A REVIEW PAPER ON DEEP LEARNING OF NEURAL NETWORK BASED IMAGE COMPRESSION TECHNIQUES

By

SHUBHAJIT KANTI DAS * ABIR CHAKRABORTY **

* Department of Electrical Engineering, South Calcutta Polytechnic College, West Bengal, India.
** Department of Electrical and Computer Science Engineering, University of Coimbra, Portugal.

Date Received: Date Revised: Date Accepted:

ABSTRACT

Image compression is an important methodology to compress different types of images, in modern days as one of the most fascinating Machine learning techniques, we have applied the idea of Deep Learning in different cases of neural networks to prove and justify that it is the most flexible method to analyze and compress the images. Several types of neural networks are available such as Deep Neural Network (DNN), Convolutional Neural Network (CNN), Binarized Neural Networks (BNN), Artificial neural networks (ANN) to perform image compression techniques. So, in this review paper we are going to discuss how deep learning concept is applied on different types of Neural Networks in order to achieve image compression of perfect qualities with proper image classifications. In order to obtain that proper image classification, we need to deep leaning on DNN, CNN, BNN, ANN and apply the same concept in different types of images in a justified manner with difference of analysis. This is called compression technique based on conceptual analysis of images.

Keywords: Deep Learning, ANN, DNN, CNN, BNN Image Compression.

INTRODUCTION

Image compression is a technique where we compress any image by using different types of methodologies that we have adopted. Basically, there are two types of image compression techniques; (Simon, Deo, Selvam, & Babu, 2016) Lossy (Once the original image is compressed there is a chance that we may lose some important data), (Kunwar, 2018), Loss less (Once the original image is compressed there is no chance to lose any data of original image). But here we are bringing a new concept, as we know many types of image compression techniques are available in internet, such as Joint Photographic Experts Group (JPEG), Portable Network Graphics (PNG) etc. out of them JPEG (Kunwar, 2018), is the most commonly used or accepted in wide range of lossy image compression techniques. But the new concept here is to implement a different kind of network that can be used as a classifier of image before image compression. Here our selected network is Neural Network. A Neural Network consists of three different stages, input stage, hidden layer and output stage layer (Simon, Deo, Selvam, & Babu, 2016). Each layer consists of neurons have learn able weights and biases. Each neuron receives some inputs, performs dot product and optimally follows it with a non-linearity. Here we are using a concept of deep neural network analysis which is an essential tool for Computer Vision, performance can be analyzed in image classification, object detection, semantic segmentation (Patel & Agarwal, 2013). Same concept can be used for low level video signal and image processing. Now further if we move in a deeper way, we can easily recognize the importance of artificial neural network for image compression analysis. The classical image compression techniques basically depend on BPNN techniques. Back-Propagation Neural Network (BPNN) method signifies back propagation of neural network logic. Here we use three or more fully connected layer of neurons. It is the most commonly used multilayer feed forward ANN technique. Actually, BPNN has the simplest architecture like ANN but it has the slowest

convergence (Patel, & Agarwal, 2013). In this case we consider the feature of intensity changes and find the number of blocks of the original image. In order to improve Network Convergence, we should map the grey level of the image pixels and their neighbors in such a way that the difference in the grey level of the neighbors within the pixel minimized.

So, our strategy will be to construct a Deep Learning based Convolution Neural Network Architecture for JPEG (Kunwar, 2018), image especially and to train the Deep Neural Network adaptable to any other type of images.

1. Related Work

In this review paper we have used JPEG which is Joint Photographic Extension Group which is universally useful in order to build up worldwide standards such as shading, still picture compressions. In image compression methods so many compression standards are available such as JPEG (Kunwar, 2018), JPEG-LS and JPEG-2000 (Li, Zuo,Gu, Zhao, & Zhang, 2018). Before performing image compression by Neural Network based applications we must apply different intelligent denoising techniques like SA-DCT, BM3D, which were proposed in late -2000, but in order to obtain outstanding results we achieve different dictionary based sparse recovery algorithms like Dic- TV, RTF, S-D2, D3 and DDCN (Kunwar, 2018). They directly address the deficiencies like blocking and ringing which are very specific to JPEG or JPEG compressions. The image compressions algorithm can be divided into several stages. Input image must be processed through following procedures (Li, Zuo, Gu, Zhao, & Zhang, 2018):

- Divide image into several 8 x 8 tiles.
- Convert 8 x 8 2D images into 64 x 1 dimensional images.
- Obtain amplitude and phase response by Discrete Fourier Transform (DFT) (Li, Zuo, Gu, Zhao, & Zhang, 2018) of the 64 x 1 image.
- Use Huffman coding to compress more 0's excluding smaller items of results.
- Huffman encoding of the results to reach the compressions.

Apart from this in the encoding stage we can perform linear transform to an image, Quantization and the lossless entropy coding are used to minimize the compression rate. Suppose we use Discrete Cosine Transform (DST) on 8 x 8 image patches which quantizes the frequency components and compresses the quantized code with variant of Huffman coding. In case of JPEG2000 (Kunwar, 2018), we use multi scale orthogonal wavelet decomposition to transform an image and encode the quantized codes. Deep learning method is a fast-growing technology which helps to generate image compression concept for both loss less and lossy images. In case of lossless compression of images, Deep learning models have achieved state of the art performance, but in case of lossy image compression it represents a Recurrent Neural Network (RNN) (Li, Zuo, Gu, Zhao, & Zhang, 2018) to compress 32 x 32 image.

Several Deep Learning methods by Neural Network analysis learn and analyze the compression models by minimizing distortion for a given compression rates. Similar work is related to Binarized Neural Network (BNN) (Kunwar, 2018) where both weight sand activations are binarized to +1 or -1 to save memory storage and run time. In such type of image compression system only the encoder out is binarized to 1 or 0, and a similar proxy function is used in back ward propagation.

2. Concept of Deep Learning

As we have already discussed that this paper needs proper understanding of deep learning that is going to be applied on several neural network based methodological approaches of image compression. So before moving to our proposed method we need to understand the basic knowledge about deep learning and how it will be implemented by using ANN, CNN, DNN (Simon, Deo, Selvam, & Babu, 2016) etc. So, let's talk about Deep learning Galong with its application in several method of Neural Network Technique for our proposed method.

2.1 Deep Learning

It is a new area of machine learning based research which has the original goal that is to implement the idea of Artificial Intelligence in Neural Network Technique.

2.2 ANN Methodology

It was first introduced by a Japanese scientist Kunihiko Fukushima in 1980, it is an interconnected network of processing units emulating the network neurons in the brain (Li, Zuo, Gu, Zhao, & Zhang, 2018); so, the idea behind ANN is to develop a learning method modelled by human brain. Now deep learning is a method to train multilayer ANN using little data (Simon, Deo, Selvam, & Babu, 2016). Let us discuss with an example what is the basic difference between Machine Learning and Deep Learning. Machine Learning algorithms learn part of a face like eyes and nose for face detection tasks, but a Deep Learning uses some extra features like the distance between eyes and the length of the noes. In many publications for example Geoffrey Hinton and Ruston Salahutdinov have applied multi layer feed forward Neural Network effectively retaine data time treating each layer unsupervised restricted to Boltzmann's machine using unsupervised back propagation for fine training. Figure 1 shows the Multilayer Neural Network.

A Deep Neural Network is defined as an Artificial Neural Network having at least one hidden layer un it between input and output layers. Extra layers are for enhancing its modeling capacity.

2.3 Convolutional Neuralnets

The most popular deep learning methodology is Convolutional Neural Nets (Figure 2) or CNN or Conv-Nets. This type of feed forward Artificial Neural Network is extensively used in Computer Vision. Each individual neuron is titled in such a way so that they respond to overlapping regions in the visual fields. In many cases CNN concept is to Automatic Speech Recognition (ASR) (Li, Zuo, Gu, Zhao, & Zhang, 2018).

2.4 DNN Methodology

Along with CNN and ANN there is another type of neural network which we have recognised in our proposed method that is DNN; but it has two major drawbacks. Those are one is over fitting while learning the training data using its hidden layer and other one is computation time. But DNN performs well if same type of training data is used as input (Simon, Deo, Selvam, & Babu, 2016); but poorly when training data is different. After a research of several years a method that is adopted called dropout regularization which is to remove some units randomly from the hidden layer that can solve the problem.

3. Neural Network Based Methods for Image Compressions

As we have already mentioned that Artificial Neural Network has the superiority over other classical methods for image or data compressions because Neural Network seems to be well suited to this particular function as they have the ability to process input patterns to produce simplest patterns with fewer components. Now we will discuss several applications of Neural Networks which are normally used for understanding Deep Learning methods (Table 1).

3.1 Back Propagation of Neural Network

One of the most successfully implemented algorithms in

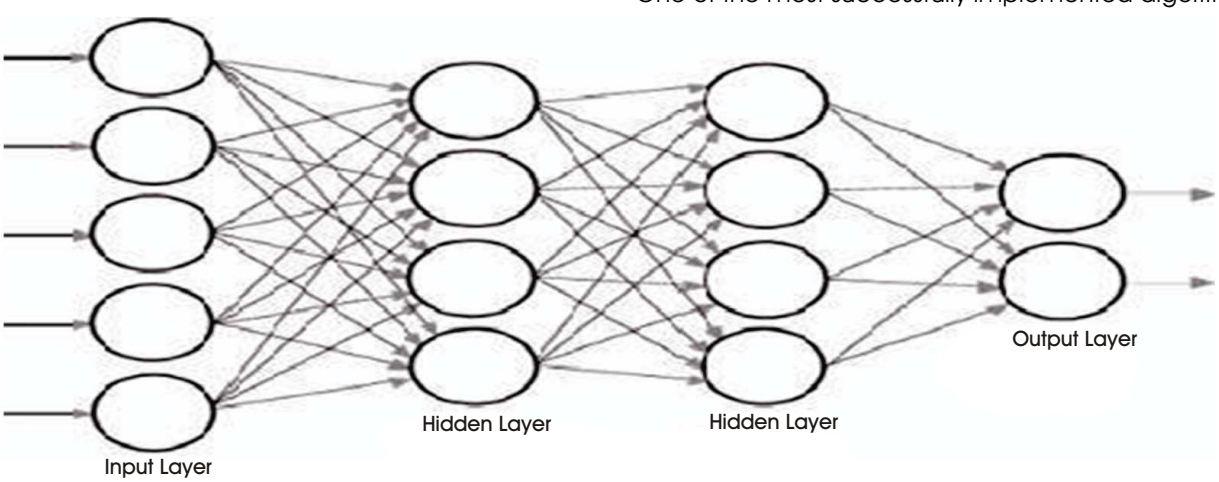

Figure 1. Diagram of Multilayer Neural Network (Simon, Deo, Selvam, & Babu, 2016)

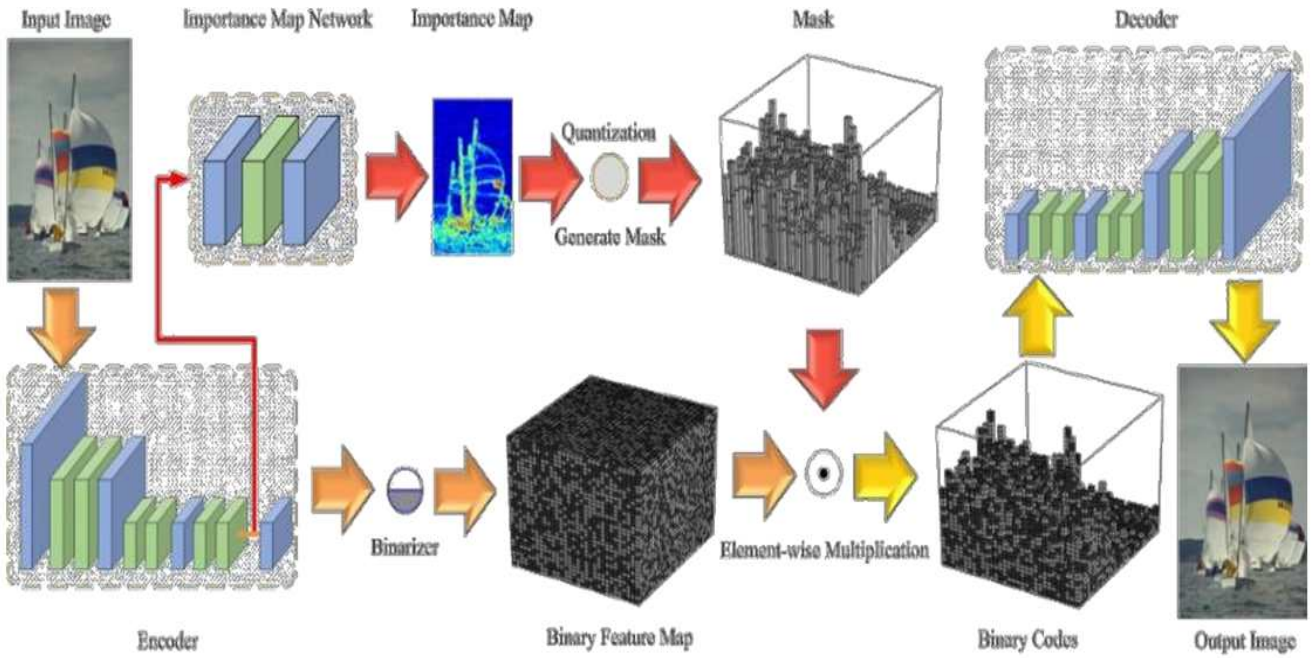

Figure 2. Illustration of the CNN Architecture for Content-Weighted Image Compression (Li, Zuo, Gu, Zhao, & Zhang, 2018)

Authors	Techniques used	Advantages
Singh and Murthy (2012)	Neuro-wavelet based vector quantization	The proposed algorithm utilized both wavelets transform and RBFNN and gives high PSNR values as well as less computation time for different wavelet filters at a given BPP in comparison to wavelet transform and BPNN. It is quite faster than BPNN. RBFNN is less susceptible to problem associated with non-binary input because the behavior of the hidden units presents in the radial basis function. Wavelet-based decomposition produces reconstructed images of high-quality compare to the neural network-based algorithms.
Seiffert (2014)	Artificial-Neural Network	Significant compression performance as well as high quality of reconstructed images produced as compared to other general image compression techniques and approaches from moving image compression.
Puthooran, Anand, and Mukherjee (2013)	Dual-level DPCM Utilizing context adaptive switching Neural Network Predictor	The cascaded architecture of linear and non-linear DPCM achieved higher decorrelation of MR images with varying intensity and texture pattern. The achieved using CAS-NNP and a non-linear predictor shows functional relationship between the pixels is considerably non-linear in nature.
Hussain, Al-Jumeily, Radi, and Lisboa (2015)	Hybrid compression techniques based on Neural-Network Predictive Wavelet	At high decomposition levels the proposed algorithm was producing compressed images of high quality on the other hand compressed image of similar quality like JPEG-2000 was produced at a low decomposition level. It requires more processing time than JPEG 2000.
Saudagar and Shathry (2014)	Neural Network	The proposed technique is capable to yield better quality of performance along with less quality of distortion rate. Unlike sub-band coding here complex bit allocation process is not required. Unlike JPEG, JPEG-2000 prior knowledge of image source is not required.
Joe and Rama (2015)	Neural Network	The burden of computation is reduced with proposed technique is quiet used in transmission as well as rendering process.
Balasubramani and Murugan (2015)	Neural Network based on Radial Basis function	The proposed method compressed CT and MR images which have low Compression Ratio, Mean square Error , BPP along with high PSNR values. RBFNN is much effective compare to Huffman, NNBP, Fractal algorithms. Vey less convergence time is taken.
Perumal and Rajasekaran (2016)	Hybrid DWT with Neural-Network Back Propagation	PSNR of hybrid DWT Back Propagation was higher than individual Back Propagation Neural Network (BPNN) and DWT algorithm. Compression Ratio is less comparing to BPNN and DWT algorithm. One of the most highly efficient compression techniques.

Table 1. A Table with Some of the Best Neural Network Based Image Compression Techniques

Neural Network technology to solve the problem of data compressions is known as Back Propagation algorithm. In this case data or image is allowed to pass through the input network. Then subsequently through a small number of hidden neurons. The compressed features of images are stored in the hidden layer (Ahmed & Alone, 2014); so smaller the number of hidden neurons means higher the Compression Ratio (CR). In case of large image compression, it may cause difficulty in training. So, for a large image compression it may be sub-divided to smaller number of sub-images and then each sub-image will be used to train an individual ANN (Simon, Deo, Selvam, & Babu, 2016). This type of process is implemented successfully for compressed and decompressed images with an impressive Compression Ratio (CR) with little or no loss of data.

3.2 Hybrid BP and Kohonen Network

We have introduced an other new type of network that is known Kohonen Network when compared with Back Propagation it was observed that Kohonen Networks better in terms of signal to noise ratio but on the other hand training time of Kohonen Network was higher which is indeed a problem for us (Ahmed, & Alone, 2014). So, for better image compression technique with better signal to noise ratio we need to combine both the network-based techniques which gives us satisfactory results.

4. Some Comparative Results with Discussions

Before showing the best results obtained from different Neural Network based algorithm (Figure 3), we are going to discuss how or in which methods those results are obtained. We use different types of training architecture for understanding the binarization of the input to encoder and output at decoder. If we binaries the sigmoid output the information is completely lost (Kunwar, 2018). Now if we add Gaussian noise before sigmoid function, it will start to find the grey code because the symbol encoded with 0 and 1 can persist noise only. That's why in our results and discussions we are showing an example of CNN (Li, Zuo, Gu, Zhao, & Zhang, 2018) final training architecture with the addition of noise;

In case of any type of images better Compression Ratio is

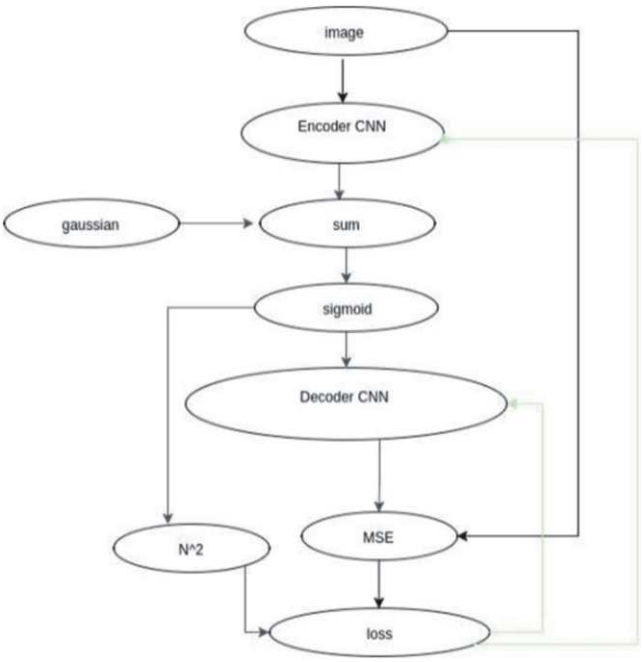

Figure 3. CNN Final Training Architecture (Kunwar, 2018)

obtained with Back Propagation rate with Neural Network based training and with highest PSNR (Kunwar, 2018). That's why some results of original and compressed images are displayed with training state graphs (Figures 4-6).

As we have mentioned earlier different applications of Neuro-Wavelet based image compression techniques. So, we are displaying a Table 2 of comparative results with different images and a set of different types of Original and Compressed images used in Medical-Based Applications and Other Applications of image compressions (Figures 7 - 9). Those images give us some extra-ordinary idea about how different types of Neural-Network techniques are adopted for image compression, whereas the table contains a comparison of Compression Ratio, PSNR, Mean Square Error (Dabass, Vig, & Vashisth, 2018), and BPP (Kunwar, 2018). It will give us some idea about different results obtained from different compression techniques using a combination of Neural Network Analysis and Wavelet Based Decomposition.

5. Future Scope of Work with Several Major Applications

In the previous mentioned sections, we have defined so many applications of Deep Learning Method related to Neural Network Analysis and we have successfully

Figure 4. Original Image

Figure 5. Compressed Image

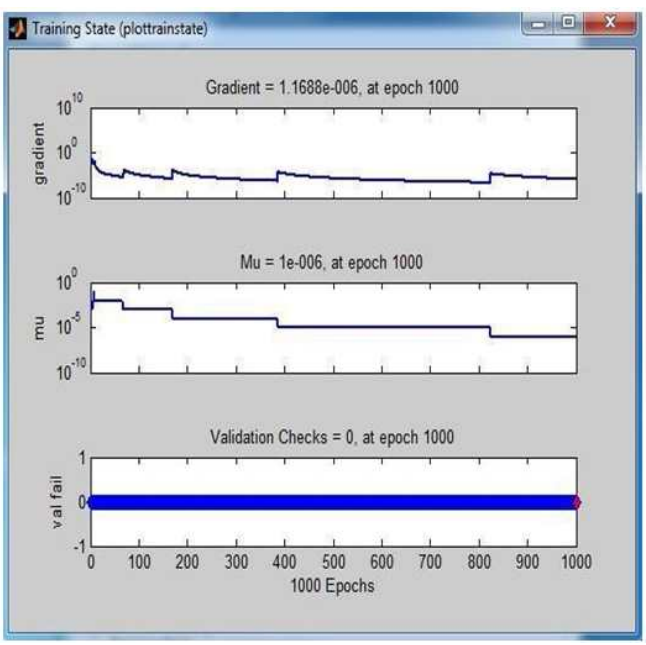

Figure 6. Training State Graph

	CR	MSR	PSNR	BPP	Time (s)
MR Image 1	1.05	5.90	46.45	7.61	283.68
MR Image 2	0.93	224.18	30.66	8.53	296.73
MR Image 3	0.88	986.79	24.22	9.03	296.52
MR Image 4	0.79	262.06	29.98	10.11	279.49
MR Image 5	0.83	837.03	24.94	9.58	294.77
MR Image 6	1.05	0.76	55.34	7.55	310.20
MR Image 7	1.05	1.87	51.44	7.55	297.91
MR Image 8	1.07	1.57	52.18	7.45	515.49
MR Image 9	1.01	223.81	30.66	7.65	291.79
CT Images	1.06	0.34	58.81	7.54	265.07

Table 2. Results Obtained using the Neural Network Radial Basis Function Algorithm (Kunwar, 2018)

Figure 7. Original Medical Images

implemented in the analysis of several types of image compression techniques. Now in this section we are sharing our idea so that we can implement our works for the future purpose. In order to achieve this, we have chosen three different fields of Deep Learning related to image compressions. In our future we want to extend our works focussing on these three methodologies;

5.1 Deep Learning in Artificial Intelligence

Artificial Intelligence (Simon, Deo, Selvam, & Babu, 2016) is a new area of research which is capable of performing a task that a human being can. In modern times it has huge applications in Speech Recognition (Li, Zuo, Gu, Zhao, & Zhang, 2018), Games Playing, Expert System, Decision Making, Medicine (Dabass, Vig, & Vashisth, 2018), Aviation and Translation of Languages. So, for example we can extend our work with the help of Deep Learning in Artificial Intelligence in the Gaming Industry (Simon, Deo, Selvam, & Babu, 2016). The same applications can be implemented in military as well as aviation industry where pilots can avoid air traffic with the help of this technique.

Figure 8. NNBP Compression Technique's Resulted Compressed Medical Image

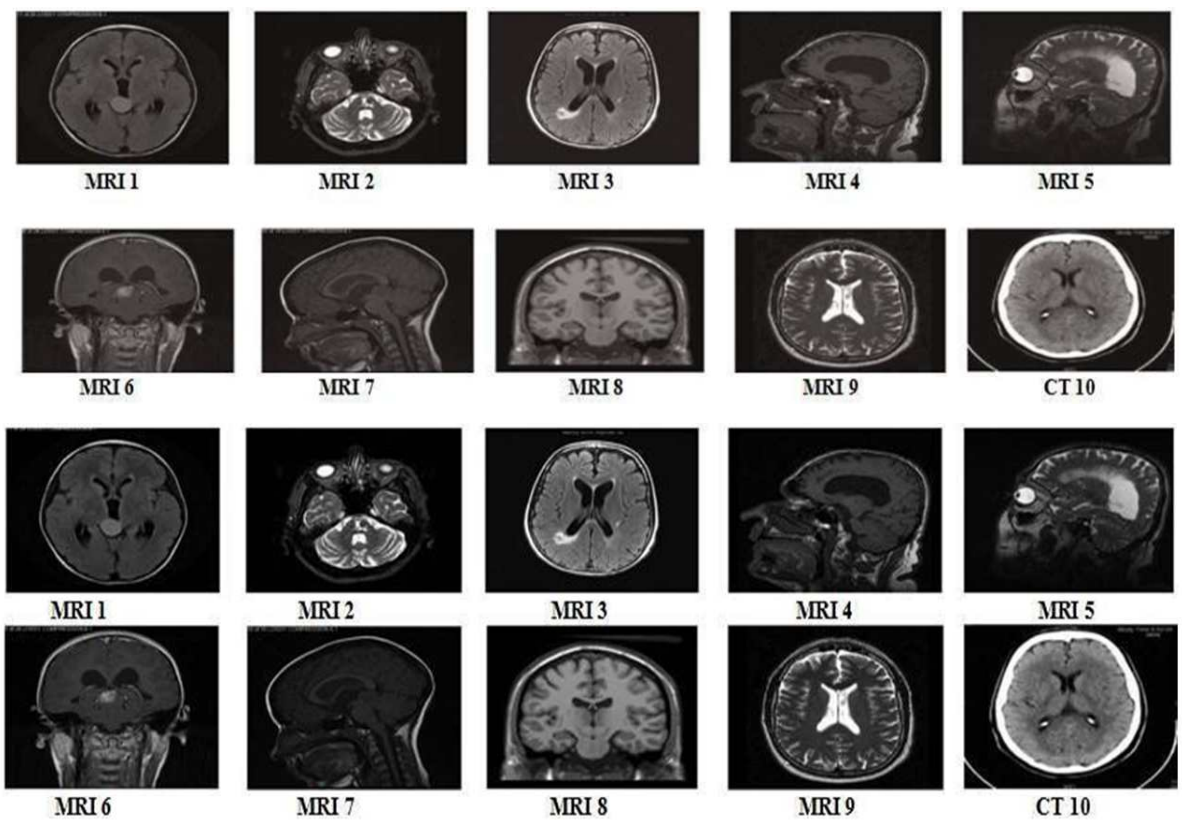

Figure 9. Comparison between our Model with and without Importance Map (Li, Zuo, Gu, Zhao, & Zhang, 2018)

5.2 Deep Learning in Self Organisation Map Algorithm

It is another best way to realize Deep Learning by using a different type of algorithm that is GSOM (Ahmed, & Alone, 2014) or Growing Self-Organizing Map algorithm. This concept has been developed in order to identify a suitable map size inself organising map. It starts with a minimal number of nodes and grows new nodes on the boundary of a heuristic. The compressed form of data is obtained from the output nodes of the network which can be further decompressed by another network (Ahmed, & Alone, 2014). We can use this algorithm as a method of Deep Learning for performing data compressions.

5.3 Applications of Wavelet Transform as Deep Learning in Image Compression

Apart from those two mentioned areas we will also try to focus another new area which is quiet interested and useful for new dimensions of research that is Wavelet Analysis. As we have already mentioned that we have used Neuro-Wavelet based analysis (Dabass, Vig, & Vashisth, 2018), in different fields of medical image processing in this paper, so we need to know what wavelet analysis is and how it can be implemented in other fields related to image compression. Wavelet Transforms (WT) or analysis that replaces conventional Fourier Transform (FT) can be used in Image Compression, Feature Extraction, Image De noising and another medical image technology. In modern physics Wavelet Transform can be applied rapidly in Astrophysics, Density Matrix Localization, Seismic Geophysics, Optics, Turbulence and Quantum Mechanics. Here we are discussing two major applications of Wavelet Transform which can be useful for our future scope of research.

5.4 Fingerprint Recognition

Fingerprint Recognition is another most important area of application where Wavelet Transform is playing an important role for our growing world of deep learning. After performing a rigorous research on the application of Fingerprint Recognition it is proved that Discrete Wavelet Transformation or DWT (Pokhriyal & Lehri, 2010) based Fingerprint Recognition is considered to be one of the best techniques because many new features such Directional Information, Central Area, Edge Parameters are extracted from DWT. Pokhrial-et-al (Pokhriyal & Lehri, 2010) proposed an algorithm of fingerprint verification Wavelets and Pseudo Zernike moments where wavelets are used to de noising and extract edges.

5.5 Application of Wavelet in Image Compression with Feature Extraction Method

Image compression and feature extraction is another important field where Wavelet has its major applications which are increasing in modern days. The main aim of image compression is to exploit redundancies in data, therefore which data can be 'thrown away' will be decided after performing reconstruction of original image. So, by removing redundant data images can be represented in smaller number of bits. Grgic, Grgic, and Zovko-Cihlar (2001) presents this comparative study by wavelet transformation analysis in his paper. In this case we can observe that Discrete Wavelet Transform methodology for both JPEG- 2000 (ISO/IEC 15444-1:2000, n. d) and still image coding. Because of having an inherent features DWT provides multi-resolution

Functionality and better compression performance at a very low bit rate compared with DCT based JPEG standard (ISO/IEC 14496, n. d). This methodology can be implemented in Computer Vision Process for better feature extraction purpose.

So, there are so many fields where we can apply Deep Learning concept or method to achieve better quality of image or data compression for our future extension of the work.

Conclusions

In this paper we have discussed concept of Deep learning methodology along with its implementation on different types Neural Network based on image compression techniques and an overview of wavelet-based analysis on Neural Network Mechanisms (i.e. neuro-wavelet analysis) to describe image compression related problems. In all case sour goal or objective is very clear and that is to obtain better image Compression Ratio (CR) and minimum loss of data during compression. Apart from this in our proposed methods and analysis of

results we have tried to improve Signal to Noise Ratio or PSNR by minimizing the effect of noise as much as possible. Noise in images can be removed by different types of filtering like Special Filtering, Motion Filtering, Average Filtering, Median Filtering etc. But only the properly justified filtering can increase the Signal to Noise Ratio by improving the quality of signal power. There are so many ways to perform this technique but we have tried to implement some of the best and universally recognized methods to achieve our aim.

References

[1]. Ahmed, S. & Alone, M. R. (2014). Image Compression using Neural Network. *International Journal of Innovative Science and Modern Engineering,* 2(5), 24-28.

[2]. Balasubramani, P., & Murugan, P. R. (2015). Efficient image compression techniques for compressing multimodal medical images using neural network radial basis function approach. *International Journal of Imaging Systems and Technology,* 25(2), 115-122. https://doi.org/10.1002/ima.22127

[3]. Dabass, M., Vig, R.,& Vashisth, S. (2018). Comparative Study of Neural Network based Compression Techniques for Medical Images. *Proceedings of the 12th INDIA Com; INDIACom-2018; IEEE Conference,* (pp. 4674-4679).

[4]. Fukushima, K. (1980). Neocognitron: A self-organizing neural network model for a mechanism of pattern recognition unaffected by shift in position. *Biological Cybernetics,* 36(4), 193-202. https://doi.org/10.1007/Bf00344251

[5]. Grgic, S., Grgic, M., & Zovko-Cihlar, B. (2001). Performance analysis of image compression using wavelets. *IEEE Transactions on Industrial Electronics,* 48(3), 682-695. https://doi.org/10.1109/41.925596

[6]. Hussain, A. J., Al-Jumeily, D., Radi, N., & Lisboa, P. (2015). Hybrid neural network predictive-wavelet image compression system. *Neurocomputing,* 151, 975-984. https://doi.org/10.1016/j.neucom.2014.02.078

[7]. ISO/IEC 14496. (n. d). Coding of Audio-Visual Objects. *National Resource Center for HER standards.* Retrieved from https://www.nrces.in/standards/iso/iso-14496

[8]. ISO/IEC 15444-1:2000. (n. d). JPEG 2000 image coding system. *Information Technology.* Retrieved from https://www.iso.org/standard/27687.html

[9]. Joe, A. R., & Rama, N. (2015). Neural network based image compression for memory consumption in cloud environment. *Indian Journal of Science and Technology*, 8(15), 1-6. https://doi.org/10.17485/ijst/2015/v8i15/73855,

[10]. Kunwar, S. (2018). JPEG Image Compression using CNN. Research gate. https://doi.org/10.13140/RG.2.2.25600.53762.

[11]. Li, M., Zuo, W., Gu, S., Zhao, D., & Zhang, D. (2018). Learning convolutional networks for content-weighted image compression. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (pp. 3214-3223).

[12]. Patel, B. K., & Agarwal, S (2013). Image Compression Technique using Artificial Neural Network. *International Journal of Advanced Research in Computer Engineering & Technology,* (10), 2725-2729.

[13]. Perumal, B., & Rajasekaran, M. P. (2016, February). A hybrid discrete wavelet transform with neural network back propagation approach for efficient medical image compression. In *2016 International Conference on Emerging Trends in Engineering, Technology and Science (ICETETS)* (pp. 1-5). IEEE. https://doi.org/10.1109/ICETETS.2016.7603060

[14]. Pokhriyal, A., & Lehri, S. (2010). A new method of fingerprint authentication using 2d wavelets. *Journal of Theoretical & Applied Information Technology,* 13(2), 131-138.

[15]. Puthooran, E., Anand, R. S., & Mukherjee, S. (2013). Lossless compression of medical images using a dual level DPCM with context adaptive switching neural network predictor. *International Journal of Computational Intelligence Systems,* 6(6), 1082-1093. https://doi.org/10.1080/18756891.2013.816059

[16]. Saudagar, A. K. J., & Shathry, O. A. (2014). Neural network based image compression approach to improve the quality of biomedical image for telemedicine. *British Journal of Applied Science & Technology,* 4(3), 510-524.

https://doi.org/10.9734/BJAST/2014/7158

[17]. Seiffert, U. (2014). ANNIE—Artificial Neural Network-based Image Encoder. *Neuro Computing,* 125, 229-235. https://doi.org/10.1016/j.neucom.2012.11.051

[18]. Simon, A., Deo, M. S., Selvam, V.,& Babu, R. (2016). An Overview of Machine Learning and its Applications. *International Journal of Electrical Sciences & Engineering,* 1(1), 22-24.

[19]. Singh, A. V., & Murthy, K. S. (2012). Neuro-wavelet based efficient image compression using vector quantization. *International Journal of Computer Applications,* 49(3), 33-40. Retrieved from https://pdfs.semanticscholar.org/7314/98c3b3a82fe55112b33fe6d01fffc0b34665.pdf

ABOUT THE AUTHORS

Shubhajit Kanti Das is currently working as an Assistance Professor in the Department of Electrical Engineering at South Calcutta Polytechnic College (One of the best diploma college in West Bengal), West Bengal, India. He previously worked as an Assistance Professor in JLD Engineering College and Management. He has done is M.Tech in Industrial Engineering and Management from WBUT and completed his B.Tech in Electrical Engineering and Electronics. His research area is Artificial Neural Network. He has also use ANN as tool in condition based monitoring.

Abir Chakrabort is currently pursuing a Ph.D in the Department of Electrical and Computer Science Engineering at University of Coimbra, Portugal. He has completed his Master Degree in the Department of Digital Electronics and Advanced Communication from Manipal Academy of Higher Education from Karnataka, India. After that he have done an Assistant Professor job in JLD College of Engineering and Management.