Introduce Improved CNN Model for Accurate Classification of Autism Spectrum Disorder using 3D MRI brain Scans

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Abstract
Convolution neural network is a multi-layered network that is very popular today. This network is very popular due to feature extraction from images, videos, etc. In this paper, we first apply three fundamental changes to the convolution neural network architecture and thus introduce a new convolution neural network that is very resistant to noise. Then we compare the newly introduced algorithm. We do this for the MNIST dataset in noisy and non-noisy mode. The results show that even if we add 40% noise to the original data, the output of the proposed method is the same as the none-noise mode.We then suggest using the IMCNN + KNN hybrid algorithm to increase the classification accuracy. For this purpose, we use the ABIDE[1] database related to Magnetic Resonance Imaging of Autism Spectrum Disorder (ASD).The accuracy of classifying Normal Control with autism in the proposed method, even in the presence of noise, is 98.9%, which is a significant improvement over the CNN algorithm.

Keywords: improved convolutional neural network (IMCNN), Autism Spectrum Disorder (ASD), Noise reduction, k-nearest neighbors algorithm (KNN),

1. Introduction

[1] Autism Brain Imaging Data Exchange (ABIDE)

Convolutional neural network (CNN) is one of the machine learning methods which is very popular in feature extraction and image classification due to its high efficiency [1].A convolutional neural network is a type of neural network created for the artificial processing and manipulation of multidimensional data such as images. Attempts have been made to have a structure similar to the human visual system. Like other artificial neural networks, convolutional neural network are made up of neurons that store weights and biases, and in their later layers, provide a way to make decisions [2]. Suppose we want to use ordinary neural networks and all connected layers to categorize images. In that case, the volume of each hidden layer will be huge, and the process of updating it will be very long. The difference between this network and other neural networks is that this network offers a structure that can be used to extract the best features from images [3]. A convolutional neural network with its various layers is shown in Figure 1.

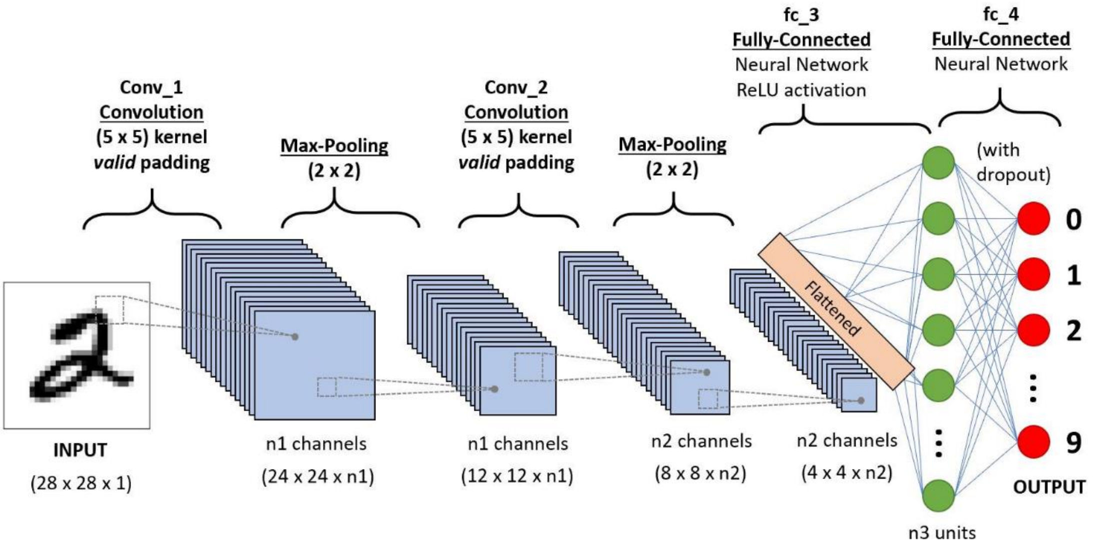


Figure 1- Image processing in convolutional neural network

One of the purposes of this article is to classify noisy data, and we want to improve the CNN algorithm so that even very high noise does not cause any disturbances in the accuracy. In addition, we introduce the hybrid IMCNN + KNN algorithm to increase classification accuracy. The details of proposed algorithm are explained in the proposed method section.

1.1. introduction to k-nearest neighbors algorithm (KNN)

The k-nearest neighbors' algorithm[4] is one of the simplest classification algorithms that has many applications in machine learning.The KNN algorithm is one of the most widely used machine learning algorithms, part of the parameterless algorithms (i.e., has no assumptions about data distribution) and lazy leaner (short learning time but long guessing time). This algorithm aims to use datasets in which data points are separate and divided into several categories [5]. The non-parametric nature of this algorithm is perfect because most of the data in the real world do not follow the usual theoretical assumptions. Therefore, when we do not have prior knowledge about data distribution, one of the best options for classification is to use the KNN algorithm [6]. KNN performance is based on feature similarity. In other words, when a test data is provided to us, we specify its class label according to how similar it is to the training data.

2. The proposed method

The proposed method is schematically shown in Figure 2 .The figure on the left is the convolutional neural network, and the figure on the right is the proposed improved neural network that we call it IMCNN in this paper. Assume we have h layers in the convolution neural network (shown on the left), y is the network output, w is the weight vector, and U is the bias. Also, the activity function is considered Relu[7]. To improve CNN, We propose to build a sparse neural network from the convolutional neural network. The first fundamental change is that Instead of the Relu activation function, we use K-winners. The k-winners step is a non-linear function in which the active units in each layer are kept in yl, and the rest are set to zero. The second fundamental change is that We use a sparse random distribution to initialize the weights, so most weights are zero, and Only a small percentage of the weights have non-zero values. The last significant change is that the inputs in the new algorithm are a subset selected from the primary input.

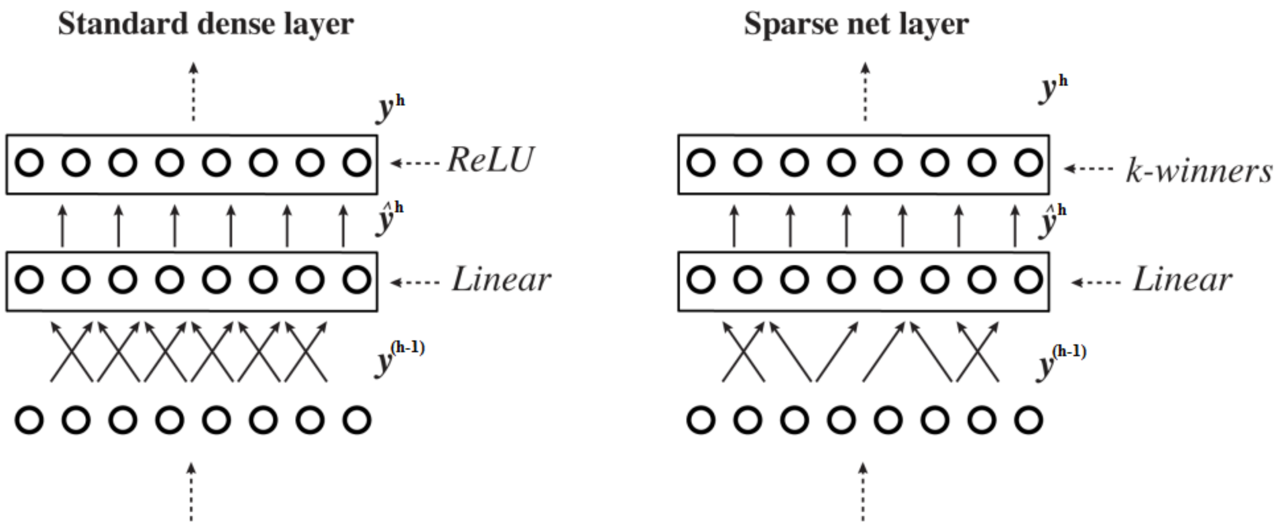
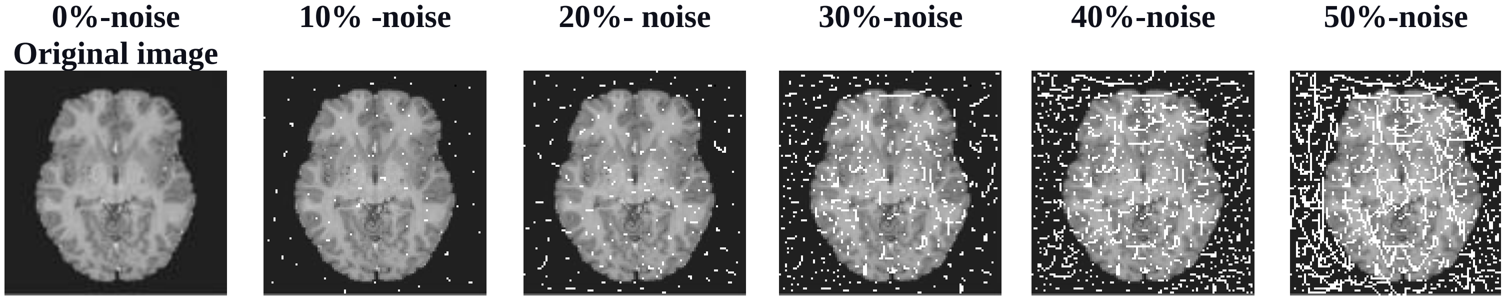


Figure 2- (left) Convolutional Neural Network, (right) improved Convolutional Neural Network (IMCNN)

The proposed algorithm was testeed on the BraTS 2015 brain tumor dataset [8]. , the training set includes 220 cases of high-grade tumors (HGG) and 54 cases of low-grade tumors (LGG). These images are presented in the dimensions of 155 * 240 * 240. As shown in Figure 3, we selected some slice of the brain tumor datasets and then added 10%, 20%, ..., 50% noise to them. We then fed this data once as input to the CNN algorithm and again as the proposed method. The output of the two algorithms is shown in Figure 4. As can be seen, the classification accuracy of the two algorithms is similar in the none-noise mode; even when 10% noise is added to the images, the accuracy of both methods is the same. But when adding the higher noise to the input images, the proposed method is more accurate than CNN. So the proposed algorithm is more noise- reduction than CNN.



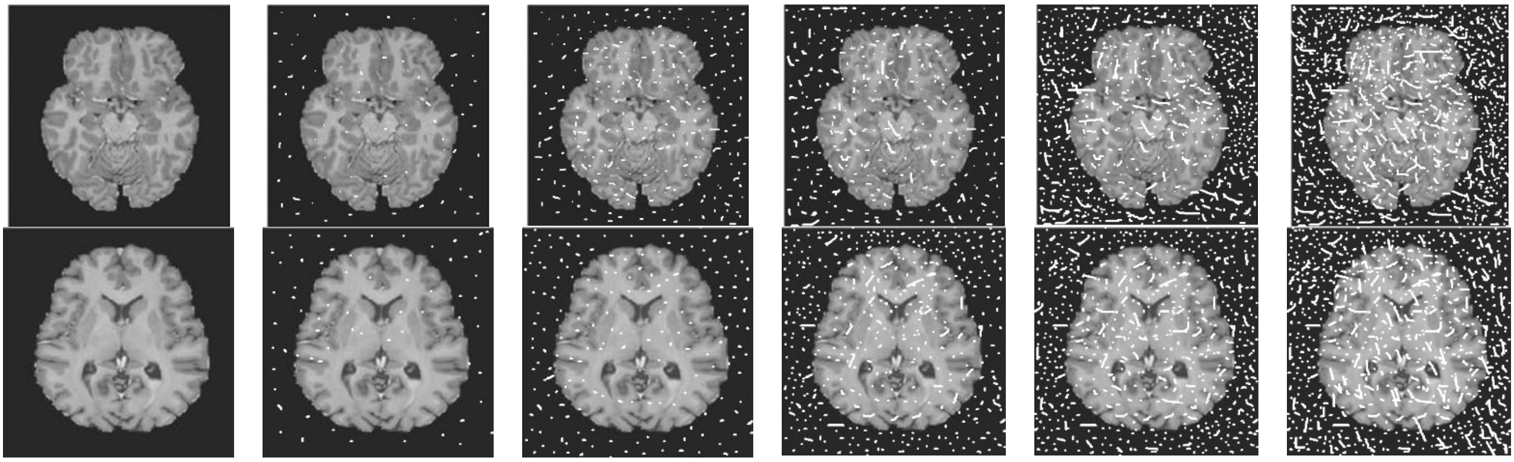


Figure 3- brain tumor slice images with noise

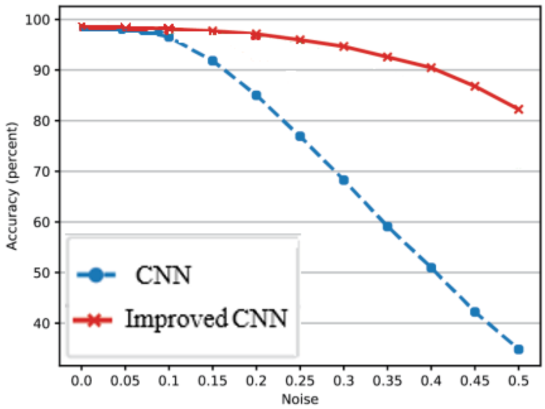


Figure 4- The classification accuracy (y-axis), and the noise level (x-axis). The comparison results of the two algorithms show that the proposed method is more accurate than the CNN algorithm.

Our next suggestion is to use a hybrid IMCNN +KNN algorithm. Therefore, the output of the improved CNN algorithm is given as the input of the KNN algorithm. For this purpose, we use the 3D-MRI brain (256*256*180) of Autism Spectrum Disorder (ASD) in ABIDE dataset (ABIDE.loni.usc.edu). Autism Spectrum Disorder (ASD) occurs in the early years of life, and early detection is essential [9]. Diagnosis of autism from the Normal Control is an important issue and helps to cure the disease faster [10]. Many research has been done to study and diagnose ASD [11,12,13]. This paper proposes a method for classifying ASD from NC based on the improved CNN method. First, we converted the 3D image of the brain with coronal slices to 180, 2D-images and divided the obtained images into several slice groups. Then, we fed the images of each slice group as input of the proposed method. The output obtained from the proposed method was passed through FC_1 and FC_2 layers. We gave it to KNN Classification to increase the classification accuracy. To show that the KNN classifier is the most appropriate choice in this algorithm, we did all these steps again and finally used the softmax classifier (shown in Figure 5). The classification accuracy in the hybrid algorithm IMCNN +KNN was 98.9%, and the classification accuracy in the IMCNN +softmax was 96%.

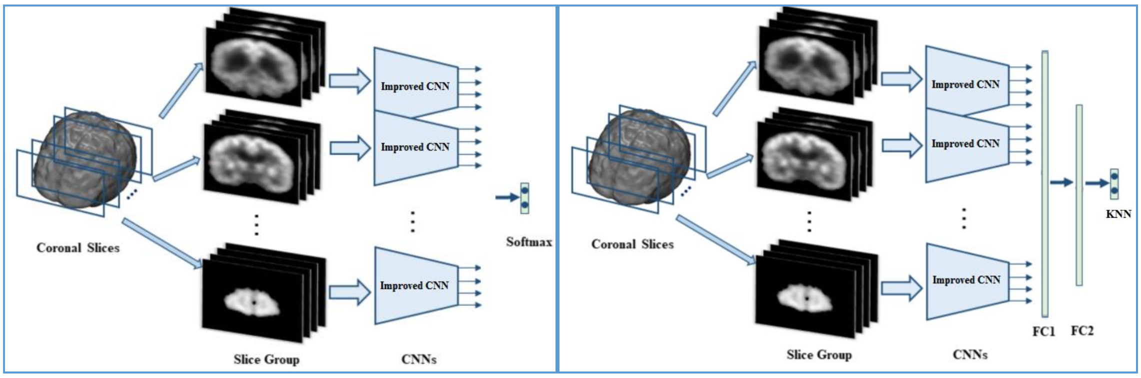


Figure 5- the steps of classifying Autism Spectrum Disorder (ASD) from the Normal Control (NC) in the proposed method,(left) softmax classifier,(right) KNN classifier.

Now we add noise to all the 3D images of the ABIDE dataset and compare the classification accuracy of the two proposed methods in the presence of noise. The result of this experiment is shown in Figure 6. As we expected, the accuracy of the hybrid algorithm IMCNN +KNN is very high in the presence of noise.

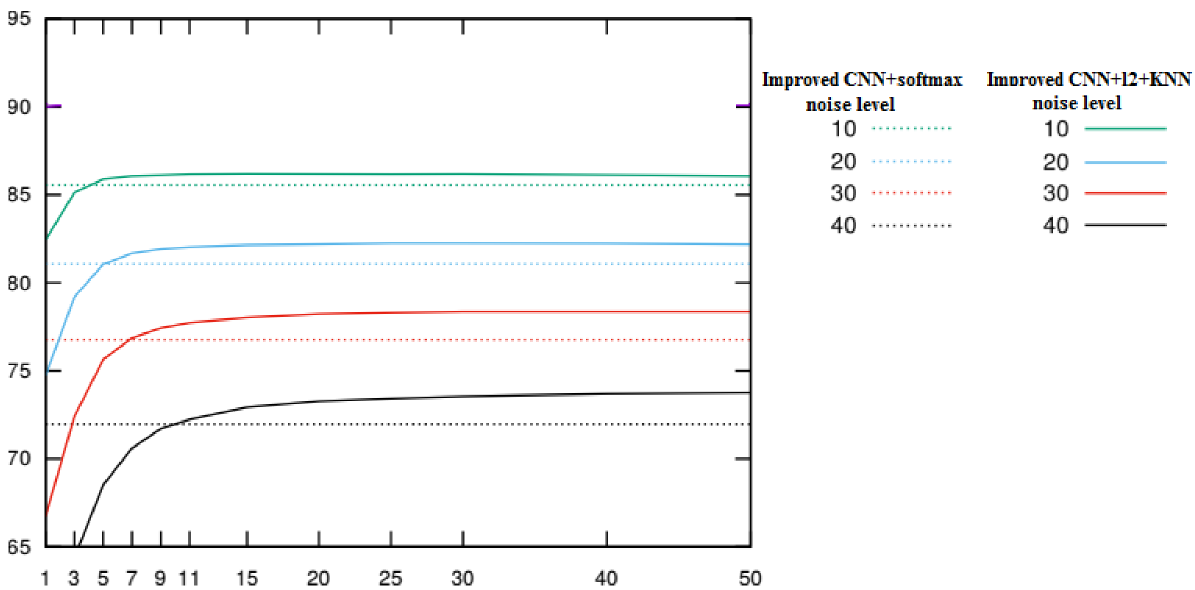


Figure 6- Comparison of the performance of two methods in the presence of different levels of noise

In image processing, a color image [14] is obtained by combining three images in red, green, and blue (Figure 7). The same process is used to process brain images, and by combining coronal, sagittal, and axial slices, a three-dimensional image of the brain is obtained with full details. Another innovation we used in this article is to create a fully detailed image of the brain that can accurately classify Autism Spectrum Disorder (ASD) from **Normal Control** (NC). Once we created a three-dimensional image of the brain obtained from the coronal slices and fed it in the proposed method, we did this simultaneously for sagittal and axial slices. Then we multiply the output of the proposed method obtained from coronal, sagittal, and axial images in weights w_1 to w_3, respectively. Finally, we use the KNN classifier to classify ASD from NC. The steps of the algorithm are shown in Figure 8. The classification accuracy with this method is 99.8%.

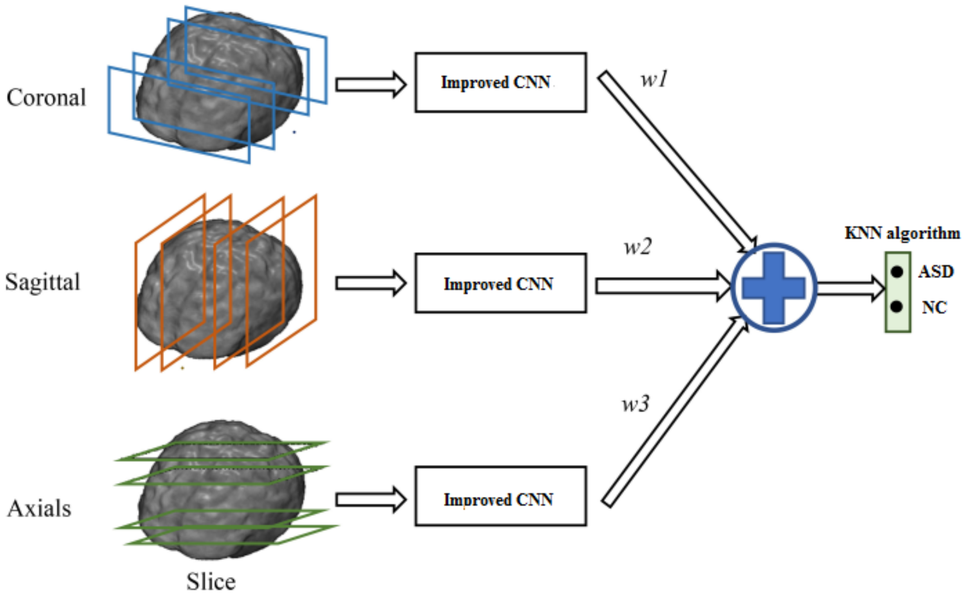


Figure 7- Classification of ASD and NC in 3D-MRI brain images

3. Conclusion

In this article, we proposed a new method for improving the convolution neural network. There were three significant changes to CNN's algorithm.1) Instead of the RELU activation function, we use K-winners,2)We use a sparse random distribution to initialize the weights, and 3)the inputs in the new algorithm are a subset selected from the primary input. The proposed method, called Improved CNN (IMCNN), is so resistant to noise that adding 40% noise to the input data does not change the algorithm's output. The brats2015 dataset was used to compare the proposed method and CNN algorithm, and the high accuracy of the proposed method was reported. The second idea of this paper was to use a hybrid method that combined the IMCNN algorithm and the KNN classifier to obtain more accurate results. In this way, we separated the brain MR images of the Autism Spectrum Disorder (ASD) from Normal Control (NC) with high accuracy of 98.9%.

4. References

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