International Journal of Advanced Scientific Research
www.allscientificjournal.com
ISSN: 2456-0421
Received: 26-08-2025, Accepted: 25-09-2025, Published: 09-10-2025
Volume 10, Issue 4, 2025, Page No. 33-37

An optimized convolution neural network technique for stroke detection in magnetic resonance images

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Abstract
Artificial Intelligence (AI) is the use of mathematical algorithms to mimic human cognitive abilities. Convolution Neural Network (CNN) is an outstanding branch of deep learning applications in artificial intelligence which could be used in medical imaging specially to detect neurovascular disease which is stroke in Magnetic Resonance images. It has been difficult to train considerably deep CNNs with the lack of training data, the poor spatial resolution of MR images and the need for a short prediction time. However, existing CNN based systems are limited by inability to perform faster convolutions thereby rendering them inadequate to efficiently manage patients with neurovascular diseases like stroke. Hence this work developed an optimized convolution neural network (CNN-GSA) technique that detect neurovascular disease (stroke) in magnetic resonance images. 5000 datasets were retrieved from kaggle which is an online public repository. The retrieved datasets were pre-processed by employing median filter and image enhancement techniques. The pre-processed images were segmented by using garbor filter technique. Gravitational Search Algorithm (GSA) was used to assign optimal weight parameters for the Convolution Neural Network (CNN) to produce CNN-GSA technique. The developed method (CNN-GSA) was used for feature extraction and detection. The implementation of the CNN-GSA was done by using Matlab R2020a. The performance of the CNN-GSA was evaluated based on Precision, Sensitivity, Specificity, False Positive Rate, Recognition Accuracy and computational time. There are eight (8) classifications for the model's predictions of True Positive (TP), False Negative (FN), False Positive (FP) and True Negative (TN). The results showed that the standard CNN based system has a degree of average of False Positive Rate (FPR) to be 7.83%, recognition accuracy to be 92.57%, sensitivity which is also recall to be 92.98%, precision to be 92.24%, specificity to be 92.17% and computational time to be 86.98% across all classes. The binary threshold across all classes were 0.25, 0.25, 0.35, 0.5, 0.5, 0.75 and 0.75 respectively. The result of the developed CNN-GSA has a degree of average of False Positive Rate (FPR) to be 3.15%, Recognition Accuracy to be 97.26%, sensitivity which is also recall to be 97.67%, precision to be 96.89%, specificity to be 96.85% and average computational time to be 54.59% seconds across all classes. It is evident from the results that Convolution Neural Network algorithm can be used to detect neurovascular disease (stroke) in magnetic resonance images but an optimized Convolution Neural Network (CNN–GSA) technique is needed to assist radiologists in making the right decisions with minimum errors. Hence Radiologist can use the developed system as a second opinion, which will greatly improve diagnosis of neurovascular disease (stroke) in order to reduce stroke mortality rate.

Keywords: Artificial intelligence (AI), convolutional neural network (CNN), optimized cnn (CNN-GSA), stroke detection, magnetic resonance imaging (MRI)

Introduction

As the computer becomes more and more ubiquitous in the society, the medical field also faces new challenges resulting from the rise of technology, specifically in the field of diagnosis. With increasingly sophistication and intelligence, more and more physicians are relying on technology to aid in their diagnosis. Artificial Intelligence (AI) offers excellent progressive opportunity to the Medical Imaging Technology (MIT) and it is based on computational models and bioinformatics-based algorithms, it can determine any abnormal cellular growth and biological changes in the body. AI-assisted MIT not only plays a decisive role in radiology but also has huge impact on medical resonance imaging and neuro-radiography (Iqbal *et al.,*2021). The Healthcare system would be incomplete without radiology, especially in neurovascular diseases detection and other related complications. Radiologists are expected to have more digital knowledge than any other medical professional because they are always on the frontline to adopt digital information related to medical imaging. Deep Learning (DL) is preferable over the traditional Machine Learning (ML) because of its high performance and AI-based cognitive ability. (Iqbal*et al.,*2021). Machine Learning is an application of Artificial Intelligence (AI) that provides a system the ability to automatically learn and improve from experience without being explicitly programmed. Deep learning is a subset of machine learning that, in very simple terms, can be thought of as the automation of predictive analytics (Tucci, 2021) [32].

Neurovascular disease is a leading cause of adult disabilities and death and includes any abnormality of the blood vessels within or supplying blood to the brain and spine. This includes narrowing of the arteries, which decreases blood flow to the brain and increases the risk of a stroke (Mason, 2019). Magnetic Resonance Imaging (MRI) is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body (Powell and Psychol, 2015). Magnetic resonance imaging (MRI) of brain diseases provides excellent anatomical details—location, size, distribution, signal characteristics and also reveals functional information about vascularity, brain edema, and the preserved brain tissues. Significant role for the development of MRI has the use of contrast agents. It increased the quality and diagnostic capabilities. (Lachezar, 2019) [15]

According to Bernal *et al.,* (2018) [3] it has been difficult to train considerably deep CNNs due to lack of training data, the poor spatial resolution of MR images and the need for a short prediction time. To train such networks, a considerable effort is needed in designing faster methods to perform convolutions. Fast Fourier Transform (FFT) algorithms and quicker matrix multiplication methods have been used to improve the computation speed of CNNs, but there is yet room for improvement.

In this research, Convolution Neural Network algorithm was optimized for detection of stroke in Magnetic Resonance Images. Magnetic Resonance Imaging has been widely used as a medical imaging approach, therefore, the purpose of this research is to use the huge amount of MRI images from kaggle which is an online public repository, based on the method of an optimized convolution neural network, to discover clear features that identify stroke. The features to be extracted from MRI images of multiple slices can be used to calculate the distribution location and area of the lesion block, establish a 3D model to simulate the entire brain lesion location, and quickly find the problem, thereby assisting the physician in the diagnosis of stroke. Therefore, this work developed an optimized convolution neural network technique for stroke detection in magnetic resonance images by using Gravitational Search Algorithm (GSA).

Review of Related Works

In recent years, there has been a growing use of deep learning to solve medical problems, such as detecting lung symptoms, brain tumor location, neurovascular diseases etc. and such studies have also been shown to help medically especially in Magnetic Resonance Imaging. Many researchers have done tremendous work on detecting abnormalities in the brain. Most of these researchers differ in the classification, feature extraction and segmentation techniques used in the detection of neurovascular diseases.

Hosseini *et al*. (2017) worked on the limitations of Convolution Neural networks in recognizing negative images. CNN architectures and standard image datasets were used, the result shows that when training on regular images and testing on negative images, the accuracy of CNNs is significantly lower than when they are tested with regular images. Specifically, it was observed that the accuracy on negative images is relatively good, only if there is significant diversity within the training data.

Stember *et al*. (2018) [31] developed and train a convolutional neural network (CNN) to detect and measure cerebral aneurysms from magnetic resonance angiography (MRA) automatically and without geometric shortcuts. The clinically pertinent application of computing maximal aneurysm one-dimensional size and two-dimensional area was demonstrated all images were two-dimensional MIPs and the Normal vessel curvature could hinder two-dimensional MIP images because a normal bend in vasculature may appear from a certain projection as a focal outpouching, i.e., an aneurysm. The system has high accuracy and Area under the ROC Curve (AUC) values (ROC curec is a Receiver Operating Charateristic curve) but Fully three dimensional Magnetic Resonance Angiography (MRA) and Computed Tomographic Angiography (CTA) image stack can help to improve.

Bernal *et al*. (2018) [3] worked on Deep Convolution Neural network for brain image analysis on Magnetic Resonance Imaging. He considered noise filtering techniques, inter and intrapatientnormalisation and skull-stripping methodsin the preprocessing stage, the data was prepared to be processed by the classifier, the classification took place and the segmentation results were obtained. The researcher worked with limited training data and it affetcted the full exploitation of the algorithm. The system has an improved performance but with low computation speed.

Zhu *et al*. (2019) [37] developed an application of deep learning to Neuro-imaging techniques. The system has an accuracy of 0.76 and AUC value of 0.78. The results show that Deep learning algorithms have revolutionized computer vision research and driven advances in the analysis of radiologic images.

Sarvamangala and Kulkarni (2020) [20] worked on Convolution Neural Network (CNN) in medical image understanding using the the major medical image understanding tasks, namely image classification,segmentation, localization and detection. The system has low acuracy, low sensitivity, low AUC, low Discret Source Classifier(DSC) and low time taken or low performance.

Shoeibi *et al*. (2021) [30] developed an application of Convolution Neural Network techniques for automated multiple sclerosis desertion using magnetic resonance imaging. The methods were performed using MRI modalities and Deep Learning Techniques. The system has a high performance but faced with the chalenges of datasest and Deep learning (DL) techniques, there was similarity in lession intensified and CSF difficulty segmentation.

From the literature, it is evident that there is need for a system that will improve the convolution neural network performance through optimization of its hyper parameters. Table 2.1 shows the review of related works. This research is expected to assist in increasing the rate of detection of stroke by developing an optimized Convolution Neural Network based Gravitational Search Algorithm (CNN-GSA) thereby, increasing the survival rate of stroke patient.

Methodology

The first stage is to acquire data, MR images were retrieved from kaggle.com which is a publicly available database and the retrieved images were preprocessed by removing the noise, normalizing image contrast and increasing the quality of image. Median filter and image enhancement technique were used for preprocessing. Then the preprocessed images were segmented by using garbor filter segmentation technique. Gravitational Search Algorithm (GSA) were used to assign optimal weight parameters for the Convolution Neural Network (CNN) which were used for feature extraction and classification. The developed technique was implemented. The optimized Convolution Neural Network (CNN) were used for training and classification for the stroke detection. The detection system was evaluated based on precision, sensitivity, specificity, false positive rate, recognition accuracy and computational time and the performance of the CNN – GSA was compared with CNN.

This research makes use of the online MRI datasets from kaggle.com which is a publicly available database. The dataset contains five thousand (5000) samples in which three thousand and one hundred (3,100) are normal images, the seventy percent (70%) of the normal images is two thousand, one hundred and seventy (2,170) which is loaded into the train folder and the thirty percent (30%) is nine hundred and thirty (930) which is loaded into the test folder. The abnormal images are one thousand, nine hundred (1,900), the seventy percent (70%) of the abnormal images is one thousand, three hundred and thirty (1,330) which is loaded into the train folder and the thirty percent (30%) is five hundred and seventy (570) which is loaded into the test folder. Gravitational Search Algorithm was used to select CNN optimal weight parameters and was used as feature extraction and classification.

The developed system was implemented by using MATLAB 9.8 (R2020a), which was run on Hewlett-packard (pavilion g8) with intel ® core^{TM}i5-3230m, Windows 10, 64-bit operating system, Central Processing Unit (CPU) with a speed of 2060GHZ, 10GB Random Access Memory (RAM) and 512GB hard disk drive. The workflow and flowchart of this research is shown in figure 1 and 2 respectively.

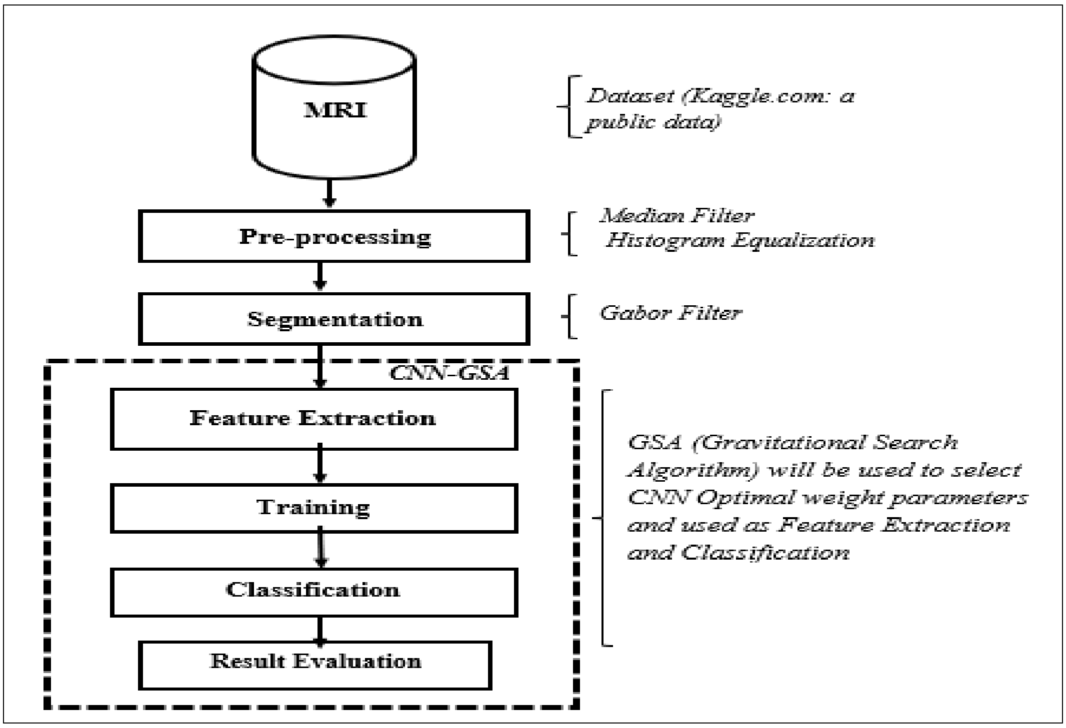

Fig 1: The workflow of the Neuro Vascular Disease (stroke) Detection System

Results and Discussion

The detection of neurovascular disease (stroke) was achieved using the existing system and the developed technique, there is improvement on the performance of the developed technique compared to the existing system. The datasets Contains five thousand samples (5000), three thousand, five hundred (3500) were loaded into the train folder while one thousand, five hundred (1,500) were loaded into the test folder.

Table 4.1 shows the result of the existing system (CNN) while table 4.2 shows the result for the developed technique (CNN-GSA), the True Positive (TP), False Negative (FN), False Positive (FP), and True Negative were derived for each classification by using confusion matrix. False Positive Rate (FPR), Accuracy (ACC), Sensitivity which is also Recall, Precision and Specificity and computational time were computed using the formula for the evaluation metrics that was earlier explained. The type and Threshold for each type of classification were also shown.

The method (CNN) is chosen first in which CNN-GSA was subsequently chosen. The MRI image were preprocessed and segmented and then classified. A total number of three thousand, five hundred (3500) images were used to train the system. Optimized Convolution Neural Network (CNN-GSA), technique was developed in order to get a higher accurate system that will rightly detect stroke in Magnetic Resonance Images. Tables 4.1 and 4.2 shows the contingency table for Normal/stroke classification phase of Magnetic Resonance Images for CNN and CNN-GSA respectfully. A total of one thousand, five hundred (1500) magnetic resonance images were used to test the developed technique (CNN-GSA) in which nine hundred and thirty (930) were normal images while five hundred and seventy (570) images were stroke.

Table 1: Results for Convolution Neural Network Algorithm

TP	FN	FP	TN	FPR (%)	ACC (%)	RECALL (%)	PREC (%)	SPEC (%)	time(sec)	Threshold	Tech	Type
266	19	26	259	9.122807	92.10526	93.33333	91.09589	90.87719	95.8326	0.25	CNN	stroke
253	17	24	246	8.888889	92.40741	93.7037	91.33574	91.11111	78.13225	0.25	CNN	normal
265	20	24	261	8.421053	92.2807	92.98246	91.6955	91.57895	95.8326	0.35	CNN	stroke
252	18	22	248	8.148148	92.59259	93.33333	91.9708	91.85185	78.13225	0.35	CNN	normal
264	21	22	263	7.719298	92.45614	92.63158	92.30769	92.2807	95.8326	0.5	CNN	stroke
251	19	20	250	7.407407	92.77778	92.96296	92.61993	92.59259	78.13225	0.5	CNN	normal
263	22	19	266	6.666667	92.80702	92.2807	93.26241	93.33333	95.8326	0.75	CNN	stroke
250	20	17	253	6.296296	93.14815	92.59259	93.63296	93.7037	78.13225	0.75	CNN	normal

Table 2: Results for the developed technique (CNN-GSA)

TP	FN	FP	TN	FPR (%)	ACC (%)	RECALL (%)	PREC (%)	SPEC (%)	time(sec)	Threshold	Tech	Type
279	6	14	271	4.912281	96.49123	97.89474	95.22184	95.08772	55.37609	0.25	GSA-CNN	stroke
266	4	12	258	4.444444	97.03704	98.51852	95.68345	95.55556	53.80195	0.25	GSA-CNN	normal
278	7	11	274	3.859649	96.84211	97.54386	96.19377	96.14035	55.37609	0.35	GSA-CNN	stroke
265	5	9	261	3.333333	97.40741	98.14815	96.71533	96.66667	53.80195	0.35	GSA-CNN	normal
277	8	8	277	2.807018	97.19298	97.19298	97.19298	97.19298	55.37609	0.5	GSA-CNN	stroke
264	6	6	264	2.222222	97.77778	97.77778	97.77778	97.77778	53.80195	0.5	GSA-CNN	normal
276	9	6	279	2.105263	97.36842	96.84211	97.87234	97.89474	55.37609	0.75	GSA-CNN	stroke
263	7	4	266	1.481481	97.96296	97.40741	98.50187	98.51852	53.80195	0.75	GSA-CNN	normal

From Table 1, it is showed that the standard CNN based system gave False Positive Rate (FPR) of 7.83%, recognition accuracy of 92.57%, sensitivity of 92.98%, precision of 92.24%, specificity of 92.17% and computational time of 86.98 seconds. From Table 2, it showed that the developed technique gave False Positive Rate (FPR) of 3.15% in detecting stroke, it also gave an accuracy of 97.26% and sensitivity of 97.67%. The results also showed that the developed technique gave the precision and specificity of 96.89% and 96.85% respectively. The computational time is 54.59 seconds.

Table 3: Comparison Summary

Evaluation	CNN-GSA	CNN
False Positive Rate	Very low	low
Accuracy	Very high	high
Sensitivity	Very high	high
Precision	Very high	high
Specificity	Very high	high
Time	very low	high

Conclussion

This thesis developed an optimized convolution neural network technique for detection of stroke in magnetic resonance images. The developed technique (CNN-GSA) overcame the existing one (CNN), in terms of high False Positive Rate (FPR) and low searching accuracy. The design and implementation in MATLAB of the developed technique were discussed in this research. The developed technique has not only demonstrated an improvement in accuracy, sensitivity, specificity and computational time but also proven that it can efficiently detect stroke in magnetic resonance images. Radiologist can use the detection system as a second opinion, which will greatly improve diagnosis of the neurovascular disease in order to reduce stroke mortality rate.

Future work might include application of the developed technique to detect other type of neurovascular disease. It can also be used to detect a particular type of stroke (ischemia or hemorrhage). In addition, GSA can be used to optimize other machine learning algorithms because of its high-performance rate. In view of that, the detection system can be adopted by radiologists for quick detection of stroke, which will reduce the mortality rate of the patients.

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