

Brain Tumour Detection using Convolutional Neural Network with Machine Learning Algorithm

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Abstract—Detecting brain tumour earlier is very important and critical for treating a patient. By using feature extraction combined with convolutional neural network (CNN), this paper proposes a different approach to detecting brain tumours earlier as possible. NMRs of both healthy and brain tumour patients are taken for the dataset with CNN and classifiers used to evaluate the performance. The results show that the Sigmoid and ReLu classifiers achieved a good accuracy of 97.55%. Deploying a feature extraction algorithm in the CNN has increased the accuracy to 99.05%. The method proposed helps to improve the accuracy and precision of brain tumour decisions.

Keywords—Brain tumour, deep learning, convolutional neural network, Alexnet architecture, Nuclear Magnetic Resonance imaging, feature engineering.

I. INTRODUCTION

The classification of brain tumours can be divided as normal and malignant. Both of the cases pose a huge health risk as they rapidly spread and worsen the patient's condition. Factors such as location, shape, size and type are significant in detecting a malignant tumour. Early diagnosis is crucial for better treatment, but is mostly challenged by difficulties such as accurately measuring the tumour size and resolution. This paper discusses the complexity and approaches in detecting brain tumour with the help of CNN combined with machine learning algorithms. Among all the diagnosing methods like medical examinations, computer tomography and magnetic imaging, Nuclear magnetic resonance imaging (NMR) stands out being a prominent tool, providing brain images with high resolution. The proposed methodology uses CNN, a neural network that can automatically and locally extract features from brain images. This process is important and crucial to eliminate the risk of misclassification of fatty masses as tumours and vice-versa.

A machine learning algorithm is introduced into the CNN to increase the efficiency of the method. To be specific, a clustering algorithm is applied to the datasets before feeding them into the CNN. The outcomes demonstrated a rise in the efficiency and extent of accuracy of the method perfectly identifying tumours. The need to pre-process the data by means of a clustering algorithm is to confront the potential flaws of misclassifying fatty masses as tumours and tumours as fatty masses leading to critical medical errors. This process also boosts the overall precision in detecting brain tumour.

The method proposed is very useful in identifying the tumour type of the patient earlier as possible. This is very useful and handy in treating a patient beforehand avoiding any undesirable outcomes in the end due to hasty treatment and diagnosis. If improved well, this very method can be implemented in every hospitals and testing centres for early diagnosis and prediction so that brain tumour cases will be reduced drastically. The CNN used along with the clustering algorithm and the various activation functions and classifiers has paved a way for a new and cutting-edge detection of brain tumour method which is also able to detect and classify tumours not only with high accuracy but also as earlier as possible.

A CNN model with 8 Convolutional layers is trained. The dataset includes malignant and benign tumours, split into training, testing sets and validation. Image processing involves cropping and extracting brain portions using Canny Edge Detection. Data augmentation is applied to make the size of the dataset big. The proposed CNN model architecture includes convolutional and a fully connected layer following after a max pooling layer.

In conclusion, the deployment of CNN with machine learning algorithms presents a promising advancement in the field of brain tumour detection. This new approach not only addresses the challenges of early diagnosis but also the importance of feature extraction in enhancing the overall accuracy of neural networks. As new cutting-edge technologies rise, researchers continue to invent new technologies and methods in improving the well-being of the patients through timely detection of faults and diseases.

II. LITERATURE REVIEW

The concept of an automatic identification of NMR images is proposed in [2]. The method uses the super pixel technique to classify any abnormalities or anomalies in detecting brain tumour. This method also uses the ERT (Extremely Randomized Trees) for better results. This technique is evaluated on two datasets: 19 NMR FLAIR images and the BRATS 2012 dataset, showcasing favourable results with the ERT classifier. A CNN with 3x3 small kernels is deployed for an automatic identification of tumours in [3]. Another approach using data samples of blood tests has been proposed in [4].

Achieving top positions for complete, core, and enhancing regions in dice similarity coefficient metrics (0.87, 0.82, 0.78). Various methodologies for detecting brain tumour have been proposed with a slightly varied approach that reduces any round-off errors. Having considered the decision trees, the CNN network seems to be a more powerful approach for this process. [5] puts forth a multi-stage Fuzzy C-Means (FCM) brain framework tumour segmentation from NMR images. A novel approach of brain tumour detection using AI is proposed in [6]. The investigation of the multiphase of NMR images has been proposed in [7]. It also uses this same way to compare and evaluate grading results. The results reveal an 18% improvement in how the neural network performs based on CNN sensitivity and specificity compared to traditional neural networks. In [8], the approach using a CNN combined with a clustering algorithm used for much better accuracy results has been proposed with testing and comparisons conducted with a lot of sample classifiers. It also includes most of the idea to predict brain tumour as earlier as possible. [9] Proposes a different kind of approach with using DNN to deal with low resolution imaging and low-quality images.

[10] Proposes a deep study of brain tumour detection using deep learning techniques which provided much better results. The paper proposes a fine approach with the assistance of CNN in which the layers learn and extract features from the previous layers.

A. Deep learning

Deep learning is an improved form of machine learning which imitates the human nervous system thus obtaining the other name of neural networks. A lot of combinations of layers which consist of neurons are used to train the network with various activation functions and classifiers.

B. Convolutional Network

It is a neural network which has been rather optimized to perform well with feature extraction and feature selection. The layers of this network need not have to be fed with all the outputs of the previous layers, thus they choose their own features to train with. The proposed method in this paper uses such type of neural network to have an optimized feature selection and extraction.

C. Alexnet Architecture

This is a type of convolutional neural network which uses 8 different layers. 5 of them are convolutional filter layers, 3 of them are fully connected max-pooling layers and the final one is the output which usually uses a softmax function for classification. This paper has slightly altered the followed method and used a sigmoid function in the output layer for binary classification.

- Convolutional layer: A convolutional layer is among the various layers of a convolutional neural network that contains a set of filters whose parameters need to be learned. Usually the height and weight of the parameters are small than the input volume of the features. Each filter is mapped to the previous input volumes to select the best or the appropriate feature from the input volume.
- Max-pooling layer: Just like convolutional layers, a max pooling layer is also among the various layers of a CNN also called a pooling layer which performs a pooling operation to select the maximum feature from mapped function thus giving us the most prominent feature that should be selected from the previous or the before map function layer. The layer is usually used for obtaining the best set of prominent features possible.

III. METHODOLOGY

The methodology of NMR is explained, emphasizing its non-ionizing and harmless radiation, which utilizes RF pulses and a strong magnetic field to construct images of the body's internal structures. The key factors controlling NMR images, TE (time to echo) and TR (repetition time), are introduced in NMR particular, is highlighted for its non-invasive nature and 3D imaging capability, especially in locating anomalies in soft tissues. It begins with pre-processing steps such as converting RGB to grayscale, applying a median noise reduction filter, and employing edge detection. Watershed segmentation is then utilized to identify tumour locations. Feature extraction involves using Grey Level Co-occurrence Matrix (GLCM) to deal with texture feature extraction, including energy, contrast, correlation, and homogeneity.

The proposed solution involves employing Convolutional Neural Networks (CNNs) for brain tumour detection, utilizing a deeper architecture with small kernels. It also provides background information on brain tumours, their types, and the importance of NMR imaging in diagnosis. The proposed system involves the use of CNNs, specifically in the context of automatic brain tumour classification, with a focus on pre-processing, feature extraction, and loss function optimization during the training and testing phases.

A. Dataset

The datasets which the paper uses are NMR-scanned images of 167 patients of both healthy and tumour-affected patients taken from external image scanning centres prescribed by doctors. The dataset included around 86 healthy patients' images which included around 1430 images out of which 60 images were separated for testing and 520 images for training. 81 patients with tumours included 580 images of which 175 images and 1150 images were separated for testing and training respectively. Of the total patients, 85 were women and 82 were men with ages ranging from 8 to 65 years old. Of a total of 167 patients, 1900 images were collected of which 1670 images for training and 235 images for testing were taken. The images taken had a size of 512x512 initially.

B. Training and Evaluation

Based on the physician's skill, some area of fatty mass picture were mistaken for tumour images as the diagnosis was completely dependent on the physician's skill. This paper portrays the use of the CNN to detect tumour images. More margins were included from the imaging centres from where the images were extracted. These margins were later then reduced to decrease noise and other unwanted data and features. The main reason for using feature extraction with CNN is to increase the accuracy of the classification of tumour brains and select only the appropriate features. As the proposed method uses a CNN network, the process of feature extraction is thereby done efficiently. Therefore, for the purpose of increasing the accurate level of the network a clustering algorithm was proposed to be used along with the CNN.

C. Feature Extraction Method

A clustering algorithm will be suitable for feature extraction. A clustering algorithm selects different centres of the clusters in the data set, which are nothing but the mean centres of the cluster, to find the least distance between the points and the centres of the clusters. For simplicity, the cluster centres are randomly selected and the points are assigned to the clusters based on their similarities, resulting in the formation of new clusters. Figure1 shows the images obtained after the clustering algorithm was applied to the image dataset.

D. Convolutional neural method

How the models perform is studied and evaluated using common and standard model-metrics such as accuracy, specificity, sensitivity, precision and spuriousness. The grid search optimization is used for automatically tuning the hyper parameters of the CNN model, taking into account both the architectural and the fine-tuned hyper-

parameters. The experimental results and performance evaluation metrics are crucial for assessing the effectiveness of the proposed CNN models in multiple classifications of brain tumours based on NMR images. The images were initially fed to the CNN with no feature extraction methods with an initial size of 227x227. The Alexnet architecture was used to determine the classification of the images based on their properties. The architecture consisted of 5 convolutional layers and 3 layers for max-pooling. Of the 3 max-pooling layers, 2 layers were used for normalisation and made into fully connected layers (with 4216 neurons) with two categories, namely brain tumour patients and normal patients, and finally the output layer or the classification layer using a sigmoid classifier instead of a softmax classifier.

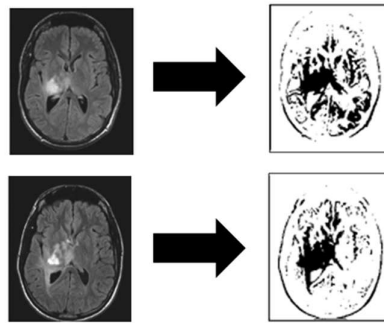


Figure 1. Clustering Algorithm Introduced into the Image

IV. RESULTS AND DISCUSSIONS

The extent of which the CNN accurately classified the images into tumour patients and normal patients was 97.55%. For the purpose of refining the model and better feature extraction, a clustering algorithm has been deployed. Activation functions such as the Sigmoid classifier, SVM classifier and the BINARY STEP FUNCTION classifier have been used to test the performance of the neural network. The criteria respectively are Accuracy, Specificity, Sensitivity, Precision and Falseness. The evaluated results have been showed in TABLE I below. The sigmoid showed the highest accuracy of 97.55% with the other classifiers showing 96.37% and 92.55% respectively. The accuracy was later increased to a percentage of 99.05% after applying the clustering algorithm.

TABLE I. THE RESULTS OBTAINED FOR VARIOUS CLASSIFIERS AFTER FEEDING THE TEST IMAGES

Methods	Accuracy	Specificity	Sensitivity	Precision	False
CNN+ Sigmoid	97.55%	93.98%	100%	97.12%	4
CNN+ SVM	96.37%	89.48%	100%	95.43%	6
CNN+ Binary Step	92.55%	86.79%	100%	95.22%	12

As seen in the table, the sigmoid showed the highest accuracy of 97.55% while the SVM demonstrated an accuracy of 96.37% and the Binary step function with an accuracy of 92.55% respectively.

As per the results that have been obtained, 4 images out 235 images were falsely classified and wrongly diagnosed by the neural network. The images are shown in Figure 2.

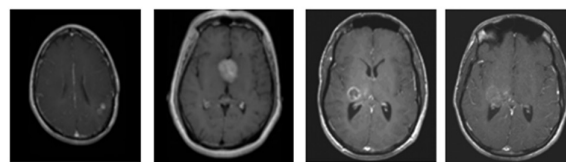


Figure 2. Images Misclassified by the Convolutional Neural Network

The results after the clustering algorithm was introduced into the CNN to get the accuracy of the network high, are listed in TABLE II below.

TABLE II. THE RESULTS OBTAINED FROM THE CNN AND THE CNN WITH THE CLUSTERING ALGORITHM APPLIED

Methods	Accuracy	Specificity	Sensitivity	Precision	False
CNN+ Sigmoid	97.55%	93.98%	100%	97.12%	4
Proposed method	99.05%	95.46%	100%	98.03%	2

After clustering algorithm was introduced into the neural network, 2 images from the same set of 235 test images were misclassified increasing the accuracy. The misclassified images are shown in Figure 3.



Figure 3. Images Misclassified by the Proposed Method

The after results of the clustering algorithm being applied to the network are that the accuracy has been increased from 97.55% to 99.05% and the misclassified images count has been reduced from 4 to 2 giving us better results. The graphical representation of the accuracy of the network and the algorithm during the training process has also been listed in Figure 4.

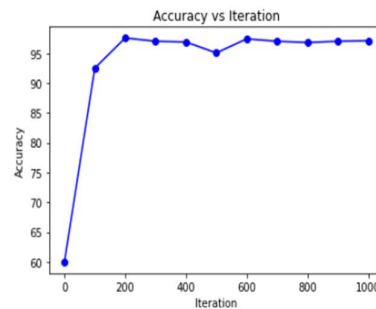


Figure 4. Network accuracy process

Also the graphical representation for the loss calculation is also portrayed in Figure.5 below.

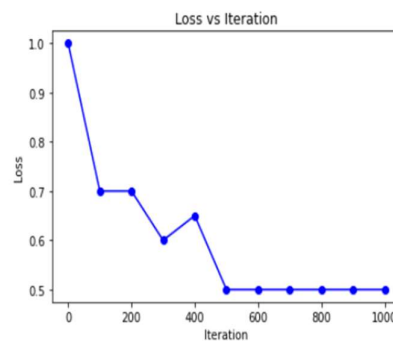


Figure 5. Network Loss Process

Both of these were run through 1000 iterations to obtain better results. The iteration process carried out the evaluation of the model and the results based on various sub-fields were listed and based on that data we could see that the proposed methodology has performed with better results.

V. CONCLUSION

So in this paper a new method of detecting brain tumour using CNN combined with a clustering algorithm has been proposed. It is very useful in auto-selection features from brain scan images. With the help of clinicians labelling the images in the centres, two categories of images were obtained, tumour and normal brains. A sum of 1900 images were collected of which 1670 training images and 235 images testing were taken. To compare the performance of the CNN, other classifiers and activation functions were used and evaluated in the output layer or the classifying layer. This helped us to gain an insight of how well the proposed method had performed and it turned out it performed better than other methods yielding an accuracy of 97.55% and an overall accuracy of 99.05% when combined with a clustering algorithm. With such accuracy, the prediction of tumour brains and normal brains has been refined to a fine level. An improvement in the method after applying the clustering algorithm proves that the various combinations of algorithms can efficiently improve and refine the model's performance. Thus this is the end of the paper, the methodology proposed in this paper can be optimised and enhanced further using other advanced algorithms and can be implemented in hospitals and testing centres for earlier prediction of the existence of tumour in the human brain.

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