CONSTRUCTING A STROKE DIAGNOSIS AND PROGNOSIS SYSTEM BASED ON THE BPN ALGORITHM USING TC-99M-ECD SPECT IMAGES

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ABSTRACT

Background: The technology of deep learning in artificial intelligence (AI) is increasingly applied to medical image recognition. These applications are focused mainly on the analysis of CT or MRI images and seldom intended to support research of nuclear medical images. SPECT is one of the few examination tools that can sensitively reflect abnormalities in the brain at an early stage. In addition to diagnosing cerebrovascular diseases, it can also be used as a tool for prognostic evaluation. Therefore, constructing a stroke image recognition system for diagnosis and prognosis is the goal of this study. Method: We collected all the Tc-99m ECD SPECT brain images from Kaohsiung Chang Gung Memorial Hospital over a period of five years from 2017 to 2021. A total of 144 medical records that met the ICD-10-Code I60-I69 cerebrovascular disease extraction rules were obtained. In the preprocessing of data, noise and defective images were removed. Data augmentation technology was exploited to avoid overfitting and underfitting due to the small amount of data and obtain more new images for higher generalization ability. The back-propagation neural network (BPN) algorithm was adopted to train stroke images and extract important features according to the distribution of blood flows in the brain. Result: The proposed model is compared with the VGG16 through transfer training. It delivers an accuracy of 94.4% (1.3% higher) and a sensitivity of 90.3% (5.4% higher). Its recall rate and F-score reach 90.3% and 94.2% respectively. The ROC curve and average AUC (0.89±0.08) indicate that this model has an excellent discrimination capability. Conclusion: Based on the strengths of the BPN algorithm, we construct a stroke image recognition system to support stroke image recognition, assessment of the possibility of a second stroke, and prognostic evaluation. This system can also assist physicians in performing a rapid diagnosis and reduce errors. It is hoped that the developed software can be ported to real-world medical systems for testing, so as to connect the theory with practical situations.

KEYWORDS

Stroke Diseases, Cerebral Perfusion Image, Transfer Learning, Back-Propagation Neural Network, Nuclear Medical

1. INTRODUCTION

Stroke is a common neurological disorder. It has been recognized as the leading cause of death and disability across the world. According to the 2017 and 2018 statistics on the top 10 causes of death in Taiwan released by Ministry of Health and Welfare (MOHW), cerebrovascular disease ranks fourth, claiming more than 10,000 lives each year on average [1], and the trend is rising year by year as shown in Figure 1. Stroke is scientifically referred to as a cerebrovascular disease. It is a condition in which sudden bleeding in the brain causes internal pressure, poor circulation or cell death due to ischemia, resulting in brain injury and neurological dysfunction, which can be severe and even fatal in the acute stage. Clinically, there are three types of stroke: cerebral infarction, cerebral hemorrhage and transient ischemic attack. Ischemic stroke induced by a blockage of the artery is more common, accounting for approximately three-fourth of all stroke cases, with bleeding-induced hemorrhagic stroke taking up the rest one-fourth. The most common diagnostic tools for stroke is single-photon emission computed tomography (SPECT) and drug used is Technetium-99m ethyl cysteinate dimer (ECD).

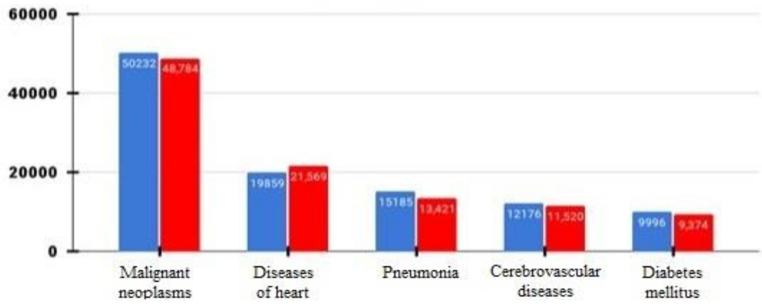

Figure 1. The study integration (data source：MOHW2018 ~2019year)

2. MATERIALS AND METHOD

In this study, the back-propagation neural network (BPN) algorithm is used. Feed-forward propagation is to transfer weighted data from the input layer to the hidden layer. Through the transfer function, the output value and error function corresponding to each neuron can be calculated. When the expected output cannot be obtained from the feed-forward output layer, the predicted output value and target output value are substituted into the error function. By means of the gradient descent method, the new weight can be obtained. This algorithm is known for backward propagation of errors (BP). Characterized by high accuracy and fast recall, BP is the most representative and widely used algorithm for training neural networks. The basic structure of a BPN is as illustrated in Figure 2 [2]. The data extraction procedure of the proposed system comprises three stages. In the first stage, it connects to the health information system (HIS) of the hospital to search for the medical records of the Department of Neurology and the Department of Neurosurgery. Based on the epidemiological distribution of the different types of strokes in Taiwan, the system collects the data of patients who underwent cerebral perfusion scan with SPECT (ECD examination item code N73-005) in the Department of Nuclear Medicine of our hospital. In the second stage, based on International Classification of Diseases (ICD-10-CM) and the criteria of the previous stage, patients whose disease meet any of the following code will be selected: I60 subarachnoid hemorrhage, I61 intracerebral hemorrhage, I63 cerebral infarction, I64, I66, I67, and I69 sequelae of cerebrovascular disease. I68 is cerebrovascular disorders in diseases classified elsewhere [3]. In the third stage, the system connects to the picture archiving and communication system (PACS) of the Department of Nuclear Medicine to collect the structured imaging reports for patients who meet the sampling criteria of the second stage. Finally, if the system's analysis result meet any of the structured extraction rules, the structured neurological medical reports and images will be stored in the examination report database for subsequent deep learning. More data is needed to ensure that training does not result in overfitting or underfitting. To make up for our lack of data, we exploit data augmentation technology within a reasonable range. The techniques of this technology include flipping, rotation, cropping, enlarge/lessen, horizontal flip, lean left/right.

3. RESULTS

In this study, we collect 144 sets of images, including (1) 72 sets of stroke images, and (2) 72 sets of normal images. Of these stroke patients, 45 are male (62.5%) and 27 are female (37.5%). Their average age is 65 years old. 48 patients have cerebral infarction or occlusion/stenosis of cerebral arteries, making up the largest proportion of the sample (66.7%). Cerebrovascular atherosclerosis or other cerebrovascular diseases account for 12.5% of the sample. Intracerebral hemorrhage and subarachnoid hemorrhage respectively constitute 6.9% and 1.4%. The images for machine learning are classified into two groups, image of stroke patient (labeled as 1) and image of non-stroke patient (labeled as 0). In machine learning, this is the method of supervised learning. Through use of labels in the analysis, the model can make predictions after training. The proposed system is designed to have two convolution layers and two pooling layers. Through binarization, all the images are converted from 3-dimensional color images into 2-dimensional grayscale images, with kernel size set as5x5 and filters respectively set as 32, 64, 128, and 256. To reduce generalization error, accelerate model convergence, and avoid internal covariate shift (ICS), we incorporate batch normalization into the operation. Excluding the dropout layer can reduce the training time by half. In nowadays, this has become a common approach. As to the activation function, ReLU is a common activation function for hidden layers. The pooling size is set as [2x2] or [3x3]. The parameters considered are very complicated.

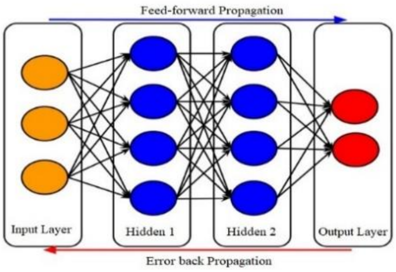

Figure 2. Back-propagation neural network

4. CONCLUSION

To address the limitation of the insufficient image data for research, we used the transfer learning technique to apply the pre-training weights of the VGG16 model to the Tc-99m ECD SPECT images in this study. VGG16 training has an accuracy rate of 93.1%, and the proposed BPN model achieves 94.4%. In comparison, the proposed model is not inferior at all. It delivers a 1.3% higher accuracy in image recognition, and 5.4% higher sensitivity. Under clinical requirements, the highest recall of 90.3% and the highest F-score of 94.2% are obtained. Although these statistics confirm the proposed model's differentiation ability, its learning curve is still not ideal, and its convergence is slower than VGG16. Unlike foreign studies that use huge data for training, this study relies on a small amount of data, which may be the cause of the high oscillation of the waveform. In our future studies, we will collect more data for training and consider the consumption of hardware resources required for processing huge data.

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