EVALUATION OF DIAGNOSTIC ACCURACY OF MACHINE LEARNING ALGORITHM FOR COMPUTER AIDED DIAGNOSIS (CAD) OF SPACE OCCUPYING LESIONS IN COMPUTED TOMOGRAPHY (CT) IMAGES OF BRAIN

Abstract:

Objectives-Objective of this project was to formulate a low cost and user-friendly SOL detection computational model through machine learning and test its diagnostic efficacy through retrospective evaluation of radiologist confirmed normal and abnormal CT images.

Materials & Methods-The neural network has been created in the Wolfram language, using our own dataset. A total of 249 images were obtained from a CT scan center’s human brain data. A database of 89 normal and 76 SOL images from 128 slice CT scan machines was used for formulating the model. The test trial was done using 50 different normal and 34 different abnormal images.

Results-The sensitivity of ability to identify abnormal images was 97% and the specificity was 92%. Only one out of 34 images with tumor was reported wrongly and 4 normal images out of 50 normal test images were wrongly identified by the CAD system. The software was able to achieve a diagnostic accuracy higher than the confidence interval of 95% set for the diagnostic test.

Conclusion - The CAD system is novel and innovative as it is a simple, low-cost and user-friendly computational model which can be used by doctors on their office PCs.

Keywords: Computer Aided Diagnosis (CAD), Artificial Neural Network (ANN), Machine Learning, Algorithm, Intracranial Space Occupying Lesion (ICSOL)
Objectives

The objective of this project was to formulate and test a low-cost and user-friendly SOL detection computational model through machine learning and test its diagnostic efficacy through retrospective evaluation of radiologist-confirmed normal and abnormal CT images.

Materials & Methods

The neural network has been created in the Wolfram language using our own dataset. Wolfram was considered as it seemed to be an appropriate platform for our project since it enabled us to later offer a custom web service/app with the algorithm, which would simplify the whole process for doctors, as they usually have less time and little technical knowledge. A total of 249 images were obtained from a CT scan center’s human brain data. A database of 89 normal and 76 SOL images from 128 slice CT scan machines was used for formulating the model. The test trial was done using 50 different normal and 34 different abnormal images. Non-enhanced and contrast-enhanced axial images with various sections at the level of the midbrain, pons, ventricles, and cerebellum were taken to include most of the brain sections.

Inclusion & Exclusion Criteria

Normal and abnormal (with findings of Space Occupying Lesions) images of both children and adults were included. We also included a few images with mild age-related atrophic changes in the brain so that the software would not interpret these changes as abnormal. Images with artifacts, fractures, and other lesions were excluded from the database as well as the test sample. It was ensured that the test sample images are not added to the software database.

In order to remove chances of subjective bias, test samples were allotted unique numbers and were randomly subjected for diagnosis by the software. Diagnostic results of the system were recorded by another person unaware of the type of image subjected to the test. A confidence interval of 95% sensitivity and 90% specificity was determined for the evaluation of the efficacy of the algorithm.

Results

Diagnostic Accuracy of Computational Algorithm -

<table>
<thead>
<tr>
<th>Result of Software System</th>
<th>Diagnosis given by Radiologist</th>
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<tbody>
<tr>
<td></td>
<td>SOL CT Image</td>
</tr>
<tr>
<td>SOL</td>
<td>33</td>
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<tr>
<td>Normal Result</td>
<td>1</td>
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<tr>
<td>Total</td>
<td>34</td>
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Sensitivity - 33/34*100 = 97.05%
Specificity - 46/50*100 = 92.0%
Predictive Value of SOL diagnosis by CAD System - 33/37*100 = 89.18%
Predictive Value of Normal diagnosis CAD System - 46/47*100 = 97.87%
Percentage of False Positive SOL Finding - 4/50*100 = 8.0%
Percentage of False Negative Normal Finding - 1/47*100 = 2.12%

Discussion

Radiological diagnostic investigations are gaining importance every day. Early detection of many pathological abnormalities such as tumors is very important for initiating timely treatment. Failure to diagnose such space occupying lesions can be disastrous. Despite the increasing availability of costly diagnostic equipment, many countries - especially developing ones - are facing huge shortages of qualified radiologists. Lack of adequately trained doctors to serve a large number of patients is a pressing problem. Space Occupying Lesions are one of the most frequent causes of rising mortality among children and adults worldwide. Hence, early detection helps in timely intervention and management.

Computer-aided diagnosis can augment the diagnosing capabilities of doctors, reduce the time required and also lessen the workload faced due to a dearth of qualified radiologists.

With the advent of technology CT scan has emerged as a modality frequently being used for most of the ailments ranging from a simple headache to a headache related to SOLs. Computer-aided diagnosis can screen the normal brain images and abnormal brain images which can then be sent to a qualified doctor for further investigations.

While interpreting medical images, brain tumor recognition through computed tomography (CT) and magnetic resonance images (MRI) is an arduous task because of the complicating structure of the brain and high diversity in appearance of tumor tissues. Hence, the need for effective, methodical and objective tumor recognition technique is rising, for routine clinical applica-
tion. CT is a valuable tool in differentiating communicating from non-communicating hydrocephalus depending on the level of obstruction and is also useful in determining the etiology of hydrocephalus in children. Trans-fon-tanellar USG can be used in infants for diagnosing space-occupying lesions.

In medical imaging, the precise diagnosis and/or assessment of an ailment depends on both image acquisition and image interpretation. With the advent of technology, devices with faster acquisition rates and high resolution have improved the process of image acquisition substantially, over recent years. However, most of the medical images are interpreted by physicians/ radiologists; it has its own limitations due to subjectivity, large variations across interpreters, and fatigue. Many diagnostic tasks entail an initial search process to detect abnormalities, to quantify measurements and changes over time. Computerized tools, specifically image analysis and supervised and unsupervised machine learning, are the key enablers to improve diagnosis, by facilitating the identification of the findings that require treatment and to aid the expert’s workflow. Among these tools, deep learning is rapidly proving to be the state-of-the-art foundation, opening up new frontiers in data analysis, resulting in improved accuracy.

In a study conducted by Subrata Kar et al, of the 16-sample database, 10 datasets for training, 3 datasets for validation, and 3 datasets for testing were used. The number of output datasets of true positive, false positive, true negative and false negative was 6, 0, 10, and 0, respectively with the sensitivity, specificity, and accuracy each equal to 100%. The method of diagnosing brain cancer presented in this study is a successful model to assist doctors in the screening and treatment of brain cancer patients.

The experiments were carried out on 101 images consisting of 14 normal and 87 abnormal (malignant and benign tumors) from a real human brain MRI dataset. The classification accuracy on both training and test images is 99% which was significantly good.

The study conducted by Sridhar et al applied Probabilistic Neural Network with Discrete Cosine Transform for Brain Tumor Classification. Decision making was performed in two steps, i) Dimensionality reduction and Feature extraction using the Discrete Cosine Transform and ii) classification using Probabilistic Neural Network (PNN). The evaluation was performed on image database of 20 Brain Tumor images and yielded fast and better recognition rate.

Another research work demonstrated that Analysis of Brain Tissue Density (ABTD) method is a useful algorithm to extract features that can potentially be integrated with CAD systems to assist in stroke diagnosis. A multifarious database of real post-contrast T1-weighted MR images from 10 patients has been taken, consisting of primary brain tumors namely Meningioma (MENI-Class 1), Astrocytoma (AST- class 2), and Normal brain regions (NORM- class 3). An Artificial Neural Network (ANN) was used to classify these three classes.

In another study, the MRI image dataset containing 20 brain MRI images in which 10 images with tumor and the other 10 brain images without tumor were taken from the publicly available sources. The performance of the proposed technique was evaluated by means of the QR for all the segmented tissues. As well, the results for the tumor detection were validated through evaluation metrics namely sensitivity, specificity, and accuracy. The Comparative analysis was carried out by K-NN classification and the Bayesian classification. The obtained results depicted that the proposed NN classification produces better results than the other classifiers in terms of sensitivity, specificity, and accuracy.

Experiments were carried out on a dataset consisting of T1-weighted post-contrast and T2-weighted MR images of 550 patients. The developed CAD system was tested using the leave-one-out method. The experimental results showed that the proposed segmentation technique achieved good agreement with the gold standard and the ensemble classifier as highly effective in the diagnosis of brain tumor with an accuracy of 99.09% (sensitivity 100% and specificity 98.21%).

The wavelet-energy based approach for automated classification of MR brain images as normal or abnormal was used in some other study. SVM was used as the classifier, and biogeography-based optimization (BBO) was introduced to optimize the weights of the SVM. The results based on a 5 × 5-fold cross validation showed the performance of the proposed BBO-KSVM was superior to BP-NN, KSVM, and PSO-KSVM in terms of sensitivity and accuracy. The study offered a new means to detect abnormal brains with excellent performance.

In a study by HC Wang et al, they have demonstrated the feasibility of a fast and fully automated approach for midline shift measurement, indicative of intracranial space-occupying lesions, on brain CT images with satisfactory accuracy.

A study to evaluate the use of artificial neural network to predict clinically relevant pediatric traumatic brain injury on CT scan, authors found the sensitivity of 99.73%, accuracy of
Conclusions

Ribiero et al evaluated the ability of artificial neural networks (ANNs) for automatic identification of ICVAs (Intracranial Cerebro Vascular Accidents) by means of tissue density images obtained by CT.20

The automated approach including several stages of image segmentation, area, and volume calculation, and its location findings using statistical and unsupervised clustering prediction method was capable of improving the overall detection, segmentation, and quantification of a variety of tumors for different cases from multiple standard datasets.21

Conclusions

In order to evaluate the diagnostic potential of the innovative CAD system, we tested random radiologist-confirmed images and noted the observations in a double-blind trial. The sensitivity of the ability to identify abnormal images was 97% and specificity was 92%. Only one out of 34 images with tumor were reported wrongly and 4 normal images out of 50 normal test images were wrongly identified as with tumor by the CAD system. The software was able to achieve higher diagnostic accuracy in comparison to the confidence interval of 95% set for the diagnostic test. It has been observed that the performance of neural network increases with an increase in the database. At this level too, such low-cost cloud-based model can definitely help public health doctors and technicians as an important screening test.

The said CAD system is novel and innovative as it is simple, low cost, user-friendly, cloud-based computational model which can be used by doctors online on their office PCs itself. Available independent CAD systems – being very costly – are unaffordable, especially in public health care settings of developing nations. In developing countries like India, there is a disproportionate ratio of people on the waiting list to available doctors. As such, doctors are often faced with increased workload – which also lowers accuracy.

Therefore, results revealed that suggested software is quite reliable & expeditious. It can be used by doctors and residents as a first screening step before being confirmed by a qualified radiologist. Cross-checking of diagnostic result of doctors will also reduce the chances of human error.

Future work

Future interventions/ research will include -

1. Acquisition of a larger database with sufficient images of various horizontal sections, as mistakes made were due to a very small database of those sections/lesions.
2. Categorizing different space-occupying lesions on the basis of their location, edema and other classical features to specify the abnormality/disease.

References


