DEEP LEARNING TECHNIQUES IN MEDICAL IMAGE PROCESSING– A SURVEY

Bhagyashree Rajendra Gaidhani, Dr. R. Rajamenakshi, Samadhan Sonavane
Post Graduate Scholar, Principal Technical Officer, Assistant Professor
Sandip University, Nashik, India, CDAC ,Pune, India, CDAC, Pune, India, Sandip University, Nashik

Abstract: Imaging in medicine is used from diagnosis to treatment in a variety of ways. This paper presents a comprehensive survey of the medical image processing using computational intelligence techniques applied on MRI images for detecting Brain stroke in patients. The stroke is due to the clot and rupture in the blood vessel that carries blood. According to WHO reports, stroke stands second that causes death and disability worldwide. Early diagnosis and treatment in time can save patients and allow them to lead normal thereafter. Need for a fast and reliable method to detect anomalies will prove beneficial. This paper presents analysis of previous work in medical image processing, a comparative study of techniques applied based on features set used and accuracy and the gaps that exists.

Index Terms **- Medical Image Processing, Brain stroke, CT/PET/MR, deep learning**

I. INTRODUCTION

Brain Stroke is the second leading cause of mortality worldwide and the major cause of long term disability in adults [1]. The term "stroke" encompasses both ischemic and hemorrhage disturbances of the cerebral circulation producing central neurological deficits of acute or sub-acute onset. Ischemia accounts for 80 to 85% of stroke hemorrhage for 15 to 20%. Figure 1 presents WHO statistics of death rate due to brain stroke. It is necessary to understand the type of stroke and the nature of treatment that is required at times of emergency. The hemorrhagic strokes that are due to bleeding around the brain that is caused due to weakening of the very small arteries in the brain and blood pressure. The effects of a stroke are unique to every patient, and recovering from a stroke is different for each person. However, it's important to remember that anyone who displays stroke-like symptoms needs immediate care. X-Rays, CT, MR and PET are commonly used imaging modalities for diagnosis. The doctors, IT professionals and researchers have looked into the problem and to provide solutions to detect and to provide treatment during the needy hour.

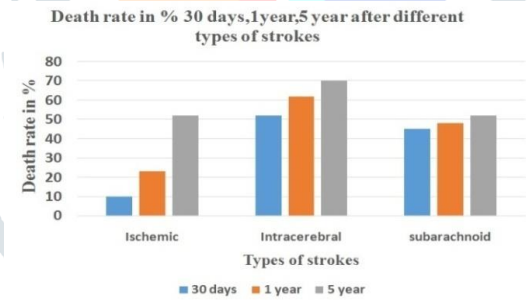

Figure 1. Death rates due to different types of Brain Strokes

Imaging in medicine is used in timely diagnosis and treatment in patients.
This article presents an overview and survey of medical image processing and analysis, details the gaps and presents an overview of the use of deep learning in identifying anomalies more precisely. Section 2 presents survey in medical image analysis section 3 presents overview of deep learning techniques Section 4 presents brain stroke related work and section 5 presents conclusion and future work.

II. STATE OF ART AND SURVEY IN MEDICAL IMAGE ANALYSIS

Biomedical image analysis has great significance in the field of medicine especially in clinical study. Interpretation of medical image analysis is a tedious task and the results might vary person to person, depending on experience. Hence to overcome this we aim to design the computer aided system to understand image structure and diagnose the disease in timely fashion with more accurate results. This will also add into active research in medical field using the medical images. Improvement in medical image quality, advances in computer hardware and software all have direct impact on medical image analysis. Medical images are multidimensional and produced with different imaging modalities. The accurate medical image interpretation and analysis require software for visualization and human computer interaction. This section presents a discussion on image processing in medicine.

A. STEPS IN MEDICAL IMAGE PROCESSING

Medical Image Processing includes series of steps before actual analysis and classification. It begins with Image acquisition and storage, image pre-processing, enhancement, image segmentation, feature extraction leading to analysis and classification.

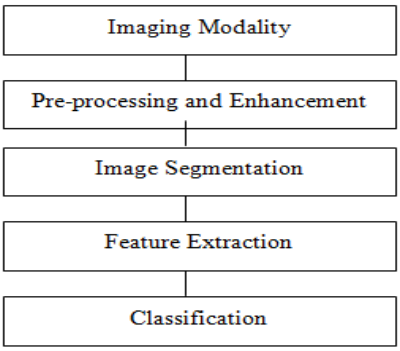

Figure 2. Image processing flow

IMAGE ACQUISITION

The medical images are captured and stored in standardized DICOM files and these images reside in PACS systems of imaging laboratories and hospital repositories. DICOM [26] files are structured files that carry patient's related details along with imaging details. A variety of image processing techniques are used in identification and classification that precisely delineates anomalies. They are also used in visualizing internal organs. Table I presents a list of existing open source tools and libraries.

Table I. Existing Tools

Software Name	Description
NAVEGATIVM	Supports intuitive touch interface, support for x-ray projection and volume reconstruction 3D
Santesoft	Popular DICOM viewer and editor and that supports various imaging modalities
MicroDicom	Free DICOM viewer in Windows platform that supports converting of DICOM image files into other formats such as JPG, GIF, PNG, TIFF etc.
RadiANT	DICOM viewer having supports window level setting for different target regions of DICOM CT (bone, lungs etc.)
3D slicer	A medical image analysis tool that supports multi-organ and multimodality imaging and analysis

IMAGE PREPROCESSING AND ENHANCEMENT

Image preprocessing is a technique to convert extract useful information from image and perform operation on it. Image preprocessing include filtering, color transformation, sampling etc.

IMAGE PREPROCESSING

Filtering techniques are used in enhancing the quality of the images and helps in removing noise that exists. In this filtering techniques, sobel and prewitt filtering are used to detect edges from images. The coefficient mask of sobel operator are not fixed and they can be adjusted according to our requirement, median filter is used to replace each pixel with median, remove salt and pepper noise and keep the sharpness of edges while removing noise, canny edge operator is used to remove any noise from image, it uses non-maxima suppression method for edge thinning, mean filter is used to replace each pixel with the average value of intensities in the neighborhood, wiener filter is used to calculate minimum mean square error between predicted and original image, homomorphic filtering is used to remove shading effects and separate illumination and reflectance pixel value of images. It is used to eliminate contrast variation. Homomorphic filtering is used to remove multiplication noise from image. A set of image filtering techniques are as shown in the Figure 3.

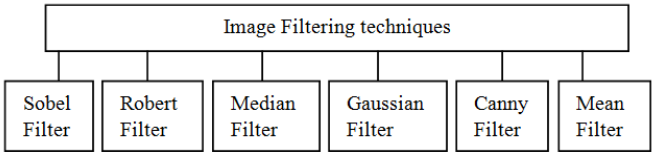

Figure 3. Image Filtering Techniques

IMAGE ENHANCEMENT

Image enhancement techniques are classified as spatial domain and frequency domain methods. Image enhancement is a operation to improve image quality. Some of image enhancement techniques are filtering, sharpening, contrast enhancement, point processing etc. In this image enhancement, point processing is used for contrast enhancement. Point processing is done on single image pixel and darken the particular level pixel and produced higher contrast image, histogram visualization is used to visualize pixel intensities in images, adaptive histogram equalization compute several histogram corresponding to each region of image using transformation function (cumulative distribution function) of pixel value in neighborhood. In frequency domain method Fourier transform of image is taken, multiply with filter and take inverse transform of image to produce enhanced image. The image enhancement techniques are shown in Figure 4.

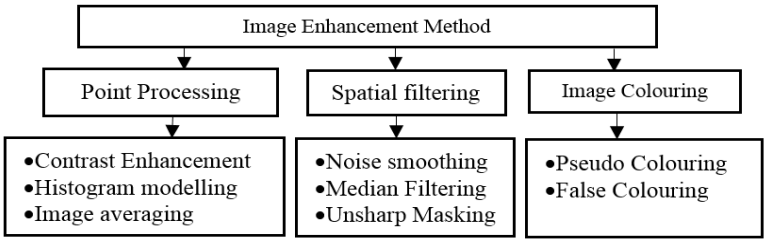

Figure 4.Image Enhancement Techniques

IMAGE SEGMENTATION TECHNIQUES

Segmentation is used to divide the image into different parts. Segmentation method takes threshold value to divide image into different parts [5]. Image segmentation techniques are threshold based segmentation, edge based segmentation, region based segmentation, clustering based segmentation etc. In threshold based segmentation, pixel are distributed to categories according to range of values in which pixel lies. Pixel with value less that 128 are belong to one category and other belong to different category. The adjacent pixel with different categories has been superimpose on white in original image, In edge based segmentation, edge filters are applied on images to detect edges, In region based segmentation seed value is selected based on the seed value pixels which have similar values are grouped together and splitting group of pixel which have dissimilar values. The image segmentation techniques are shown in Figure 5.

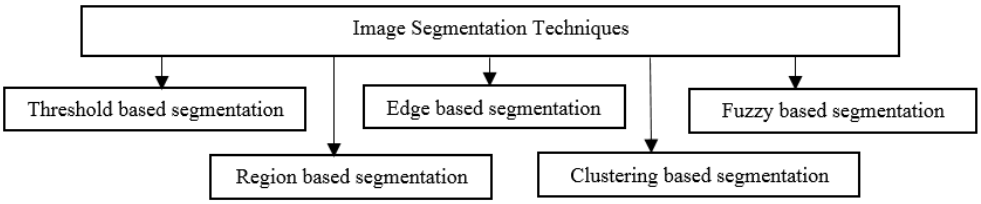

Figure 5.Image Segmentation Techniques

MACHINE LEARNING TECHNIQUES

Machine learning is a branch of artificial intelligence to design intelligent systems. It is used for fast processing, real time prediction, solves complex problems and provide better solution. Types of machine learning are supervised learning, unsupervised learning, reinforcement learning and anomaly detection. Supervised learning uses labelled dataset which contain target variable (dependent variable) and this variable are predicted from set of independent variable. The example of supervised learning are regression, decision tree, random forest, k-nearest neighbor, logistic regression, naïve bayes, support vector machine etc. Unsupervised learning do not used target variable which uses clustering approach to group similar data in one category and dissimilar data in another category. Reinforcement learning is a class of machine learning where agent learns based actions using trial and error basis. Reinforcement learning learns from past experience and capture best knowledge to make accurate decisions. The example of reinforcement learning are Markov Decision Process. The machine learning techniques are shown in Figure 6.

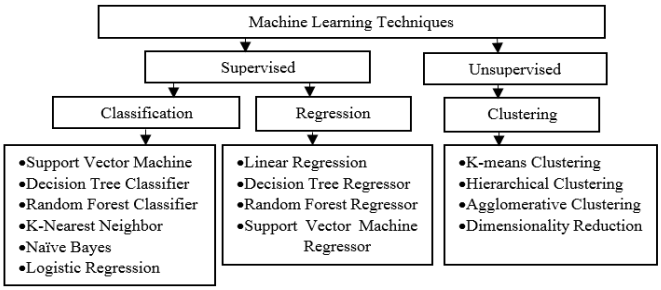

Figure 6. Machine Learning Techniques

Figure 5 presents a set of machine learning techniques that are available and used in analysis in different domains. Machine learning also used in biomedical field, computer vision, computer-aided diagnosis. Machine learning is mainly used for fast processing and real time prediction. It solves the complex problems and find the best solution. But in machine learning we have to extract features manually and we have to break down the problem statement into different parts, process first part and then combine results, so it takes more time to train the model.

B. REVIEW OF BRAIN TUMOR DETECTION

For brain stroke related survey we initially studied how to detect brain tumor from medical images and how different features extraction, segmentation and classification techniques used to detect abnormality in brain. Earlier image processing techniques used for feature extraction, segmentation and for classification machine learning technology used. This section gives overview of different classification techniques used in brain tumor detection mention table IV.

Khurram Shahzad [5] proposed a method to detect brain tumor using different image processing techniques. The Gaussian low pass filter and morphological operation are used for thresholding and for removing noise. The feature extracted in this paper are region, location, edge, area etc., and accuracy obtain is 80%.

Prof. Swati Kulkarni, Prof. Akshata Raut [6] proposed a system to detect tumor using image processing techniques and calculate area of tumor. The features used in this paper are size, edge, location and contrast, local and global thresholding used for segmentation. The accuracy obtain is 75%.Different classification/clustering techniques used in some papers are mentioned in the Table IV.

Table IV. Classification/Clustering Analysis using machine learning Techniques

Author Name	Classification/clustering method used
Arun Kumar Ray[7]	Support vector machine used for classification
Shree, N. Varuna[8]	Probabilistic Neural Network classification method used for classification
Namita Mittal[9]	Two classification techniques are used namely, k-nearest neighbor, support vector machine
Hashim M. Mokhtar[10]	Fuzzy c-means clustering method to delineate brain tumors using MRI images
Dhanalakshmi. P[11]	K-means clustering algorithm to segment brain tumors
Dopido Inmaculada,et al. [12]	Decision tree classifier is used.

From this survey, we found that bleeding from brain tumor is cause of intracerebral hemorrhage and this amount of bleeding from brain tissue determine whether symptoms are dangerous or not. Bleeding in one region of brain causes neurological symptoms and sometimes it leads to paralysis and life threatening consequences. This helped us identify that if we detect this brain hemorrhage and blood vessel block automatically using recent technology then it would save life of patient. Because brain stroke is long term disability in patients. The problem is that if the patient fails to receive proper treatment as soon as possible, the stroke will cause long lasting and life threatening consequences. Therefore, if the doctor could determine the location of stroke in the early stages of the disease, the doctor will be able to develop a suitable treatment guidelines to assist the patient. In general, before carrying out special treatment of stroke, patients will first have CT or MRI, after the treatment the doctor will then decide according to the results. But the accuracy of diagnostic strategy depends on the experience of radiologist. The lack of experience causes some mistakes. It should be noted that the diagnosis and treatment at an hour can recover the patient completely. We are presenting new state of art of deep learning techniques that are capable of detecting stroke and intend of same and it will be helpful to doctor. In this section we will see deep learning techniques for classification and segmentation and work related to brain stroke.

III. OVERVIEW OF DEEP LEARNING TECHNIQUES IN MEDICAL IMAGE ANALYSIS

Medical imaging techniques, include computed tomography, magnetic resonance imaging, PET are used for diagnostic disease. With the advancement in machine learning, deep learning plays vital role in computer assisted diagnosis (CAD) and computer-assisted medical image analysis. Deep learning is a subset of machine learning in artificial intelligence, where the algorithm are inspired by human brain, learn from large amount of data. It uses layered architecture for building computational models and perform automatic features extraction from data in order to solve intricate problems. Deep learning uses in many fields such as image recognition, image segmentation, natural language processing [14].

A. FEED FORWARD NEURAL NETWORK:

Deep learning provide multilayer approach where information flows through successive layer and there are no feedback connection in which output model are fed back into itself is called feed forward neural network and when feed forward neural network include feedback connection then it is called recurrent neural network. The feed forward neural network as shown in figure 7.

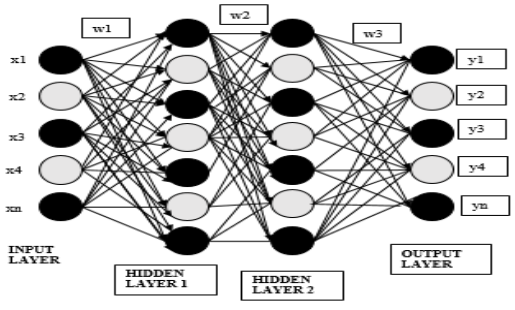

Figure 7. Feed forward neural network

Deep learning mainly has four types, unsupervised pre-trained network, supervised neural network, recurrent neural network, recursive neural network.

B. SUPERVISED NEURAL NETWORK:-

Mainly supervised learning is used for classification and regression. Model is trained on labelled dataset. The type of deep learning supervised neural network is convolutional neural network. This section presents details on CNN, a type of supervised neural network. The architecture of CNN is mention in Figure 8.

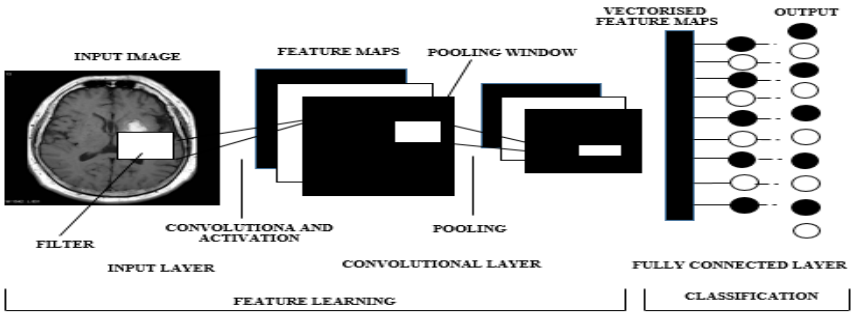

Figure 8.Convolutional Neural Network Architecture

Convolutional Neural Network (CNN) a type of supervised learning technique that is used for classification and to process huge amount of data such as images. This is composed of four layers namely convolution, activation layer, pooling and fully connected layer in which convolution and pooling used for feature extraction [17].This automatically extract features and fully connected layer mapped these extracted features and give classification [16].This techniques is mainly used in image classification, image recognition, face recognition etc. by assigning pixel into different categories or classes. Recently, CNN used in medical image analysis (MRI, CT, PET, USG etc.) for classifying different brain activity, classifying different diseases, classify whether image contain abnormality or not [13]. Tables V and Table VI presents a set of hyper parameters and architectures used in CNN.

Table V. List of parameters and hyper parameters used in convolutional neural network

	Parameters	**Hyper parameters**
Convolutional layer	Kernels	Kernel size, filters, activation function, stride, padding
Pooling layer	None	Pooling methods , stride, padding
Fully connected layer	Weights	Number of weights, activation function
Others	Optimizer	Learning rate, loss function, accuracy, epoch, batch size, early stopping, dataset splitting, and regularization.

Table VI. CNN advanced architecture

CNN Model	**No. of layer**	**No. of parameters**
LeNet	7-layer	60 thousand
AlexNet	8-layer	60 million
VGGNet	16-layer	138 million
GoogLetNet/Inception	22-layer	4 million
ResNet	132-layer	25 million

Table VII. Application Of Convolutional Neural Network in Medical Image Analysis

Method used	Image modality	Objective	Accuracy	Reference
Convolutional Neural Network	CT	Classification of lung cancer into benign, malignant, metatastic	76%	Prajwal Rao[2016]
Regional convolutional neural network	CT	Detection and classification of lung abnormalities using (R-CNN)	95%	Shoji Kido[2018]
DenseNet	CT	Classification of lung nodules using 3D neural network	90%	Raunak Dey[2018]
VGGNet, ResNet	Mammography	Abnormality detection in mammography using CNN	92%	Pengcheng Xi[2018]
CNN	Mammography	Breast cancer detection using CNN	65%	Saira Charan,

C. UNSUPERVISED NEURAL NETWORK:-

Unsupervised learning used for clustering, dimensionality reduction, representation learning and density estimation. In unsupervised learning, all the data is unlabeled and algorithm divides data into different regions and group similar data on the basis of underlying features and algorithm learn to identify patterns from data [26]. Some of the unsupervised deep learning model used in medical image analysis as mentioned in figure 9.

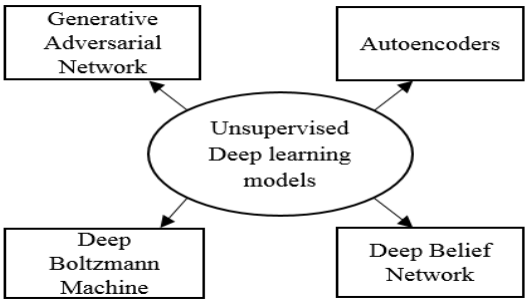

Figure 9. Deep learning supervised neural network

The architecture of unsupervised neural network are described below:-

1)**AUTOENCODERS:-**

Autoencoder is unsupervised feed forward neural network where input is same as output. It is use in dimensionality reduction technique. It is unsupervised means it does not require explicit labels it automatically learn labels from images. Auto encoder has three parts namely, encoder, code and decoder where encoder compress input image and produces the code, the decoder reconstructs image into original form. The architecture of auto encoder is mentioned below figure 10.

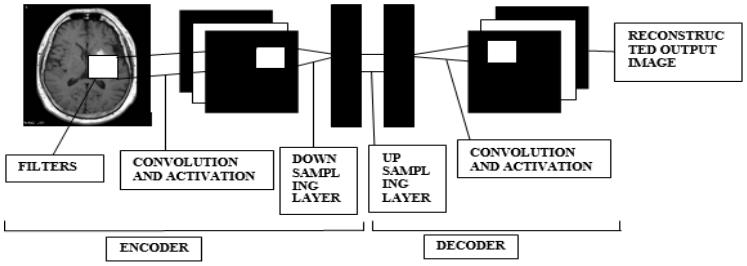

Figure 10. Auto encoder Architecture

Table VIII. List of hyper parameters used in unsupervised neural network

Hyper parameters	Description
Number of layers	The number of input and output layer in encoder and decoder part
Code size	Number of hidden layer
Number of nodes per layer	The number of nodes of each encoder and decoder layer for reconstruction of image
Loss function	Use mean squared error or binary cross entropy for calculation of loss.

Table IX. Application of Unsupervised Neural Network in Medical Image Analysis

Method used	Image modality	Objective	Accuracy	Reference
Stack sparse autoencoders	Mammography	Detection of irregular shape(Nuclei detection) on breast cancer	88.8%	Jun Xu[2016]
Deep auto encoders	CT	Classification lung cancer using benign and malignant	92%	Ahmed Shaffie[2018]
Stacked auto encoders	Mammography	Classification of breast cancer into benign and malignant	98.25%	Yawen Xiao[2018]

D. SEMANTIC SEGMENTATION IN DEEP LEARNING

Semantic segmentation is a process of giving label to specific region of an image at pixel level. It is important application in image processing and computer vision. It is also called as pixel-level classification. Semantic segmentation widely used in medical field such as segmentation of brain tissue and tumors. One of the most common image segmentation is the segmentation of gray matter(GM), white matter(WM), cerebrospinal fluid(CSF).To provide automatic segmentation deep learning techniques are used[18].

1) U-NET

U-Net is used for segmentation of biomedical images. It is built upon fully convolutional network. It has 3 different parts the contracting/down sampling path, bottleneck and expanding/up sampling path [19]. The architecture of U-Net is mentioned in figure 11.

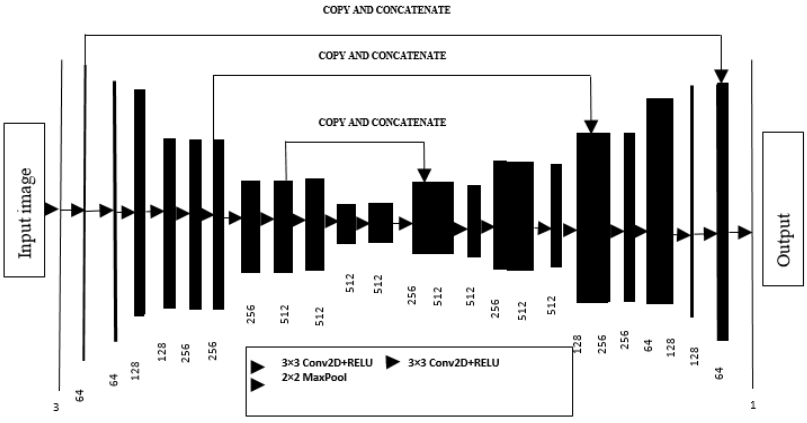

Figure 11. U-Net Architecture [19]

The recent state of art of model follows U-Net structure of feature extraction followed by multi-scale processing. Some of the segmentation model used for medical image analysis are mention in Table VII.

Table VII. Deep learning segmentation models

Author	Deep learning model	Description
Tobias & Alexander (2016)	Full-resolutional Residual Network	FPRN has two streams, pooling stream and residual stream. Pooling stream down samples features and handle high level semantic information whereas residual stream handle low level semantic information. At the last layer FPRN combines two stream feature maps.
Jianping & Jiaya(2017)	Pyramid Parsing Network (PSPNet)	PSPNet uses four different max-pooling layer with four different window sizes and strides and captures feature information from four different scales. After each convolutional step it up samples feature map at same resolution concatenates them all
Simon & David(2017)	Fully Convolutional Dense Net (FCDenseNet)	FCDenseNet uses 4 dense block of layers. A first layer create feature maps then concatenate to the input. This operation is repeated four times and finally output is the concatenation of 4 layers.

IV. BRAIN STROKE DETECTION TECHNIQUES

Chiun-Li Chin proposed an automated early ischemic stroke detection system using CNN deep learning. They use CT image. The method of this paper is divided into four stages such as Pre-processing, Analyzing and removing CSF, Data Augmentation and passed all the images to the convolutional Neural Network. In pre-processing they remove the skull and keep the brain tissue because the CT device near the skull are not stroke area. So they used Otsu thresholding algorithm to separate brain tissue and stroke area. To avoid problem of over fitting, they used data augmentation to increase the amount of images. And passed that images to the convolutional neural network and they got the accuracy of 90% [20].

Tran Van Hoa published paper on brain haemorrhage diagnosis using deep learning. The brain haemorrhage images used in this paper are DICOM format. They used normal and abnormal images (brain hemorrhage) for classification. Paper used three convolutional neural network model such as LeNet, GoogleNet, and InceptionResNet and compare their accuracy and training time required for each model. By comparing this three models, LeNet is most time consuming model as compared to GoogleNet and InceptionResNet. In terms of accuracy the GoogleNet gives 99% accuracy as compared to other two models [21].

R. Punitha Lakshmi published paper on voxel based lesion segmentation through SVM classifier for effective brain stroke detection. Paper used MRI images and used GLCM for features extraction. Otsu thresholding use for image segmentation and extracted features are given input to support vector machine and then SVM classifier identify type of stroke. Accuracy got is 80% .The limitation of this paper is that they use small dataset. Because of using small dataset the system got low accuracy [22].

Dr.Satish Devane proposed method to diagnose and classification of brain haemorrhage. Paper classify brain haemorrhage into Intracerebral Haemorrhage, Subdural haemorrhage, Extradural Haemorrhage, Subarachnoid haemorrhage. In pre-processing steps, images converted into grayscale image and detect edges. Perform morphological and watershed algorithm used for image segmentation. Feature extracted using GLCM are energy, entropy, standard deviation, covariance. This features are given to input to artificial neural network for classification. But this system classify only two types of brain hemorrhage correctly [23].

R. B. Patel published paper on Performance evaluation of segmentation methods for brain CT images based haemorrhage detection. For haemorrhage detection performance of segmentation methods namely thresholding fuzzy clustering, active contour method and region growing methods are evaluated and the results of this methods are compared on the basis of manually delineated haemorrhage. By comparing results, thresholding gives less accuracy and active contour method gives more accuracy as compared to other three methods. But the method used in this paper are not fully automatic [24].

K. SUDHARANI present paper on brain stroke detection using k-nearest neighbour and minimum mean distance technique. This paper classify irregularity of brain haemorrhage. Used LabVIEW software for estimating identification score and classification score. The distance metrics used for classification methods are Euclidean, within sum of square to calculate classification score and stroke area. The Euclidean and within sum of square method give less classification score as compared to k nearest neighbour and minimum mean distance technique[25].

Table VIII. Comparison chart of deep learning techniques used in brain stroke detection

Author Name	Technique Used	Accuracy
Chiun-Li Chin[20]	Convolutional Neural Network on CT	90%
Tong DucPhong[21]	LeNet, ResNet, GoogleNet on CT	98%
R. Punitha Lakshmi[22]	Support vector machine On MRI	80%
Dr.Satish Devane[23]	Use GLCM for feature extraction for classification artificial neural network used on CT	80%
K. Sudharani[25]	Use K-Nearest classifier on MRI	75%
R. B. Patel[24]	Used fuzzy clustering on CT	76%

V. DATA SET

Medical imaging modality involve various techniques to diagnose human body. The major imaging modalities include CT (Computed Tomography), MRI (Magnetic Resonance Imaging), Ultrasound, X-Ray. This imaging modalities are used to visualize what is going inside human body. The overview of existing dataset is mention in Table IX.

Table IX. Overview of Existing Dataset

Dataset	Description
BRATS DATASET	Multimodal tumor segmentation dataset
REMBRANDT	A repository for molecular brain neoplasia data containing samples from glioblastoma, astrocytoma and Oligodendroglioma.
ISLES dataset	103 acute stroke CT images
BIOGPS	Ischemic stroke dataset
ATLAS	Contains Anatomical tracings of lesion after stroke 229 T1-weighted MRI scans

VI. CONCLUSION AND FUTURE WORK

This paper presents an overview survey of image processing and machine learning techniques and recent deep learning techniques used for both segmentation and classification. We also compared different imaging modalities to diagnose patient. The major cause of the high death rate is due to detection of brain stroke in late stages. To solve this we will design a computer aided solution that can be used to detect the abnormalities and identify the stroke region from MRI images of brain, using deep learning techniques to provide accurate and urgent treatment to the patients.

In future we aim to use MRI images to distinguish between normal and abnormal tissues more accurately. Our aim is to develop a fast and reliable method to detect abnormal tissue due to brain stroke at an hour from MRI images using deep learning and delineate that regions which could be useful for physicians and researchers involved in the treatment or investigation of brain stroke.

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