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Image Data Compression and Noisy Channel Error Correction Using Deep Neural Network

Yijing Z. Watkins[a*], Mohammad R. Sayeh[a]

[a]Department of Electrical & Computer Engineering, Southern Illinois University Carbondale, United States

Abstract

Everyday an enormous amount of information is stored, processed and transmitted digitally around the world. Neural Networks have been rapidly developed and researched as a solution to image processing tasks and channel error correction control. This paper presents a deep neural network (DNN) for gray image compression and a fault-tolerant transmission system with channel error-correction capabilities. First, a DNN implemented with the Levenberg-Marguardt learning algorithm is proposed for image compression. We demonstrate experimentally that our DNN not only provides better quality reconstructed images but also less computational capacity compared to DCT Zonal coding, DCT Threshold coding, Set Partitioning in Hierarchical Trees (SPIHT) and Gaussian Pyramid. Secondly, a DNN with improved channel error-correction rate is proposed. The experimental results indicate that our implemented network provides a superior error-correction ability by transmitting binary images over the noisy channel using Hamming and Repeat-Accumulate coding. Meanwhile, the network's storage requirement is 64 times less than the Hamming coding and 62 times less than the Repeat-Accumulate coding.

Keywords: Deep neural network; image compression; artificial neural network; channel error-correction; Levenberg-Marguardt algorithm;

1. Introduction

Methods of compressing and transmitting data efficiently and securely are becoming of significant practical and commercial interest. Image compression techniques make it possible to provide a tradeoff between good quality digital images and to minimize the bandwidth and storage space requirements. Error Correction codes help us to communicate

* Corresponding author. *E-mail address:* traceyzhang@siu.edu

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perfectly over not so perfect communication channels by adding a controlled form of redundancy to the original data. An artificial neural network (ANNs) is an information processing system that can be used in image compression and channel error correction control that is inspired by the biological nervous system. Recently, researchers have achieved some success by training deep neural networks (DNNs) which are artificial neural networks with many hidden layers between the input and output layers. Previous research has shown that multi-layer ANNs have better performance compared to single layer ANNs [1-3].

Neural networks have been used to address image compression problems for many decades. A good review of image compression by using neural networks has been presented in [4]. The authors in [5, 6] propose a neural network with a single hidden layer for image compression. In [7], the authors describe a comparison of different deep neural network transfer functions for image compression implementation. However, they all concluded that there is still a long way to go before neural networks provide substantial improvement over non-neural network based image compression algorithms such as the Discrete Cosine Transform (DCT) and the Set partitioning in Hierarchical Trees (SPIHT) algorithm. Discrete Cosine Transform (DCT) is the most commonly used image process algorithm for compress image for over past years. Discrete Wavelet Transform (DCT) plays major role in JPEG2000 image compression algorithm and set partitioning in Hierarchical Trees (SPIHT) is a world–winning wavelet-based image compression method for years. In [8] [9], the authors apply the DCT, DWT and Gaussian pyramid algorithms to image compression and reconstruction. In their work, high frequency information was removed during the DCT, DWT and Gaussian Pyramid compression process. Meanwhile, SPIHT compression method isn't developed for artificially generated images.

There are also various technique proposed to address the error correction control problem by using the artificial neural networks (ANNs), and these techniques can be divided into two groups. In the first group, neural network that implement error correction technique do not have any self-testing ability. In [10] the proposed neural networks without self-testing ability can only correct a limited numbers of faults. In the second group, neural network with self-ability is used implement error correction technique. Self-testing Error correction classical methods are usually based in hamming distance and repeat-accumulate techniques. Two commonly used error correction methods, hamming and repeat-accumulate codes, are compared in [11], Hamming coding has more superior result over repeat-accumulate coding. Three types of Neural network models are presented in [12] as alternative way to solve error correction problem. However, the paper didn't really compare error correction results between three neural network models and hamming codes. The author in [13] proposed a Hopfield neural network by combining heuristic algorithms to increase error correction capacity and storage capability of the network. However, this technique is only tested in a small network and the error correction rate relatively low compare with hamming coding.

In this paper, there are two different problems that we address. First, we focus on developing a DNN implemented using the Levenberg-Marquardt learning algorithm designed for gray image compression and decompression without compromising the image quality and storage requirement. We demonstrate experimentally using 4 different learning algorithms and by varying the number of hidden layers that the compression for images is better while requiring less storage compared to DCT zonal and threshold coding, SPIHT and Gaussian pyramid methods. Second, we propose a DNN also implemented using the Levenberg-Marquardt learning algorithm for image error correction control over a noisy channel. Our DNN implemented by the Levenberg-Marquardt learning algorithm and constructed with two hidden layers provides more efficient results when number of hidden layers changes and for different learning algorithms and provides a superior quality image and less storage requirement over hamming coding and repeat-accumulate coding. The remainder of this paper is organized as follows. In Section 2, the image compression by using DNN is proposed. Section 3 introduces a method for error correction control by using DNN's. Section 4 and 5 reports experimental results and compares with commonly used methods. Section 5 presents the conclusion of this paper.

2. Deep Neural Network Image Compression and Decompression

Digital images are extremely data intensive and hence require large amounts of memory for storage and are very time consuming to transmit. By using image compression techniques, it is possible to remove some of the redundant information contained in images, requiring less storage space and less time to transmit. Figure 1 provides a block diagram of the DNN image data compression process. The image compression system consists of a compression module and a decompression module. S represents the original image, C represents the compressed image and S'