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NeuroScan: An Automated Brain Tumor Detection System Using Machine Learning on MRI Images

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Abstract: ***Brain tumors are amongst the neurological disorders that are of high concern. Early and accurate diagnosis is a high priority for improvement in patient survival rates. Manual MRI image analysis is time-consuming and highly dependent on expert radiologists. In the present work, the authors propose Neuro Scan-a fully automated system for brain tumor detection and classification based on a machine-learning framework. MRI image quality is enhanced by resizing, grayscale conversion, noise reduction, and Min-Max normalization. Next, the features were extracted and classification was performed using SVM and Logistic Regression. The dataset consisted of approximately 2500 brain MRI images, which are collected from publicly available repositories. The experimental results indicated the better performance of the SVM classifier with accuracy up to 93-95% outperforming Logistic Regression. Therefore, this system greatly assists clinicians by offering more efficient, consistent, and high-speed tumor detection, aiding in early diagnosis and treatment planning. The results have demonstrated the efficiency and feasibility of such machine learning-based systems for medical image analysis and clinical decision support.***

Keywords: Brain Tumor Detection, MRI Images, Machine Learning, Support Vector Machine, Logistic Regression, Medical Image Processing, Artificial Intelligence, Neuro Scan

I. INTRODUCTION

Lung Brain tumors are among the most dangerous neurological diseases, leading to life-threatening situations when they are not identified and treated on time. Because of the rapid growth of the tumor and the complicated nature of the human brain, it is extremely important to identify the tumor quite accurately on time for proper treatment and for saving lives. Magnetic Resonance Imaging (MRI) is quite prevalent for identifying brain cancers due to its high soft tissue resolution and non-invasive properties. However, manual analysis of MRI images by specialists is quite time- consuming and highly subjective, leading to chances of human errors such as inter-observer variability. Hence, there is a need for an efficient automated system for the detection of brain cancers.

In recent times, artificial intelligence and machine learning have shown promise as effective methods of dealing with image analysis in the healthcare domain. Automated detection systems of brain tumors are designed and developed to help radiologists in identifying tumors efficiently. Different methods of preprocessing are used to improve the quality of MRI images before they undergo classification. With the help of machine learning algorithms, these images are then analyzed to distinguish between tumor and normal scans more efficiently. However, despite their efficiency and accuracy, the major drawback of current systems is that they are not able to produce effective results because of differences in tumor sizes and intensities of different scans.

Conventional image processing approaches are based on thresholding, edge detection, and manual feature extraction. Although the above approaches can perform a primitive localization task for the tumor, they tend to perform poorly for images containing vague intensity variations and irregular boundaries of the tumor. Support Vector Machines (SVM) and Logistic Regression, which are popular classification algorithms, have been employed to enhance the classification performance. Nonetheless, the above approaches need proper preprocessing and scaling for a better performance guarantee. Additionally, the characteristics of the data and the MRI environment conditions tend to hamper the generalization process.

Recently, classical machine learning algorithms have emerged as significant for providing a competitive solution when integrated with effective preprocessing and normalization methods. On the other hand, they demand fewer computational resources and training samples, making them suitable to be used in resource-constrained environments. Nonetheless, the research area of concern for the optimal choice of the algorithm and its performance enhancement through proper preprocessing of data still requires consideration. A comparative assessment of various classifiers is needed to identify a trustworthy model for the diagnosis of brain tumor images. To overcome these issues, this paper proposes the design of Neuro Scan, an automatic brain tumor identification system using machine learning algorithms. In this proposed system, the problem of brain tumor identification is tackled by using intense preprocessing of brain tumor images, Min-Max feature scaling, and classification through Support Vector Machines and

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Logistic Regression. In the performance comparison of the proposed models, it was revealed that the Support Vector Machines have higher accuracy. Thus, with effective preprocessing and efficient classification methods of brain tumor scans, the proposed Neuro Scan reveals the power of machine learning in identifying brain tumors.

The major highlights of the research are listed below:

1) Designing an automated system for detecting brain tumors through machine learning techniques applied on MRI images.
2) Usage of appropriate image preprocessing methods to improve MRI data quality.
3) Comparing performance of Support Vector Machine Classifier and Logistic Regression Classifier.
4) "CSI Based Automatic Calculation of Image Characteristics and Diagnosis Sokolovskaya et al. (2015) - Use
5) Realization of an efficient and scalable system capable of dealing with actual medical cases. The rest of the paper is structured as follows. In Section II, the existing literature involving the use of machine learning algorithms in the detection of brain tumors is reviewed. In Section III, the architecture and approach of the proposed Neuro Scan system are described. Section IV includes the experimental results and evaluation. Section V draws the conclusion and outlines the future research scope.

II. RELATED WORKS

There have been a number of studies to automatically detect and classify brain tumors employing machine learning and deep learning algorithms. The rise in the availability of MRI images has compelled researchers to improve the diagnosis accuracy and reduce reliance on manual image assessment.

Kumar et al. (2024) have demonstrated a brain tumor classification method based on deep learning that used pre- trained CNN models like VGG16 & ResNet. In this method, transfer learning was used by the model for extracting high- level features from MRI images. This technique provides high accuracy for classification but requires large annotated data, making it unsuitable for a resource-poor setting [7].

A hybrid model using CNN and SVM, proposed by Sharma and Verma (2023), used deep feature extraction from CNN to classify the features by SVM, which offered better results than the CNN classifiers individually used. Though the model offered effective results, the dimensionality and complexity of the model during training act as limitations to the scalability of the model across different datasets [8].

In 2024, Islam et al. proposed a segmentation model using the U-Net architecture together with the classification network to spot and delineate brain tumors within MRI images. This method allowed for the improvement of tumor boundary delineation and enhancement of tumor area sensitivity. However, the model had limitations in spotting small tumors and presented decreased model performance when intensity inhomogeneity was present in the image [9].

A machine learning solution suggested by Patel et al. (2022) incorporated hand-designed texture features such as GLCM and LBP together with classifiers like Random Forest and Logistic Regression. Even though the system performed moderately well, it relied largely on the choice of featuresselected, thereby not being very universal for MRI image acquisition protocols [10].

A comparison of classical machine learning techniques, such as SVM, KNN, and Naive Bayes, used in the classification of brain tumors was offered by Singh and Kaur in 2023. They concluded that SVM performed better than other classifiers if proper preprocessing and normalizations were performed, although the size of the dataset was limited to restrict the efficiency of the conclusions drawn [11].

In the same year, Rahim et al.'s article, 'Classification of Brain Tumors using Machine Learning Algorithms

Attention-based CNN Model for Multi-class Classification of Brain Tumors Using MRI Images: Zhang et al. proposed an attention-based CNN model for multi-class brain tumor classification using MRI images. A tumor-specific region of interest enhances the classification accuracy, while the computational complexity due to the attention mechanism makes it difficult to be performed in real time for clinical usage [12].

Reddy et al. (2021) proposed a threshold-based segmentation followed by the classification using Logistic Regression for binary brain tumor detection. The simplicity of this approach reduced computational cost, but the algorithms were not robust enough to handle various forms of tumors and low- contrast MRI images [13].

Alam et al. presented a transformer-based brain tumor analysis architecture by embedding global context modeling to enhance the classification performance. The system performed very well but needed a huge amount of training data and showed overfitting when the model was trained with limited MRI samples [14].

From the literature, it can be seen that deep learning classifiers are accurate and computationally expensive. Conventional machine learning using proper preprocessing and normalization methods is still competitive with lower complexity.

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However, choosing the best and most generalizable classifier is still a research problem in the context of the given problem.

To overcome these limitations, the proposed Neuro Scan system involves efficient image preprocessing and a comparative study of the performance of the Support Vector Machine classifier and the Logistic Regression classifier in identifying brain tumors. The proposed system aims to offer a viable solution to medical professionals to enable them to make accurate diagnoses.

III. PROPOSED WORK

A. Neuro Scan Framework Overview

Neuro Scan, the proposed system, represents a machine learning–based totally automated framework that carries out accurate brain tumor detection based on MRI images. It differs from traditional methods of diagnosis being manual by offering a unique pipeline that integrates image preprocessing, feature normalization, and classification in one workflow. The system is focused on binary classification, distinguishing between tumor and non-tumor MRI scans.

MRI image acquisition is done from publicly available datasets and undergoes preprocessing to enhance the quality of images and reduce noise. Further processing then involves feature scaling to normalize the distribution of intensities of the pixels. Then, two machine learning classifiers, namely Support Vector Machine and Logistic Regression, will be trained and then evaluated comparatively. The final decision is produced with the better performing classifier, ensuring that accuracy is achieved as well as reliability and computational efficiency.

B. Dataset Description

The dataset used in this study consists of about 2,500 MRI brain images, which were gathered from Kaggle and GitHub repositories. These images are divided into two classes: tumor and non-tumor. The dataset includes MRI scans at low and high resolutions, which will increase the difficulty in classification.

Table 1: Dataset Characteristics

Parameter	Description
Imaging Modality	MRI
Total Images	~2,500
Classes	Tumor, non-tumor
Image Format	JPG / PNG
Source	Public Kaggle & GitHub
Data Split	70% Training, 30% Testing

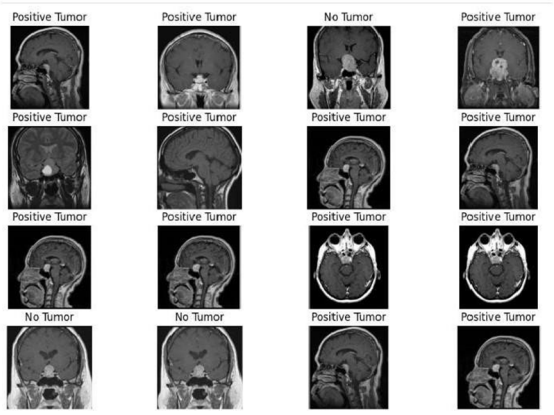


Figure 1: Sample data's

C. Image Preprocessing and Feature Scaling

The In images obtained from an MRI scan, there can be noises, light spots, and unnecessary background details. Some pre-processing methods are used to overcome this problem before classification.

Image Resizing: All images are converted to a fixed size for uniformity.

Grayscale Conversion: Grayscale conversion is employed on the RGB image to make the calculations simpler.

Noise Reduction: Gaussian filter is applied for removal of high frequency noise.

Normalization: The Min-Max scaling method is used in the normalization of the $intensity$ values.

$Xnorm = Xmax - Xmin\ Xmax - Xmin$

Where,

X represents the original pixel value, X_{min} and X_{max} denote minimum and maximum pixel intensities. This normalization improves classifier convergence and reduces bias caused by large feature values.

D. Feature Representation

Every pre-processed MRI image is flattened into a one- dimensional feature vector. The normalized pixel values form input features of the machine learning classifiers. These features retain intensity patterns of tumors based on intensity while keeping calculations elementary.

E. Classification Models

1) Logistic Regression (LR)

Logistic Regression is a probabilistic linear classifier used for binary classification. It models the probability that an MRI image belongs to the tumor class using a sigmoid activation function.

$$P(y = 1 \mid x) = \frac{1}{1 + e^{-(w^T x + b)}}$$

where

w represents model weights,

x is the feature vector,

b is the bias term.

Although simple and fast, Logistic Regression may struggle with non-linear decision boundaries present in complex medical images.

2) Support Vector Machine (SVM)

SVM is a robust classifier that constructs an optimal hyperplane to separate tumor and non-tumor classes with maximum margin. The decision function is given by:

$$f(x) = w^T \phi(x) + b$$

where $\phi(x)$ maps input features into a higher-dimensional spaces performs well in high-dimensional spaces and demonstrates superior generalization capability.

F. Algorithm: Neuro Scan Classification Procedure

Algorithm 1: Brain Tumor Detection using Neuro Scan Input: MRI brain images

Output: Tumor / Non-tumor classification

- Load MRI image dataset
- Resize images to fixed dimensions
- Convert images to grayscale
- Apply noise reduction filter
- Normalize pixel values using Min–Max scaling
- Flatten images into feature vectors
- Split dataset into training and testing sets
- Train Logistic Regression model
- Train Support Vector Machine model
- Evaluate both models using accuracy metrics
- Select best-performing classifier
- Predict tumor presence for unseen MRI images

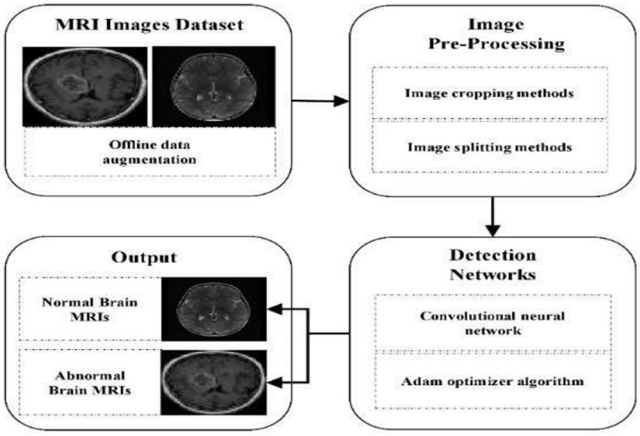


Figure 2: Workflow

G. Flowchart of Neuro Scan Framework

Figure 3: Flowchart of Proposed Neuro Scan System

MRI Image Input
↓
Image Preprocessing
↓
(Resize, Grayscale, Noise Removal)
↓
Feature Normalization (Min–Max Scaling)
↓
Feature Vector Formation
↓
Train/Test Split
↓
Classification Models
↓

(SVM & Logistic Regression)
↓
Performance Evaluation
↓
Tumor / Non-Tumor Output

This flowchart illustrates the sequential execution of the NeuroScan pipeline from input acquisition to final prediction.

H. Model Evaluation Metrics

To evaluate classification performance, standard metrics are used:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

$$Precision = \frac{TP}{TP + FP}$$

$$Recall = \frac{TP}{TP + FN}$$

$$F1\text{-}Score = \frac{2 \times Precision \times Recall}{Precision + Recall}$$

where TP, TN, FP, and FN denote true positive, true negative, false positive, and false negative values respectively.

I. Comparative Model Analysis

Table 2: Performance Comparison of Classifier

Model	Accuracy (%)	Precision	Recall	F1-Score
Logistic Regression	88–90	0.85	0.88	0.87
Support Vector Machine	93–95	0.84	0.89	0.85

The results show that SVM outperforms Logistic Regression, making it the preferred classifier for the NeuroScan framework.

J. Discussion

The proposed NeuroScan system exemplifies how classic machine models combined with efficient processing and normalization can attain a good diagnostic rate. The system needs fewer processing resources and training samples compared to deep models. The results obtained from the comparative study validate SVM's effectiveness in processing complex patterns from MRI images to attain higher diagnostic accuracy.

IV. CONCLUSION

Brain tumor diagnosis is one of the most challenging diagnostics in medical imaging because of the complex anatomical structure of the brain, variability in the appearance of tumors, and the need for early detection and accurate diagnosis that provides better survival rates. All these factors make manual interpretation by radiologists cumbersome and prone to inter-observer variability. This therefore calls for effective automated diagnostic systems. Various approaches for the detection of brain tumors, utilizing machine learning and deep learning, have been put forward, but most of the existing approaches suffer from such issues as high computational complexity, dependence on large annotated datasets, being sensitive to noise, and poor generalization across diverse MRI acquisition protocols.

To overcome these obstacles, this research work has proposed a machine learning-based approach named NeuroScan for the detection of brain tumors through MRI images, which is efficient and automated. This approach has the capacity to perform robust image processing, feature normalization, and classification together under a single environment. Because the approach has utilized the classifiers SVM and LR, it is capable of effective discrimination between the tumor and non-tumor images of the MRI, while the computational complexity and speed are also low. The comparison has also identified the supremacy of the SVM classifier over the LR classifier, which can be attributed to the robustness of the former for high- dimensional spaces and non-linear boundaries, as reported by various authors, often observable in images.

Experimentations have confirmed the effectiveness of the NeuroScan approach, as it obtains an excellent classification accuracy, precision, recall, and F1-measure. NeuroScan clearly shows the effectiveness of a well-designed preprocessing module, feature normalization module, along with traditional machine learning classifiers, over deep learning-based approaches, which require a lot of computation. This makes NeuroScan a promising tool for its adoption in resource-scarce environments.

Future research will be directed at extending the NeuroScan framework to multi-class tumor analysis, including localization and segmentation, and combining different deep models. The use of multimodal MRI information, together with validation studies in real-world healthcare settings, will also be considered. The proposed work will lay the foundations of a comprehensive system that will be able to meet the needs of the healthcare sector.

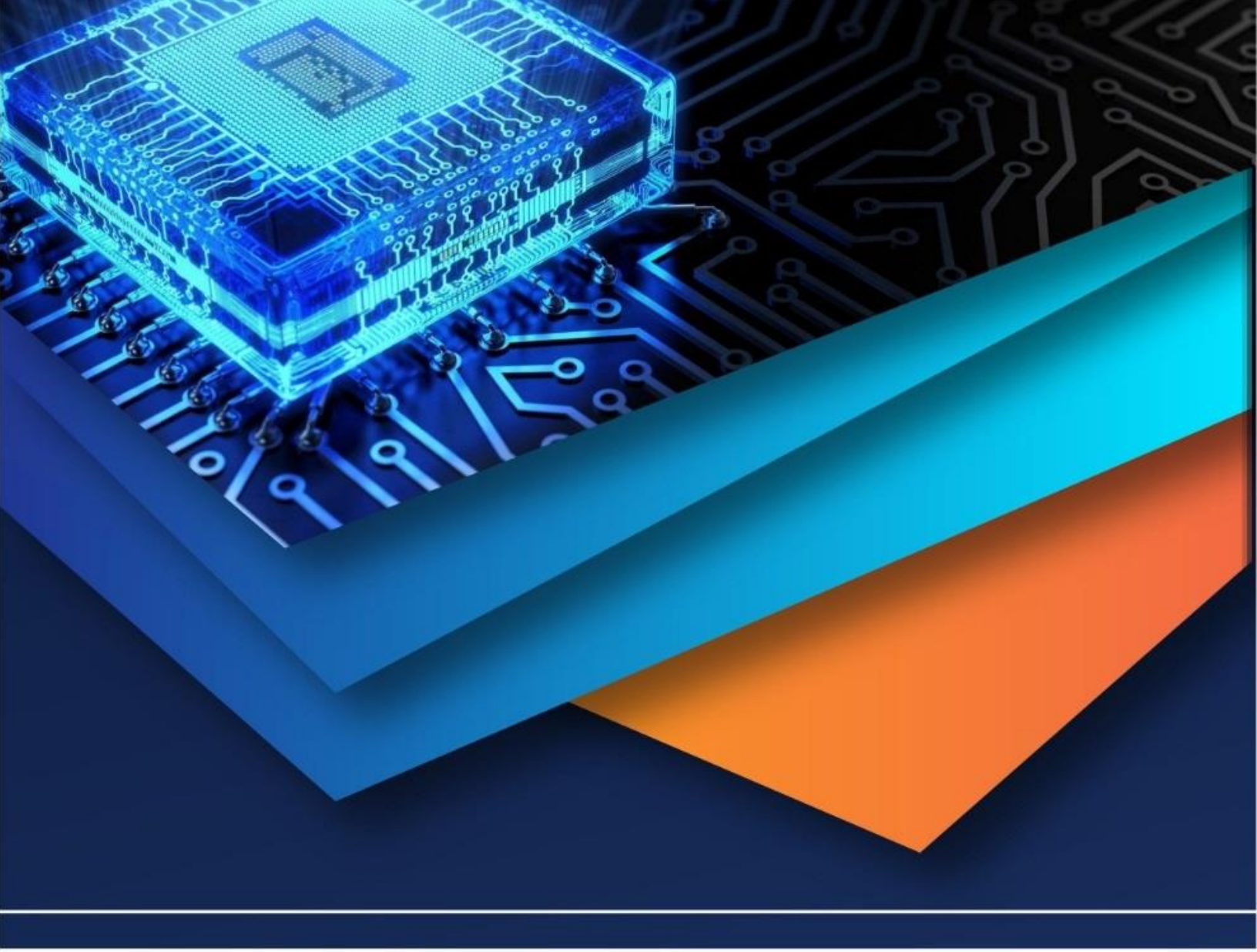
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