de-noising techniques, classifying them into categories based on the type of noise they address, such as additive white noise, real noisy images, blind de-noising, and noisy hybrid images.

In 2021, Tara Darwish Hanaway Hussein et al. [8] discussed image noise and various Image De-noising Techniques, emphasizing the importance of understanding different noise types and selecting appropriate noise reduction methods.

In 2021, Ram Narayan Yadav et al. [28] conducted a review on Image De-noising with machine learning, exploring machine learning-based image de-noising techniques, including dictionary learning models, CNN, and GAN, for various types of noise.

In 2021, Xin Zhang et al. [8] discussed the performance of image De-Noising and super Resolution Reconstruction, focusing on a novel image de-noising and super-resolution reconstruction method based on Generative Adversarial Network (GAN).

Top of FormIV. COMPARATIVE STUDY AND DISCUSSION

In this comparative analysis is a method used to compare two or more things to identify similarities and differences between them. In this, comparative analysis is used to compare deep learning based denoising filtering techniques with traditional denoising techniques.

Method	Network Used	Advantages	Disadvantages	Applicable Noise
Convolutional Neural Network (CNN)	N2N VDN, FFD Net, CBD Net, PRID Net	No pairwise training samples required, overcoming insufficient training samples issue.	Limited utilization of shallow pixel-level information, potential texture detail loss.	REAL NOISE, COMPLEX NOISE
Residual Network (ResNet)	FC-AIDE, Cycle ISP PA Net, GRDN	Effective solution to gradient issues and faster convergence.	Dense connections may lead to overfitting and impact evaluation consistency.	COMPLEX NOISE, REAL NOISE
Graph Neural Network (GNN)	GCDN, Deep GLR Over NET	Well-fits complex noise distributions with graph topology.	Unstable dynamic topology reduces feature expression ability.	REAL NOISE, COMPLEX NOISE

The research assesses the effectiveness of various denoising techniques based on deep learning, including convolutional neural networks (CNNs), recurrent neural networks (RNNs), and generative adversarial networks (GANs). Through this comparative analysis, the study aims to highlight the advantages and limitations of each technique, offering valuable insights into which method is most proficient at eliminating noise from images.

V. CONCLUSION

The paper provides a comprehensive review of deep learning based denoising filtering techniques and analyses their performance on different types of noise. The study evaluates the performance of various techniques based on two widely used metrics, namely peak-signal- to noise-ratio (PSNR) and structure similarity index (SSIM). The results shows that deep learning based denoising techniques outperform traditional denoising techniques in terms of PSNR and SSIM. The study also analyses the performance of different deep learning based denoising techniques such as CNNs, RNNs, and GANs. The result shows that GAN-based denoising techniques perform better than CNN and RNN-based techniques. The study also analyses the performance of these techniques on different noise such as Gaussian noise, impulse noise and mixed noise. The results shows that these techniques can effectively remove noise from images. The paper also discusses the advantages and limitations of these techniques and provides insights into future research directions.

VI. FUTURE SCOPE

Future research could explore the adaptability of the network to handle various types of noise, including Gaussian noise or random noise with unknown characteristics. Additionally, future studies might consider the potential for modifying this architecture to address other image-related challenges, such as blurring or in-painting.

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