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Detection and Diagnosis of Brain Tumor using Convolutional Neural Networks

Abdelkader Alrabai

Physics Department, Education Faculty – Wadi Alshatti University, Libya
Corresponding Author: a.alrabai@wau.edu.ly

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ABSTRACT

Brain tumors are one of the major health problems related to abnormalities in the human brain. An activist diagnosis of brain tumors is critical to improve patient outcomes and lives. Early detection of tumors is crucial for treatment. Magnetic Resonance Imaging (MRI) is one of the most commonly used diagnostic methods for brain tumors in the clinical area. Manual detection of brain tumors is becoming increasingly time-consuming and costly. Therefore, an automated Computer Aided Diagnosis (CAD) system is needed to help doctors and radiologists detect these deadly tumors in time, thereby saving precious lives. Convolutional Neural Networks (CNNs) are widely used in various CAD systems. CNNs play an important role in healthcare as image processing techniques for segmentation, recognition, and classification of MRI images and classification and detection of brain tumors. This paper applies the Deep Learning (DL) architectures for brain tumor detection and classification. Implement a deep learning (CNN) based computational approach that includes image pre-processing to extract regions of interest in the image itself to identify and detect tumors in the brain. The highest accuracy rate in the experiment reached 96%. Evaluation metrics used include sensitivity, precision, loss, and F1 score. The results obtained will aid in the diagnosis and detection of brain tumors.

Keywords: *Brain, CNN, DL, MRI, Tumor*

1. Introduction

The brain is vital for controlling the body's functions. If a tumor grows in the brain, it can severely affect these functions [1][2]. In 2020, around 308,102 people worldwide were diagnosed with a primary brain or spinal cord tumor. Brain tumors are the 10th leading cause of death globally. They develop within the brain or central spine, disrupting its proper operation. The causes of brain tumors are unknown, but exposure to radiation and family history can increase the risk [3]. A brain tumor is a disease that results from abnormal growth of brain matter. Normally, new cells are created in our body to replace old, damaged cells in a controlled manner. However, in the case of a brain tumor, the tumor cells multiply uncontrollably [4]. A brain tumor is an abnormal development of brain tissue that can cause cancerous tissue to spread to neighboring or surrounding cells. The spread of cancer foci to neighboring cells can be avoided if they are detected in time using various analysis methods [5]. A brain tumor occurs when abnormal cells form in the brain. There are two main types of cancer; malignant and benign. Therefore, early diagnosis of brain tumors can play an irreplaceable role in improving treatment options and increasing the chances of survival. MRI is mainly used to detect brain tumors or lesions [6]. Tumors can have many sources based on the cells or origin derived from various forms of tumors. Although there are about 1.4% new occurrences of brain tumors per year, the number of deaths from brain tumors has grown over the past several decades in industrialized nations. Computer-Aided Diagnosis (CAD) of illnesses has gained popularity recently and is assisting clinicians in making quick choices [7]. The manual evaluation of several images taken in a clinic is time-consuming and insufficient to comprehend the activity of various cancers. More accurate computer-based tumor diagnosis methods are needed to comprehend and address this complicated issue. Recently, there has been interest in more accurate and reliable tumor cell identification refers to Deep Learning (DL) techniques. A potential area for different medical diagnostic methods is automatic flaw identification in medical imaging [8]. Deep neural networks include the Convolutional Neural Network (CNN). Convolutional Neural Networks (CNNs) perform well in tasks involving the segmentation and classification of images, because they can extract characteristics from the images. The application of Artificial Intelligence (AI) in radiology lowers mistake rates more than human effort. Artificial Neural Networks (ANNs) have gained popularity as a consequence of advancements in the recurrent, feed-forward, and CNNs sectors because they perform well in pattern recognition competitions and are frequently used in sophisticated ANN implementations on graphics processing units [9].

2. Methodology

The methodology behind of this work is to detect Brain tumor using convolutional neural network. Basic three layers model with some modification was implemented.

The classification process includes two classes of Brain MRI images (normal and abnormal cases). The methodology structure is shown in Figure (1).

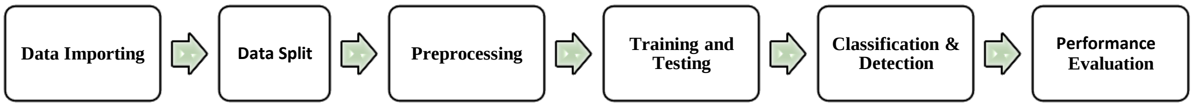

Figure 1. Methodology Structure

The datasets used are available on Kaggle [10]. These dataset consists of two classes; abnormal cases (tumor), and normal cases (non-tumor) Brain MRI images, (1,500) images for every class, total of (3,000) images. These datasets are split into training, testing, and validation sets (70%, 20%, and 10%) respectively. Normalizing, cropping, resizing and augmenting techniques are applied as a preprocessing processes. The performance measures are used to evaluate the efficiency, which include; sensitivity (Recall), precision, loss, and F1-score, then confusion matrix is computed. The following equations are used for performance evaluation [1, 3, 6, 8, 11, 12]:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\mathrm{Precision} = \frac{TP}{TP + FP} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\mathrm{Recall} = \frac{TP}{TP + FN} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$F1-score = \frac{2 * (\mathrm{Recall} * \mathrm{Precision})}{\mathrm{Recall} + \mathrm{Precision}} \quad \ldots\ldots\ldots\ldots \quad (4)$$

Where: TP denotes True Positive values, FP denotes False Positive values, TN denotes True Negative values, and FN denotes False Negative values.

All these parameters are measured in percentage and ranged between (0 – 100). Where the well detected tumor and non-tumor pixels are represented as TP and TN, respectively, whereas; FP and FN are represented non correctly tumor and non tumor detected pixels respectively [5].

3. Results and Discussion

The experiments conducted on CNN model, and dataset including (3,000) Brain MRI images. Before supplying the data to the model, data preprocessing was implemented involving all train sets. Figure (2) shows a series of training images for both (normal and abnormal) Brain MRI images.

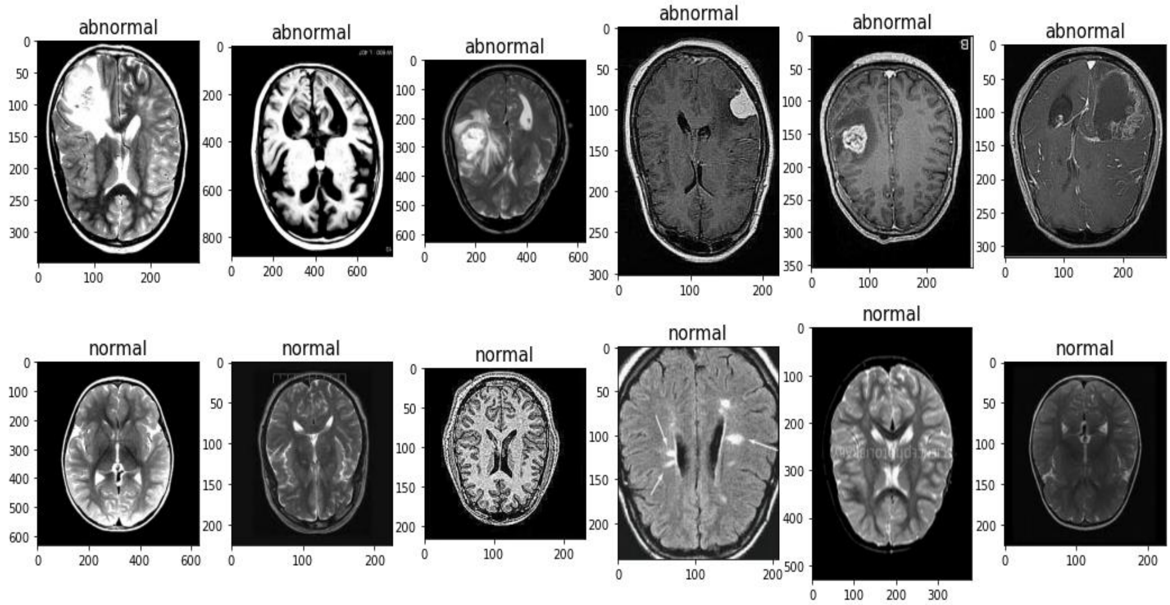

Figure 2. Series of Sample from Training set (abnormal & normal cases)

Data preprocessing used include different aspects, such as resizing normalizing, cropping, data augmentation, etc., as shown in Figures (3 – 5). A few operations on images at the most fundamental level of abstraction are called preprocessing. Before being provided as an input to the machine learning or deep learning algorithm, it refers to each and every change performed on the raw data. It is done to enhance the image and get rid of incorrect information that is extraneous yet was there when the image was collected [13]. As shown in Figures (3), and (4) image crop was produced.

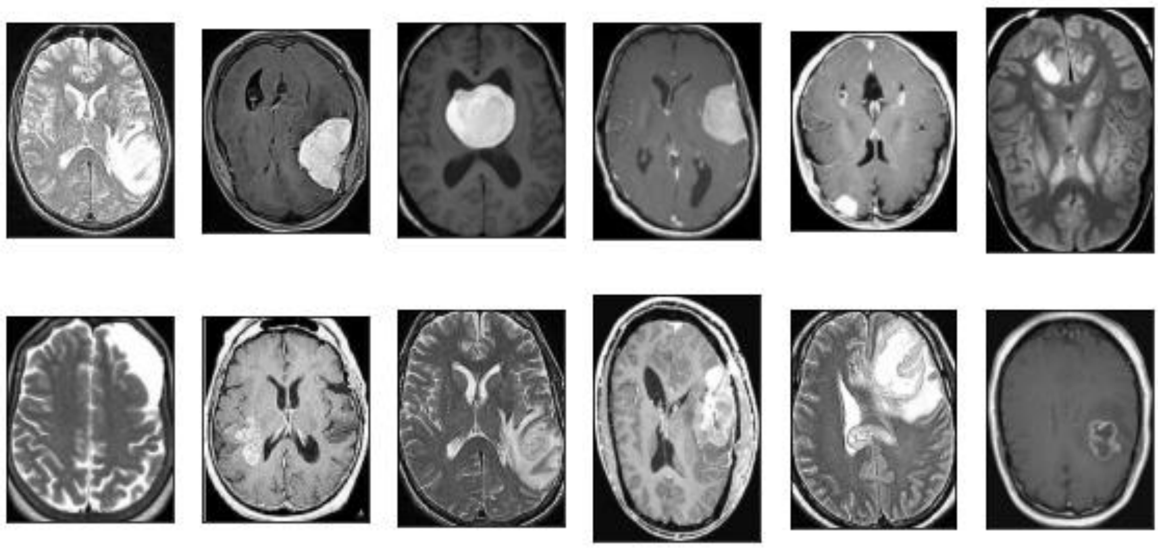

Figure 3. Random Sample of Cropped Images for Abnormal Images.

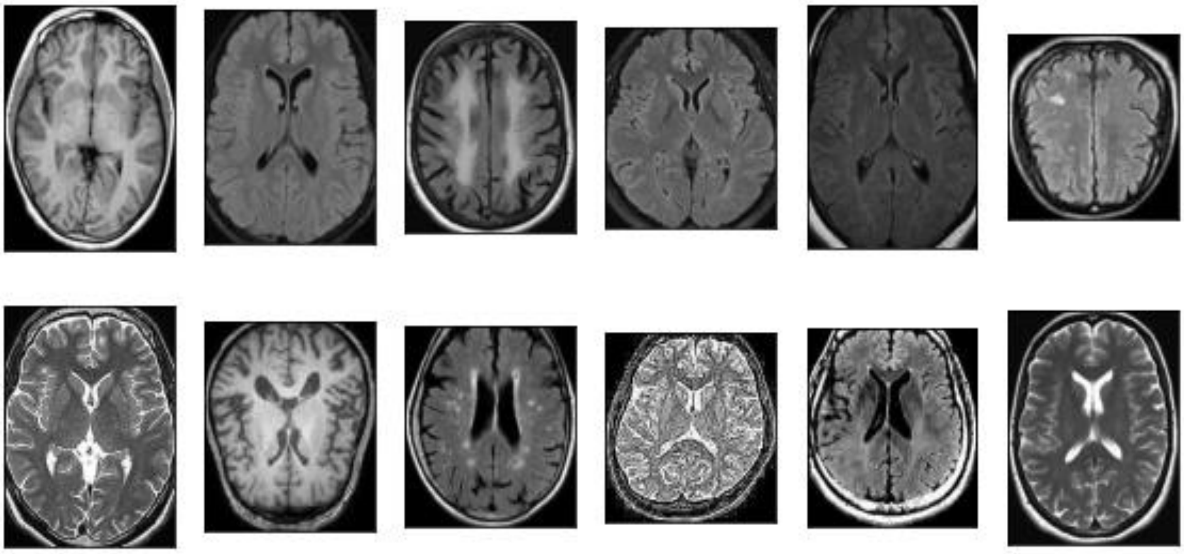

Figure 4. Random Sample of Cropped Images for Normal Images.

Cropping is one of the most common image procedures that is often used to remove undesirable or unnecessary portions of an image, as well as to add desired characteristics and extract a region of the image that is required for the classification process [13]. Data augmentation approaches have been applied to enrich the size of training sets. Figure (5) show sample of augmented images.

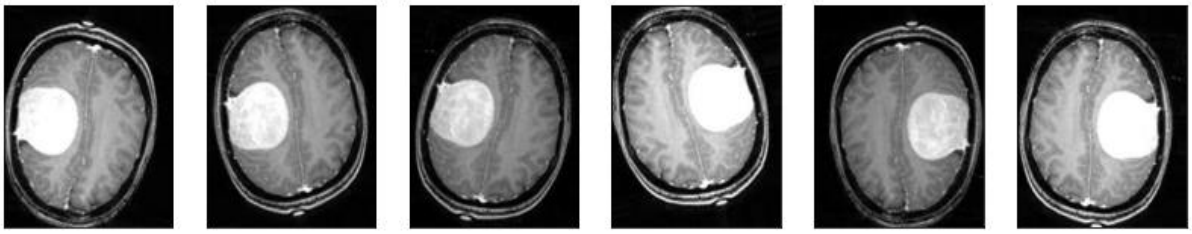

Figure 5. Augmented Images after Data Augmentation Techniques.

Data augmentation is a solution to increase the quantity and complexity of data that already exists. The main principle is to increase the number of training examples artificially. This can help prevent models from overfitting [3]. In most cases, the effectiveness of machine learning and deep learning models is determined by the quality, amount, and relevance of training data. These operations include geometric transformations, flipping, random cropping, random rotations, color space, and noise injections [11]. The experimental results obtain 96% of classification rate as shown in Figure (6). The results demonstrate the model's ability and accuracy in classifying images as illustrated in Figures (6 – 8), and Table (1).

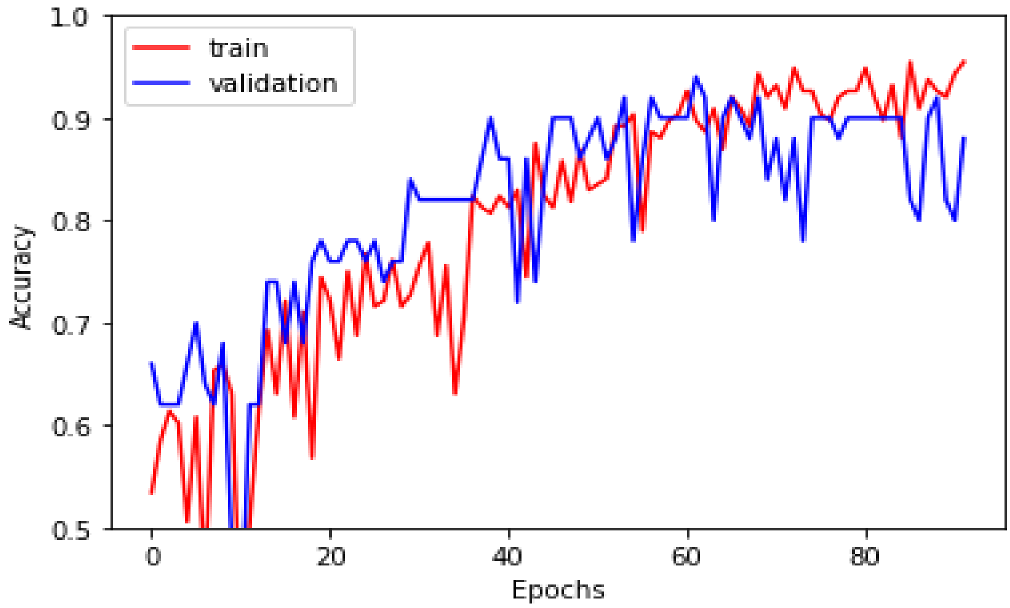

Figure 6. Model Accuracy

As illustrated in Figure (6), increasing the accuracy through the numbers of epochs, which is an adequate level of accuracy for diagnosing and classifying Brain tumor. Loss behaviour as shown in Figure (7), the loss continues to decrease and gives good results during the numbers of epochs .

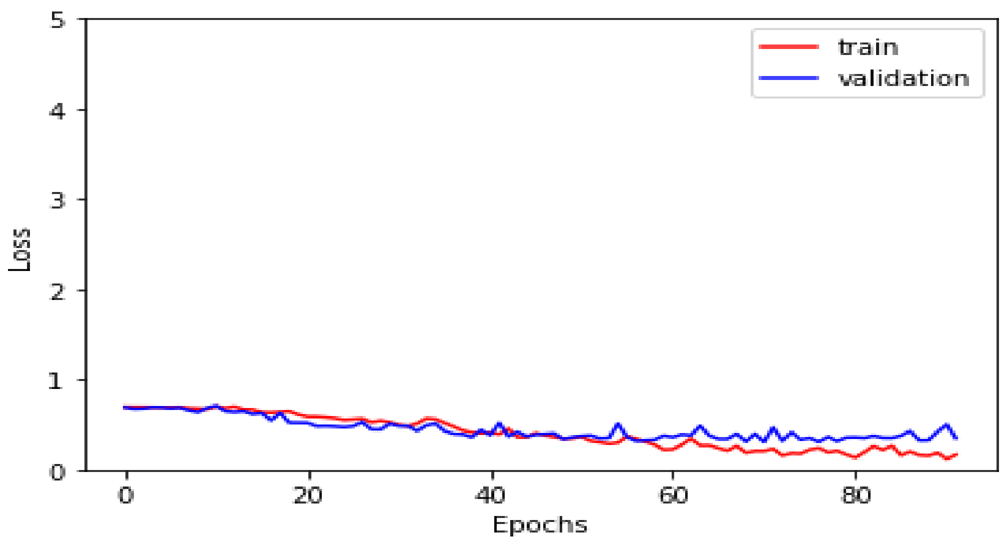

Figure 7. Model Loss

Loss function is a function that evaluates the difference between the predictions made by the neural network and the actual values of the observations used during learning. Its minimization, reducing to a minimum the difference between the predicted value and the actual value for a given observation, is done by adjusting the different weights of the neural network [12]. The results of measuring the evaluation indicators are shown in Table (1). The values of these indicators range from (0 – 1). A value of (1) means no errors. The experimental results show a maximum accuracy of 96%. As shown in Table (1), which illustrates the classification performance of the CNN model for brain tumor classification and detection, the values of all evaluation indicators are close to (1).

Table 1. Evaluation Metrics

	Precision	*Recall*	*F1-score*
Normal	0.96	0.95	0.96
Abnormal	0.95	0.96	0.96
Accuracy		0.96	
Macro average	0.96	0.96	0.96
Weighted average	0.96	0.96	3.96

The confusion matrix is used to identify the number of correctly classified and misclassified data and evaluate performance. The confusion matrix of the model is shown in Figure (8). The confusion matrix summarizes the predicted results of the classification performed and allows comparisons between the predicted correct and incorrect results to determine at which point the model is likely to be confused in its predictions and measure these performances. In the confounding matrix, the results are divided into four main categories: (TP), (TN), (FP), and (FN) [12]. The confusion matrix has equivalent rows and columns, indicating Actual category and true label (i.e. normal or abnormal). Likewise, the predicted value represents the number of correct and incorrect predictions or classifications for each validation sample. True Positive represents the number of positive samples that are correctly identified as positive, while True Negatives represents the number of negative samples that are accurately predicted as negative. A false positive is a prediction that an image is labeled as positive; however, the situation is not optimistic. A false negative is a negative result that appears to be positive [11].

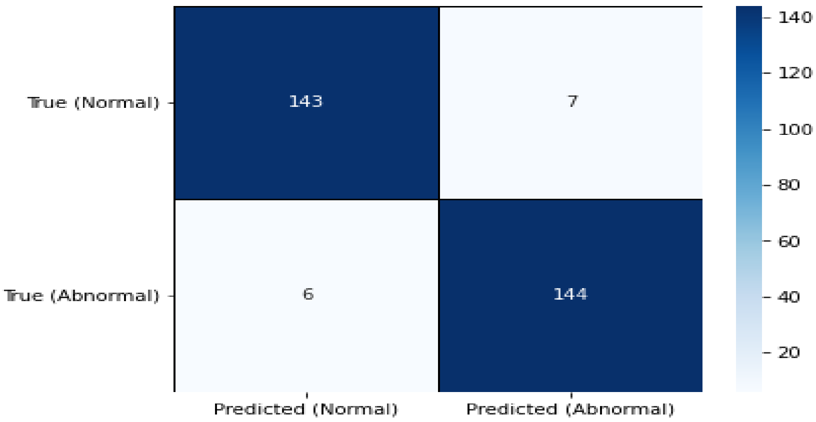

Figure 8. Confusion Matrix of the Results

Based on the results of the values obtained from the confusion matrix Figure (8), the model effectively predicted 144 images as abnormal cases, while failing to predict 6 images. The other class (normal cases) prediction of model correctly predicted 143 images as normal cases images and failed to predict 7 images.

4. Conclusion

Early diagnosis of brain tumors is one of the most important aspects that help in the success of treatment and save the patient's life. CNN is characterized by learning capabilities and infinite accuracy. CNN provides fast and accurate algorithms with excellent detection and classification performance. The deep learning model used can be used to identify brain tumors from MRI scans with high accuracy, achieving best performance and thereby minimizing false predictions, which is highly desirable. The accuracy of the presented model in this work can be further improved by adjusting some parameters related to the model and providing it with more training data sets. The results obtained are helpful and more useful in detecting various diseases.

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