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A Comparative Analysis of Brain Tumor Classification and Prediction techniques by applying MRI Images encompassing SVM and CNN with Transfer Learning Method.

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Abstract

Brain tumor is a serious disease leading to a life-threatening condition when worsen resulting in brain cancer. With a rapid fall in 5-year survival rate, brain cancer is the root cause for a large number of deaths worldwide. Diagnosis of brain tumor and detection of nature of cancer with higher accuracy at earliest possible stage is very important for proper treatment that will help patients have a better chance of surviving the disease. As per our study in this paper we conducted comparative research on various machine learning methods for detection of brain tumor at an early stage using Magnetic Resonance Images (MRI). MRIs is one of the most preferable diagnostic techniques for Brain Tumor image diagnosing as it gives more detailed images of the brain structures and blood vessels without using ionized radiations and any physical movement of the patient. This paper majorly focuses on a comparative analysis of various approaches for classification and detection of brain tumor and at last analysing the recent best technique. The process of detection followed in research till date follows Image Pre-Processing, Image Segmentation, Feature Extraction, and Support Vector Machine Classification. Various sources of datasets have been used that includes limited amount of MRI Images. Our analysis is also focused on the limitations and shortcomings of current algorithms. Thus, by comparing various researches, we summarized that when support vector machine (SVM) was used to classify brain tumor images, accuracy was trustworthy for patients but usage of limited amount of dataset reduced the essence of the prediction as using larger dataset can surely bring worthy conversion. We sum up that CNN with Transfer Learning model when used for brain tumor detection increase the reliability of prediction as this model when used with Paediatric Pneumonia detection and Covid-19 detection

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gave impressive results with increased dataset volume, resulting in early detection of disease and rapid treatment. Thus, for better results, classification and detection of Brain Tumor using CNN with Transfer Learning will be a good option.

Keywords: CNN with Transfer Learning, Magnetic Resonance Images (MRI), Brain Tumor.

1. Introduction

A major life-threatening disease Brain cancer has been a rapidly growing disease that can be detected with a presence of a brain tumor in human brain. Brain tumor is a lesion mass of abnormal tissues and cells in the brain. In most of the cases the root cause of the tumor isn't clear but some risk factors such as radiations from mobile phones and those present in environment may cause the body cells to change their form, some may state that defective growing of genes may cause cells to grow uncontrollably resulting in a tumor. Stated as a rapidly growing disease, brain tumor causes a serious health condition including symptoms such as headache, seizers, body paralysis and if left untreated in worse cases leading to death.

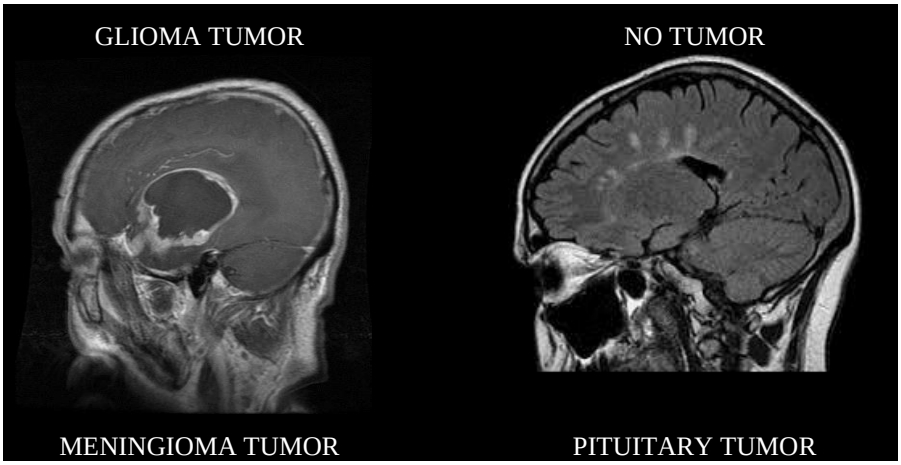
According to a survey by National Library of Medicine the overall 1-year relative survival estimate described from time of diagnosis is 67.8%. When compared to the relative 6-month survival rate the estimate is 85.7%. With very low chances of long-term survival the 5-year relative survival estimate derived from time of diagnosis is 3.6% [1]. As per the survival rates the solemnity of the disease is firmly determined. Affects caused on the functioning of the nervous system totally depends on the growth rate as well as location of the brain tumor. Cerebrum, Cerebellum and brain-stem are the major constituents of the brain and brain tumor located in different regions of brain has distinct effects on the human body. Brain tumours are classified as Benign and Malignant. Benignancy of a tumor states that the cells are not cancerous hence non-cancerous tumor, while malignancy states cancerous cells are present in the tumor. Furthermore, Brain tumor can be divided into 4 parts based on the location, growth rates, and malignancy of the tumours i.e., (TYPE 1: Astrocytoma's, TYPE 2: Glioblastoma Multiforme, TYPE 3: Meningioma and TYPE 4: Pituitary tumours).

Type1: Occurring in the largest part of brain, Cerebrum, it is the most common type of brain tumours. Often referred as benign tumor.

Type2: Glioblastoma or GBM is considered as the most common and most aggressive type of primary brain tumor. Another name suggested to it is Gliosarcoma, which suggests the inclusion of harmful sarcomous cells in the tumor.

Type3: Meningioma tumours are primarily developed in membrane that surrounds brain and commonly found in women.

Type4: Pituitary tumours are a compound lesion mass that are formed in pituitary gland. Considered as benign, according to a survey by American Cancer Society only few hundred cases have been accounted for the same.



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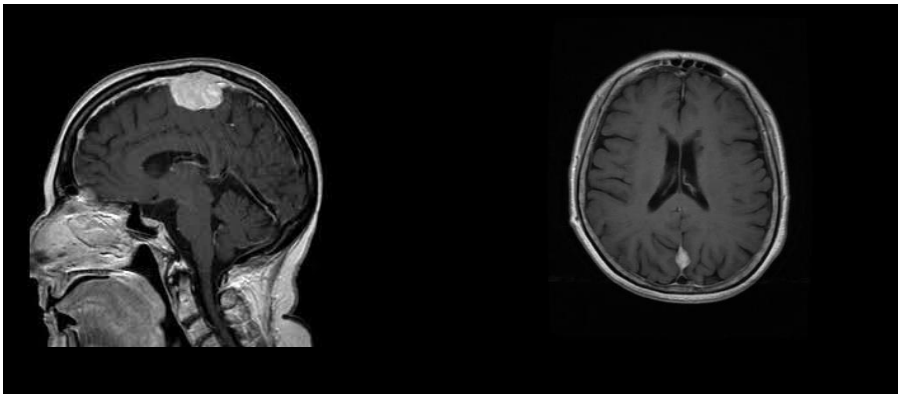

Figure 1: Comparison of tumor and no tumor image

Glioblastoma Multiforme has been designated Grade IV by WHO and it accounts for 50% of all glioma tumours in all age groups [2]. Being mitotic in nature, the growth rate of the tumor certainly affects the patient's health thus reducing the life of the patient. With a survival rate of 14 to 15 months after diagnosis makes it a crucial health issue for the patient [3].

According to research conducted by American Society of clinical oncology, the cases for brain tumor have been rapidly increasing. As per the results an estimated 25050 adults (14170 men and 10880 women) will be diagnosed by primary cancerous tumours this year[4] . Another research by National Library of Medicine, states that incidences of central nervous system (CNS) tumours in India has reached 5 to 10 cases per 100,000 population. The report also indicates an increasing trend with raise in 2% of malignancies [5]. This predicts a 2% raise in cells being cancerous that results in more diagnosing more patients with Brain Cancer than past year in India. This rapid increase in growth rate of number of cases is a point of worry, thus early diagnosis and rapid treatment is the only medium to make an increasing difference in the survival rate for patients. Over the range of time the techniques of diagnosing brain tumours have evolved. The first step of diagnosing is detecting the early symptoms that are common and indicates occurrence of a brain tumor. These can be challenges in vision, hearing, strength, blood pressure etc. Now in medical science there are several imaging techniques that uses strong magnets or radioactive substances to create highly detailed pictures of brain.

Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scans are good to go for tumor imaging. In earlier times CT scan was considered majorly but as MRI gives far more detailed images without physical movement of patients and no use of ionized radiation. An MRI has an optimized version known as Perfusion MRI, where a special dye is pressed into the blood vessels resulting in more detailed and accurate brain tumor images. According to research by National Library of Medicine, accuracy of radiation diagnostic methods in brain tumor were compared with a dataset of 108 Brain tumor images for CT scan and 120 Brain tumor images for MRI. Results shows that 7 CT scans failed to match with the final results, while 5 MRI Scans weren't able to match with the original results. If compared, the sensitivity for CT scans were found only 0.73 while for MRI the sensitivity increased to 0.89 [6].

This clearly indicates that MRIs are preferable for Brain tumor imaging diagnosing, thus in this research paper we picked MRIs for comparison rather than CT scans for better detection and classification results as MRIs are certainly the best technique present. Once the imaging process has been completed and brain tumor has been diagnosed, there is another histopathical method for detection of presence of cancerous cells. This histopathy report is called, Biopsy, that takes a longer period of time for the results. Thus, it states that, even after diagnosing a brain tumor, to detect that presence of cancerous cells and to predict the nature of tumor is a time taking as well as costly process, that may delay the beginning of treatment as well.

Medical science just like any other field has stepped into automation process by developing systems capable of learning and taking decisions from previous data, this is known as Machine Learning [37], [40] .

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Thus, in this research paper we will compare MRI images and Contrast MRI Images using different machine learning models to rapidly predict the occurrence and nature of brain tumor in human brain. So, the treatment process can be commenced as early as possible.

2. Literature Survey

As per the definitions through the latest statistics from research, the patients diagnosed with malignant brain tumor and other central nervous system (CNS) are only 35% in case of men while the percentage increases for 36% when we talk about minimal 5 years of survival rate [7]. This states that occurring of malignant tumor is surely a life-threatening situation for patients. Back to the earlier times, to extract the features out of segmentation some hand-crafted techniques were used, these techniques also lead to the classification of those tumors rather than just segmentation. As the time changed for good, some rapid advancements came into existence in biomedical imaging technologies, MRI (Magnetic Resonance Images) took an insightful turn along with that, high resolution medical images such as contrast or enhanced magnetic resonance (MR) scan images are nowadays a vital tool for studying human brain anatomy and disease detection, e.g., brain tumor detection, Alzheimer's disease, multiple sclerosis and other neurological disorders [8]. As per the reports of CBTRUS Fig. 2., Support Vector Machine (SVM) has been used as a classifier for classification of type of tumors [9],[10],[11],[12],[13],[14]. By Zacharaki et. al the multiclass classification of different brain tumor grades was attempted, and the results suggested these grades, i.e., glioma grade II, glioma grade III, glioblastoma and metastasis using one versus all SVM voting scheme [15]. In research, the following classification of multiple brain tumor types are suggested such as: astrocytoma, glioblastoma multiforme, childhood tumor-medulloblastoma, meningioma, secondary tumor metastatic, and normal regions [16]. In this research the PCA-ANN approach concluded that highest overall accuracy achieved in order to classify was of 85.23% [16]. Thereafter multiple brain tumor types and grades classification using SVM (Support Vector Machine) had been proposed by [13].

As per the reports and conclusions an accuracy of 85% and 78.26% were achieved respectively when higher second order features were utilized. Jayachandran conducted a study regarding a multi class brain tumor was conducted that classifies tumors using hybrid structure and fuzzy logic-based pair of RBF kernel SVM. This classification achieved an accuracy of proposed system of meningioma as 98.6%, metastasis as 99.29%, gliomas grade II as 97.87% and gliomas grade III as 98.6% [9].

Thereafter brain tumor was classified into different grades and types as suggested by. An accuracy of 85% and 78.26% was achieved using higher order features for different types and grades [17]. The one of the major studies stated that combined wavelets and Gabor features are another way fir the classification of brain tumors and a tremendous accuracy of 95% was achieved in same [14]. Usage of Gray Level Co-Occurrence Matrix (GLCM) and Grey-Level Run Length Matrix (GLRLM) was suggested in a study and features of brain tumor images from MRIs were extracted to the greater extent that resulted in an enhanced accuracy of 95.80% and 87.50%, respectively for GLCM and GLRLM [9], [11].

A special approach was introduced by the authors that stated that using three texture and intensity feature sets and a specific use if Genetic algorithm was done to select some major informative features that gained a major breakthrough in the research resulted in a decent accuracy. Their results showed that using the proposed technique even SVM results an accuracy up to 83.22% that was a major achievement in brain tumor classifications [18]. Usage of discrete wavelets was also done that achieved an accuracy of about 86% [19]. In a research, discrete wavelet transforms were used for feature extraction and reported 96.7% accuracy [19]. Various research works thereafter, started targeting Neural Networks (NNs) for classification after manual extraction of features either by wavelets, matrices or any other classifiers [20], [21], [22], [23], [24]. Similarly, some researches in order to classify Brain tumors used Back Propagation Neural Network (BPN) [21], [23]. In the former research, authors used GLCM for features extraction and reported an accuracy of about 96.84% while latter decreased to 73% that used PCA for feature extraction [11]. Again, an important combination of Gabor and wavelets found a breakthrough and added up the accuracy to about 97% in [14]. This combination found to be an important point in the brain tumor classification.

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Again, a fuzzy c-means clustering was used to generate a feature vector and it was trained on Probabilistic Neural Network (PNN) and General Regression Neural Network (GRNN). After making a deep comparison in the accuracies it was found that PNN were better than GRNN as PNN resulted in the higher accuracy of 97.29% while GRNN gave 96.31% of accuracy [24]. In a study, some different approaches were used in PNN for classification using some different feature extraction technique that are named as PCA and Wavelets Transforms, respectively [20], [7]. The approach showed that PNN with Wavelets combination achieved higher accuracy [20].

The authors used various Machine Learning algorithms with manual feature extraction techniques in [25], [22], [26]. These approaches marked out with accuracy of 98% that included KNN as a classifier and DWTs for feature extraction such as in [27]. An unsupervised approach is also proposed where the authors have used Stationary Wavelet Transform (SWT) for feature extraction. The segmentation was performed using self-organizing map (SOM) that is trained with unsupervised learning algorithm and fine-tuned with Learning Vector Quantization (LVQ). The results showed that average dice similarity indexes for tumor is 61% [28].

3. Comparative Survey

As discussed, and briefed about the overall scenarios about the existing scope of the classification, segmentation and detection details of different types and grades of brain tumor in human, we have looked into different research and studies that gives various tumbling accuracies [39]. With a rapid advancement in technologies from hand crafted to neural networks, from MRI and Enhanced MRI image segmentations to Gabor and wavelets transformations. As suggested in some studies, a SVM classifier was a breakthrough that could be used as a classification technique in Brain Tumor [9], [18], [11], [12].

Study	Year	Feature Extraction Technique	Classifier	Accuracy
[22]	2016	1st and 2nd order Features	SVM	85.00%
[14]	2015	Wavelets and Gabor Features	SVM	95.00%
[9]	2013	Gray Level Co-Occurrence	SVM	95.80%
[18]	2012	Texture and Intensity Features	SVM	83.22%
[11]	2017	Discrete Wavelet Transforms	SVM	86.00%
[12]	2015	Grey-Level Run Length Matrix	SVM	87.50%
[22]	2018	Discrete Wavelet Transforms	NN (1)	96.70%
[12], [29]	2016	Fuzzy C-means Clustering	PNN (2)	97.29%
[30]	2015	P Component Analysis	PNN	97.14%
[31]	2013	Wavelets Transforms	PNN	97.50%
[21]	2013	Gray Level Co-Occurrence Matrix	BPN (3)	96.84%
[23]	2013	Principal Component Analysis	BPN	73.00%

[14]	2013	Wavelets Transforms	ANN	90.00%
[28]	2015	Gray Level Co-Occurrence Matrix	KNN	96.15%
[17]	2010	Discrete Wavelet Transforms	KNN	98%

(1) Neural Networks
(2) Probabilistic Neural Networks
(3) Back Propagation Neural Networks
(4) Naïve Bayes

Table 1: Comparison of Algorithms

From Table.1., following stats can be predicted that when some 1st and 2nd order feature extraction techniques were used with SVM classifier an accuracy of 85% was obtained, and further different classifying techniques were added on with SVM classifier. In 2015, Wavelets and Gabor feature extraction was used that resulted in 95% of accuracy in brain tumor detection. Further Gray level Run Length matrix and Gray level co-occurrence matrix techniques were done by SVM and KNN respectively, GLRM with SVM gave 95.80% of accuracy, while GLCM with KNN gave 96.15% accuracy but their datasets tested and trained are different. With all this some advancement came and Neural Networks were further added with various feature extraction techniques, When Discrete Wavelet technique was used with NN, it gave 96.70% of accuracy, further fuzzy c-means clustering technique came into existence that in combination with PNN gave 97.29% of accuracy. Principal Component Analysis (PCA) technique was combined with PNN resulting in 97% of accuracy, GLCM was checked with BPN3 classifier, and it resulted in a accuracy of 96.85% of accuracy.

But when PCA and BPN classifier came together a sudden drop in accuracy was seen coming down to 73% only. Wavelets and Gabor feature extraction techniques were then used along BPN resulting in 97% of accuracy. Hence it can be said that SVM classifier is consistent along with many feature extraction techniques irrespective of the dataset and results, the accuracy levels are lying somewhere between 85 to 96, but when

Compared with Neural Networks, the accuracy took a rise to 97% in fuzzy c-means clustering but had a sudden drop to 73% with PCA feature extraction technique. Hence, it is concluded from the above comparative survey that although Neural Networks are giving higher accuracy with a margin of about 3 to 5 percent but with SVM classifiers the feature extraction techniques are working quite more efficiently in a maintained and an insightful manner.

Further as we see, All the neural networks have been working great with the SVM Classifier and CNN Model, but the dataset is generally to a confined amount i.e., only limited amount of dataset have been trained and model have been made. But as we see high accuracy with limited data is not good then high accuracy with more dataset. Thus, the author proposes to the new Transfer learning model with CNN and with SVM Classifier that not only give the higher accuracy but also uses the efficient and useful IMAGENET dataset. To cut short the process of data training that may take even weeks, author will reuse the model weights pre-trained models that were developed for standard computer vision benchmark datasets.

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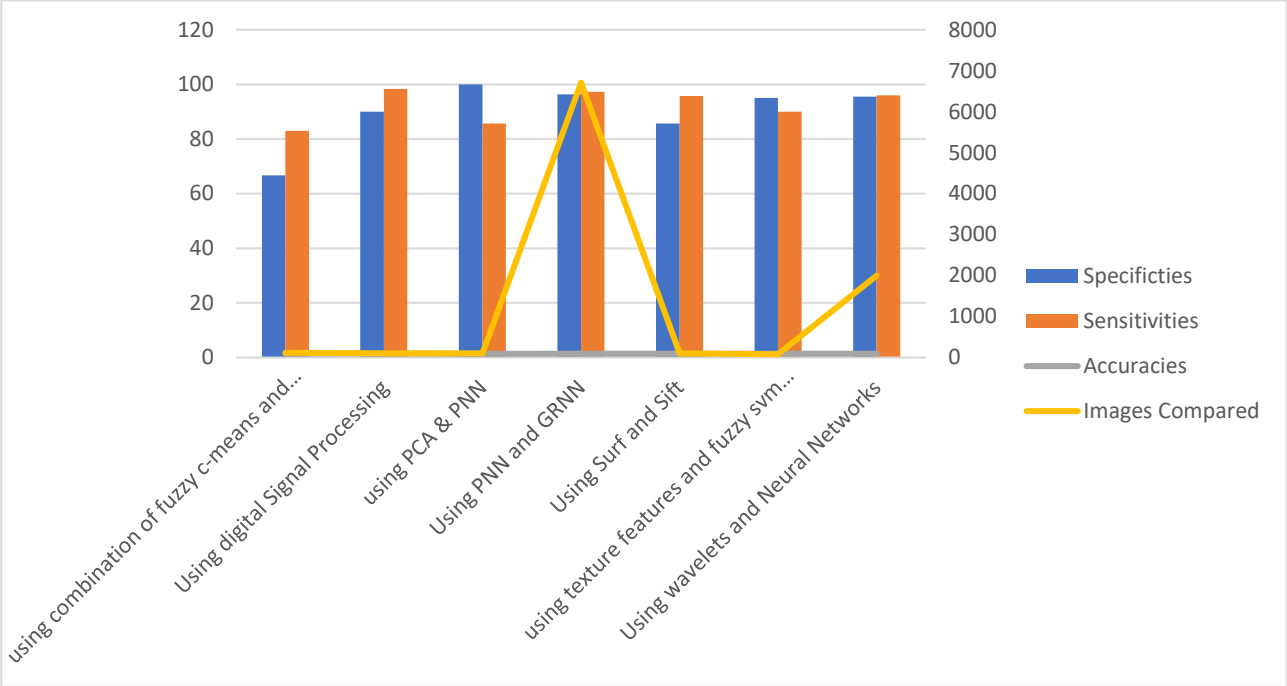

Graph 1: Comparing Sensitivity, Specificity, Accuracy & NO of Images

From the Graph 1, sensitivity, specificity, accuracy, and number of images have been compared for different algorithms used to classify and detect brain tumors.

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Author	Method Of Detection	Dataset	Problem Statement	Accuracy	Advantage	Year	Segmentation Technique	Feature Extraction Technique	No. Of Images
Endang Tri Hastuti, Alhadi Bustamam, Prasnurzaki Anki, Rizka Amalia, Amnia Salma	CNN	largest open-source dataset	Performance of True Transfer Learning using CNN DenseNet121 for COVID-19 Detection from Chest X-Ray Images [29]	98% accuracy	Transfer learning methods show better classification accuracy than traditional learning methods.	2021	System performance is measured from the level of accuracy by the use of transfer learning and the selection numbers of epoch and batch size parameters.	Transfer Learning model used in this research is DenseNet 121	1500
Chhaya Narvekar, Madhuri Rao	CNN	Not Applicable	Flower classification using CNN and transfer learning in CNN-Agriculture Perspective [32]	Not applicable	A flower classification can be used in various applications such as field monitoring, plant identification, medicinal plant, floriculture industry, research in plant taxonomy	2020	Not Applicable	VGG16, MobileNet2 and Resnet50	Not Applicable
Kyu-hong Hwang, Myung-jae Lee, Young-guk Ha	CNN	Real Time Application	A Befitting Image Data Crawling and Annotating System with CNN Based Transfer Learning [33]	97%	Offer a method to automatically generate training data by detecting objects and making object coordinates necessary for CNN learning at the same time.	2020	Convolutional Neural Network (CNN), collecting and training	Transfer Learning	Not Applicable
Nusrat Jahan, Arifatun Nesa, Md. Abu Layek	CNN	dataset consisting PD patient and Healthy (without PD) contro	Parkinson's Disease Detection Using CNN Architectures withTransfer Learning [34]	96.67%	Determines PD patients on the basis of fine motor symptoms using sketching	2021	CNN	Inception v3 and ResNet50	Unknown

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Gaurav Labhane, Rutuja Pansare, Saumil Maheshwari, Ritu Tiwari, Anupam Shukla	CNN	pediatric pneumonia dataset	Detection of Pediatric Pneumonia from Chest X-Ray Images using CNN and Transfer Learning [35]	97	Human assisted diagnosis has its own limitations like the availability of an expert, cost, etc and hence an automated method for the detection of pneumonia from x-rays is a necessity	2020	VGG16, VGG19	Inception V3	2992 pneumonia and 2972 normal chest xrays, tested using 854 pneumonia and 849 normal images
Ashek Seum, Amir Hossain Raj, Shadman Sakib, Tonmoy Hossain	CNN	(SARS-COV-2 CT-Scan)	A Comparative Study of CNN Transfer Learning Classification Algorithms with Segmentation for COVID-19 Detection from CT Scan Images [36]	88.60% as the F1 Score and 89.31% as accuracy is achieved by training DenseNet 169 architecture, U-Net segmentation method- F1 Scores as 89.92% and 89.67% respectively on DenseNet 201 model	Conducted a qualitative investigation to inspect 12 off-the-shelf Convolution Neural Network (CNN) architectures in classifying COVID-19 from CT scan images	2020	U-Net segmentation method, DenseNet20	Transfer Learning	2481 CT scan images +

Table 2: Comparison Table for Proposed Approach

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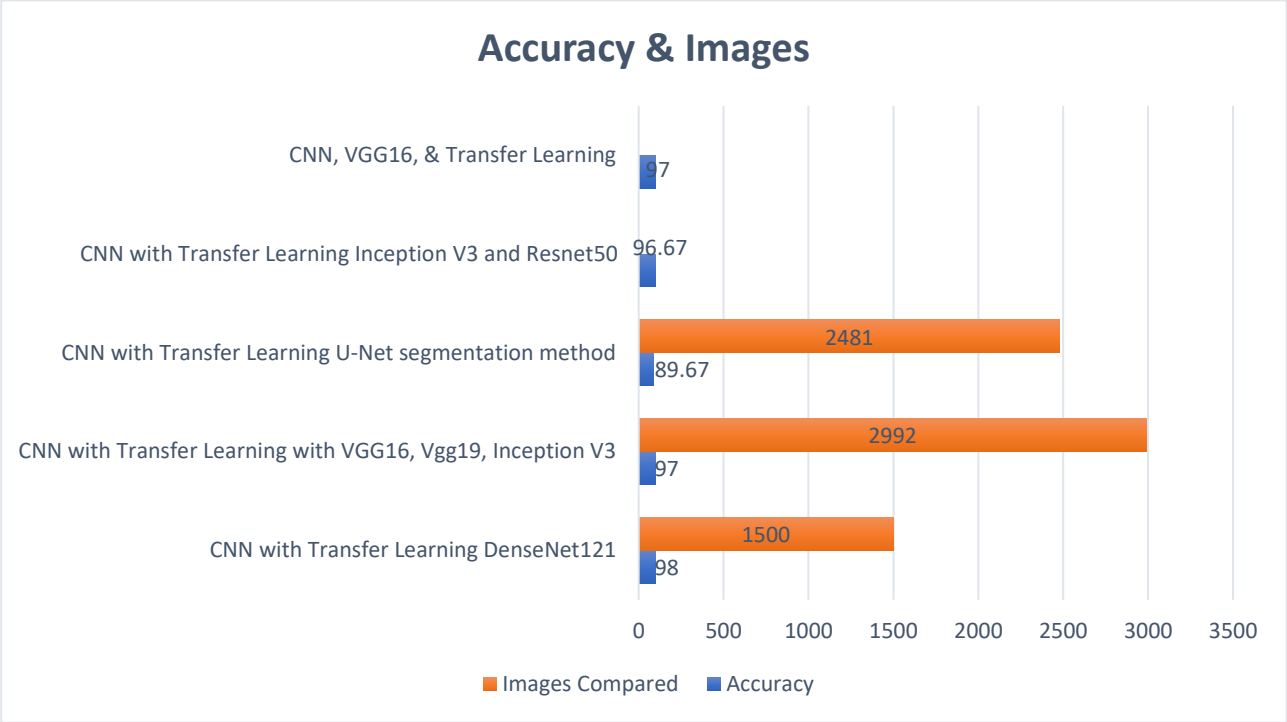

Graph 2: Accuracy & NO of Images

After implementing classification with Support Vector Machine and other machine learning techniques, it was seen that, using CNN approach when compiled with Transfer Learning gave better results and better prediction with accuracy including a greater number of images or dataset [38], [41] . Here is a Graph 2 for comparing dataset with respect to their accuracies and images that uses CNN with Transfer Learning model for implementation.

4. Conclusion

While working with the traditional methods, to select the highly representative features was a tedious and tiresome task. Thus, CNN used with Transfer Learning is an optimized approach towards classification and detection of brain tumor through MRI Images. As seen in current scenarios lesser number of MRIs have been used in training, testing and validation phases conclusive resulting in major fall of accuracy. The dataset that has been used is not up to the mark for better prediction results as it is been checked only on particular limited data that results in higher accuracy. But to predict better and accurate, a greater number of MRI images must be classifying and detected using multiple machine learning algorithms for classification and detection. For the future works, testing more amount of data is the major good to go. As more the amount of data or MRI Images will be there for testing, better will be the prediction results. This will be resulting in precise and reliable accuracy that can be further built to a model in order to help for the medical field. After comparing results in of above used machine learning models, it is clearly found that when CNN is used with Transfer Learning, training and testing is conducted on larger dataset resulting in higher accuracy. Dataset from ImageNet can be used further to increase the dataset from thousands of images to ranging into around more than 1 Lakh images to be trained, tested and validated. Hence our comparative analysis study concludes that main focus should be on increasing the dataset quantity resulting in higher accuracy.

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