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Convolutional Neural Networks in Image Retrieval System

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Abstract*: Image is an important medium for monitoring the treatment responses of patient's diseases by the physicians. There could be a tough task to organize and retrieve images in structured manner with respect to incredible increase of images in Hospitals. Text based image retrieval may prone to human error and may have large deviation across different images. Content-Based Medical Image Retrieval(CBMIR) system plays a major role to retrieve the required images from the huge database.Recent advances in Deep Learning (DL) have made greater achievements for solving complex problems in computer vision ,graphics and image processing. The deep architecture of Convolutional Neural Networks (CNN) can combine the low-level features into high-level features which could learn the semantic representation from images. Deep learning can help to extract, select and classify image features, measure the predictive target and gives prediction models to assist physician efficiently. The motivation of this paper is to provide the analysis of medical image retrieval system using CNN algorithm.

***Keywords* : Content Based Medical Image Retrieval (CBMIR), Deep Learning, Convolution Neural Network(CNN), Feature Extraction, Optimization, Classification, Similarity Measurements..**

I. INTRODUCTION

Images are playing a major role in digital world especially in medical field. Imaging modality devices are used to scan the human body anatomy images in radiology department. In general, the humans are affected by various kinds of diseases. To know the accurate results of diseases, the doctors are asking us to take the scan of particular part of human body. The radiology departments are taking scan of particular part as image in different ways using medical devices and saving all the images in computer disks. Everyday a lot of images are saved in databases. To analyze, manage and retrieve a particular patient image from large repositories is a challenging task. To overcome this task, an effective mechanisms to be framed to retrieve an images. Each and every images should be stored in an organized way and whenever images are needed by the physicians, it would be retrieved from the database by surfing the similar images. The range of medical image collections is increasing rapidly in hospitals due to the widespread propagation of Picture Archiving and Communication Systems (PACS). Text analysis based image retrieval is a laborious task due to the vast diversity of medical image collections. Content-Based Medical Image Retrieval (CBMIR) [1][2]is proposed to overcome this problem and have an automated labeling and retrieving of images from huge medical data bases[3].

CBMIR system helps the physicians for taking correct decisions about a particular disease. The doctors can take a decision about the patient's disease stage and further treatment to be given to patients. An efficient algorithm can be developed at several stages of CBMIR system[15]. Most of the CBMIR system is working using four steps such as image feature extraction, selection of features, classification of features, and similarity measurement techniques [5]. Fig.1 represents the CBMIR system. Initially, a query image is given where the CBMIR system extracts the features using any of Shape, Texture or Color algorithms [6]. Then a specific features are selected using feature selection algorithms such as Linear Discriminant Analysis (LDA) Principal Component Analysis (PCA), Particle Swarm Optimization(PSO), Cuckoo Search(CS), Ant Colony Optimization(ACO), and Grey Wolf Optimization(GWO)[7] & etc.,.Once features are selected, it will be given to classification where it clearly classifies the output of images. The most widely used classification algorithms are K-nearest neighbourhood (KNN), Support Vector Machine (SVM),Gaussian mixture models (GMM)-based Baye's classification and Relevance Vector Machine [8] and finally CBIR system performs similarity measurements between query image and database of images. Some of the similarity measurement [9] techniques are Manhattan Distance, Euclidean Distance, Chord Distance and Earth Movers Distance. A massive improvement in CBMIR system is being developed for medical images where the physician to diagnosis and take decisions.

The following are the major challenges faced by CBMIR Systems:

- Semantic Gap Problem: It occurs between the low level visual contents obtained by medical imaging devices and high level semantic data seen by human
- High Dimensionality of Image Features: The dimensionality of image feature vectors for one image is quite high which increases the complexity for classifying the images and decreases the accuracy of retrieval process.

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Recent years have shown that some advances in machine learning algorithms called 'Deep Learning (DL)' [10] is introduced for solving the above problems. The conventional machine learning methods have used "shallow" architectures, while deep learning act like human brain where it is organized as deep architecture and processes data in multiple stages of representation and transformation[11][12]. There are many open-source libraries such as TensorFlow (https://www.tensorflow.org) and PyTorch (https://pytorch.org/) that allow the creation of deep neural nets in Python .

DL is applied in various applications such as handwriting recognition, face detection, recommender systems, behavior recognition, speech recognition, Natural Language Processing (NLP), and image classification. DL models represent complex relationships without acquiring more nodes as like K-nearest neighbor (KNN) and Support Vector Machines. DL is being applied in bioinformatics, medical informatics and image analysis.

There are various deep learning algorithms[13] such as Convolutional Neural Network (CNN), Auto Encoders (AE), Recurrent Neural Network (RNN), Deep Belief Networks (DBNs), Restricted Boltzmann Machines (RBMs), Deep Boltzmann Machines (DBM) and Generative Adversarial Networks (GANs). CNN is being applied in computer vision and medical image analysis. One of the best deep learning technique is CNN which is adapted for learning feature extraction and classification of different images for effective retrieval of images from the huge database. CNN is recognized as the second best error rate on the image classification task on the ImageNet Large-Scale Visual Recognition Challenge (ILSVRC) in 2012. Deep CNN is having hierarchies of feature representations in image classification tasks, where the semantic gap problem will be solved[16]. CNN is able to extract the significant image features in various layers, and allocate the image feature content into semantic concepts where the high-level of features descriptor will have good image depictions whereby it improves the image retrieval performance.

The paper is organized as follows. CNN in Image retrieval system is discussed in Section 2, problem identification and suggested approaches in image retrieval is presented in section 3, performance analysis is mentioned in section 4 and section 5 discusses the conclusion.

II. CONVOLUTIONAL NEURAL NETWORKS IN IMAGE RETRIEVAL SYSTEM

Convolutional Neural Network (CNN) is a multi-layer neural network, designed to identify visual concepts from pixel images with nominal preprocessing. CNN is a feed forward neural network that is generally used for Image recognition and object classification. CNN is having the following characteristics:

- Useful representations of images and other structured data.
- Take a fixed size input and give fixed-size outputs.
- Use minimal amounts of preprocessing.
- Ideal for images and videos processing.
- For training of CNN,GPU-accelerated computing techniques are being applied
- Minimal preprocessing and backpropagation algorithm is used to improve the CNN performance
- More than two layers where it accept complex non linear relationship
- Capable for converting 2D Data to 3D data without noisy using convolution filters
- Most required method for large scale image data set applications.
- Fewer parameters are required due to Spatial relationship than fully connected deep networks
- Classification and regression is possible and accuracy level is high.

Fig. 2 represents the CNN model. CNN has 4 layers namely: Convolution layer, ReLU layer, Pooling and Fully Connected Layer. Input Layer accepts the pixels of the image as input in the form of array .There are three hidden layers such as Convolution layer, ReLU layer & Pooling layer .Convolution layer is used as feature extraction where it uses matrix filter and performs convolution operation to detect patterns in the image. ReLU activation function is applied to the convolution layer to get a rectified feature map of the image. Dimension reduction is the process of dropping higher dimension data set into a smaller dimension, where the final minimized data must carry corresponding information briefly .Pooling Layer is used for reducing the high dimensional features into lower dimensional features where it uses multiple filters for detecting the edges, corners, eyes, feather, beak etc.The flattened matrix from the pooling layer is fed as input to the fully connected layer to classify the image. For retrieval tasks, the feature vectors are used to classify the images which were used as the feature descriptors. Then it will be used for measuring the similarity among the images. The ImageNet project is designed for visual object recognition software research. This project was applied for an annual software contest as ImageNet Large Scale Visual Recognition Challenge (ILSVRC), where good software's were checked for the classification of objects in an image. The interest in CNN started with LeNet in 1998 and it has improved exponentially. CNN is improving from 8 layer LeNet to 152 layer ResNet.Table I represents various the types of CNN architectures .

III PROBLEM IDENTIFICATION AND SUGGESTED APPROACHES IN IMAGE RETRIEVAL

The following problems have been identified based on various research findings[8][14]:

- The majority of CNN-based methods pull out image features at the final layer using only one CNN architecture with order less quantization methods, which restrict the use of in-between Convolutional layers for categorizing image local model and feature selection to be a major issue.
- For Classification, SVM needs large number of training set, which in turn needs more storage space.SVM is uneven for small training set, over fitting happens when the quantity of feature dimensions is superior than the training set.SVM needs extra support vectors for classification and Kernel functions should convince Mercer conditions.

The above problems would be solved by using the following suggested approaches:

- An effective Bilinear Root Pooling method is applied for feature selection with CNN and to reduce the dimension of image features.
- A hybrid CNN-Fuzzy based Relevance Vector Machine (FRVM) Algorithm is used to classify the images.
- Finally Euclidean Distance to be applied as similarity measurement for identifying the similarity among query image and image database.

IV. PERFORMANCE ANALYSIS OF CBMIR SYSTEM

The assessment of CBMIR system is based on how exactly a system displays the needed images for the user. The retrieval accurateness is assessed using precision and recall. Precision specifies the retrieval correctness while recall states the potential of retrieving related images from database. The Precision and Recall are mentioned as follows:

$$Precision = \frac{\text{Number of relevant images retrieved}}{\text{Total Number of retrieved images}}$$

$$Recall = \frac{\text{Number of relevant images retrieved}}{\text{Total Number of relevant images in the Database}}$$

The accuracy and error rate of classification methods are used as estimation criterion for all preferred subset of features.

Datasets : Brain image datasets (https://www.kaggle.com/navoneel/brain-mri-images-for-brain-tumor-detection/data#) are used to evaluate the performance measures. Fig. 3 shows the sample normal brain images and brain tumor images in the dataset. This proposed CBMIR system is implemented in MATLAB.

Table II and Fig. 4 shows the performance analysis of CBMIR system using SVM, CNN and the proposed CNN-FRVM algorithms for brain image dataset. Fig.5 and Fig.6 shows the top normal brain images and brain tumor images using proposed CBMIR System.

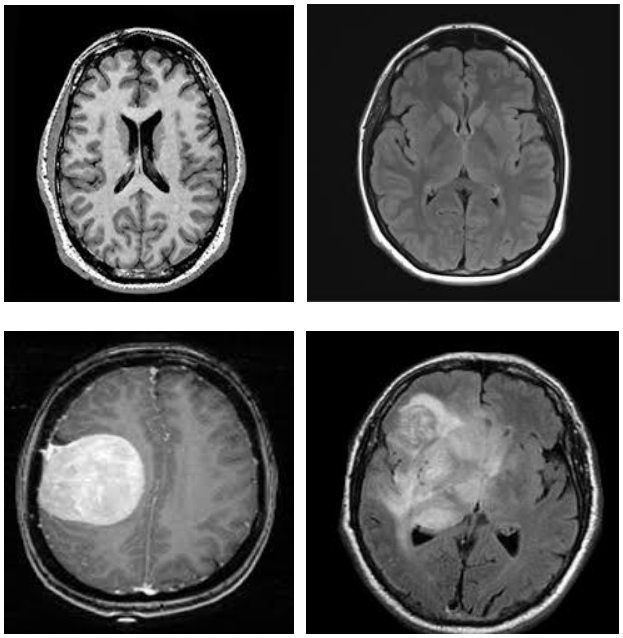

Fig 3.Sample Normal Brain and Brain Tumor Images

Table II : Performance Analysis of CBMIR System

Parameters	SVM	CNN	CNN-FRVM
Precision	70.45	78.15	81.37
Recall	72.68	80.69	83.84
Accuracy	88.58	90.23	94.85

VI. CONCLUSION

This paper analyses the Content Based Medical Image Retrieval (CBMIR) system by extracting the features, selecting the subset of features for optimization, feature classification and similarity measurements among query image and database of images. The semantic gap and high dimensional problem will be solved by Deep Learning algorithms. Convolutional Neural Networks (CNN) is being applied in medical image retrieval system. An effective Bilinear Root Pooling method is applied for feature selection with CNN for reducing the dimension of image features. Fuzzy based Relevance Vector Machine(FRVM) Algorithms to be applied with CNN for classifying the images. Finally similarity measurement is applied for identifying the similarity among the query image and image database. The proposed CNN-FRVM based CBMIR system has achieved 94.85% of Accuracy as compared with SVM and CNN algorithms.

Most of the current image retrieval applications are developed for limited computation, which will not be used for huge image storage applications. The effective image retrieval has to be developed further for distributed storages using cloud environment.

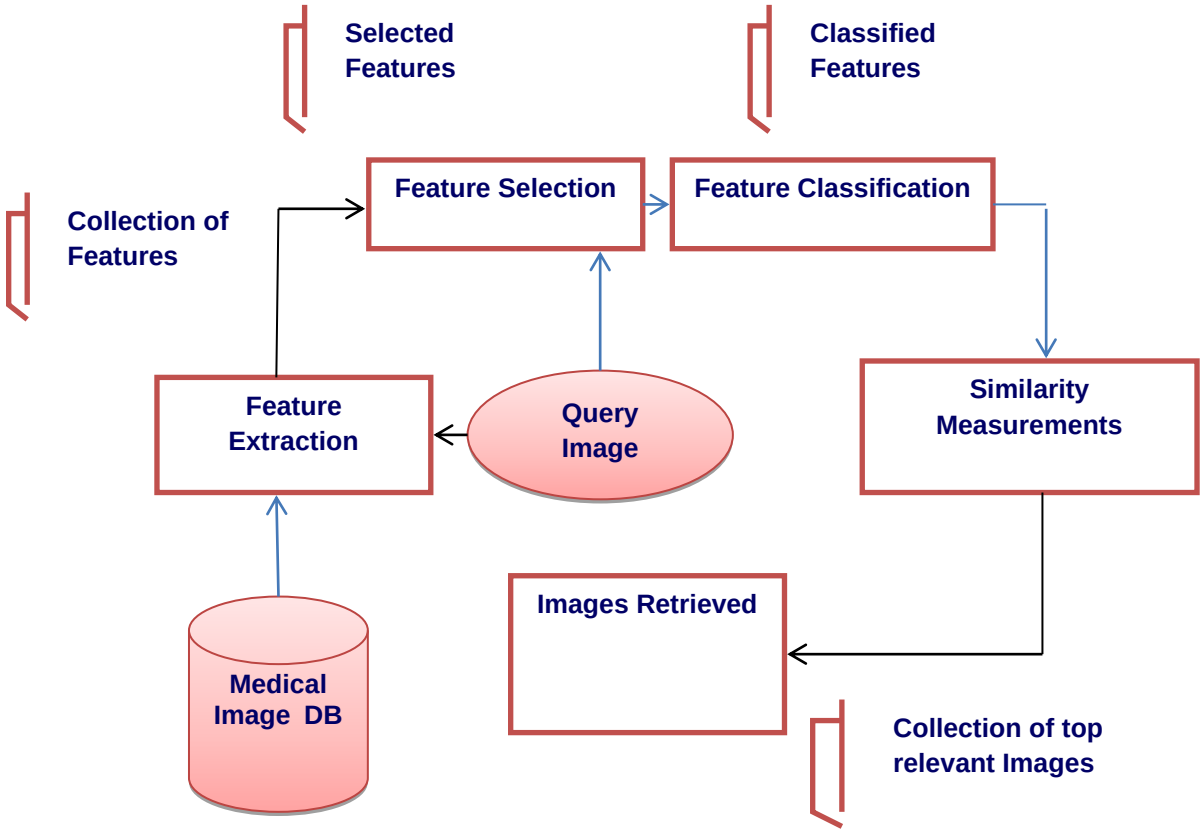

Fig 1. CBMIR system Design

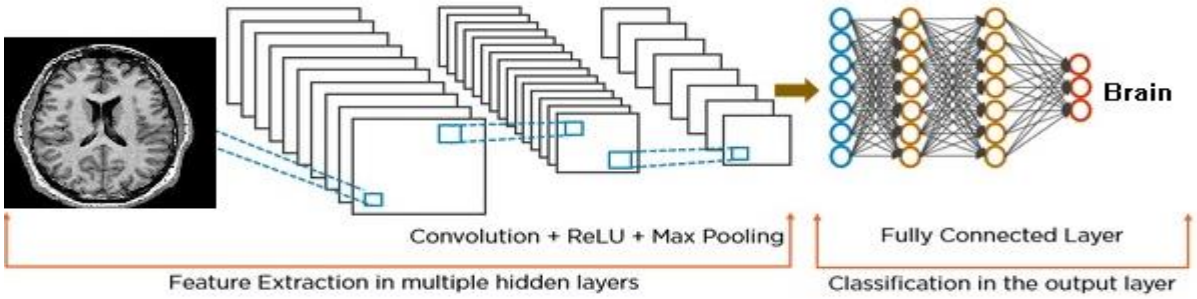

Fig 2 : CNN Model

Table I : CNN Architecture

Architecture of CNN	Details
LeNet developed by Yann LeCun et al(1998) with 8 layers	– First CNN – 7-level convolutional network by LeCun – Classify digits from hand-written numbers – No GPU for training and also CPU also slow – Requires large no.of convolution layers. – Parameters are 60 thousand
AlexNet developed by SuperVision group comprises Alex Krizhevsky,Geoffrey Hinton & Illya Sutskever (2012) with 8 Layers	– Deeper version of LeNet with 11x11, 5x5,3x3, convolutions, ReLU activations,max pooling, SGD with momentum ,dropout, data augmentation, ,. – won the test of ILSVRC 2012 by achieving top-5 error as 15.3% – Used to learn complex objects and object hierarchies and GPUs NVIDIA GTX 580 is used to reduce the training time – two CNN line trained on two GPUs through cross-connections. – Parameters are 60 million

ZFNEt developed by Matthew Zeiler and Rob Fergus (2013) with 7 layers	– Won first prize in ILSVRC 2013 competition with top-5 error rate of 14.8% – visualization concept of the Deconvolutional Network was introduced – ZFNet architecture,having 5 shareable Convolutional layers, 3 fully connected layers , dropout layers, and max-pooling layers .ZFnet also having 7×7 size filter and a stride value is decreased in foremost layer. – The last layer of ZFNet is the softmax layer – Tweaking the hyper-parameters of AlexNet
GoogLeNet developed by Christian Szegedy and his team at Google (2014) with 19 layers	– Won first prize in ILSVRC 2014 competition with a peak error rate of 6.67%. – Having inception modules and deep CNN & Parameters are 4 million
VGG net developed by Karen Simonyan and Andrew Zisserman (2014) with 16 layers	– Won second prize in ILSVRC 2014 competition with peak error rate as 7.3% – Using 16 convolutional layers with uniform architecture. – Having 3x3 convolutions with more filters. – Trained on 4 GPUs for 2–3 weeks. – Widely used feature extractor from images. – Baseline feature extractor. – VGGNet consists of 138 million parameters – Mentioned thet depth of network was a critical factor in good performance
ResNet developed by Kaiming(2015) with 152 layers	– Won in ILSVRC 2015competition with peak error rate of 3.57% – Having residual connection (gated unit) and features deep batch normalization. – Similar to RNN – Train a NN with 152 layers – Low complexity than VGGNet.

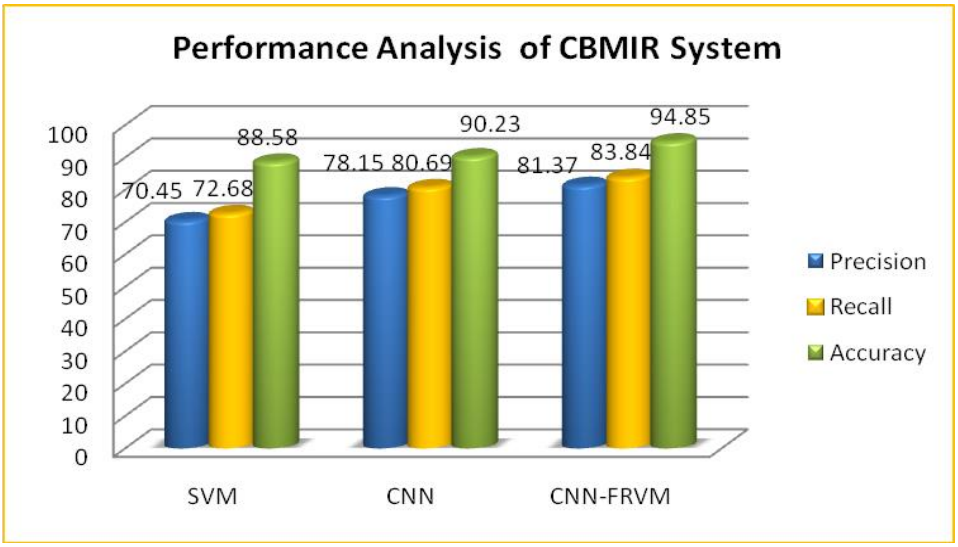

Fig 4. Performance Analysis of CBMIR System

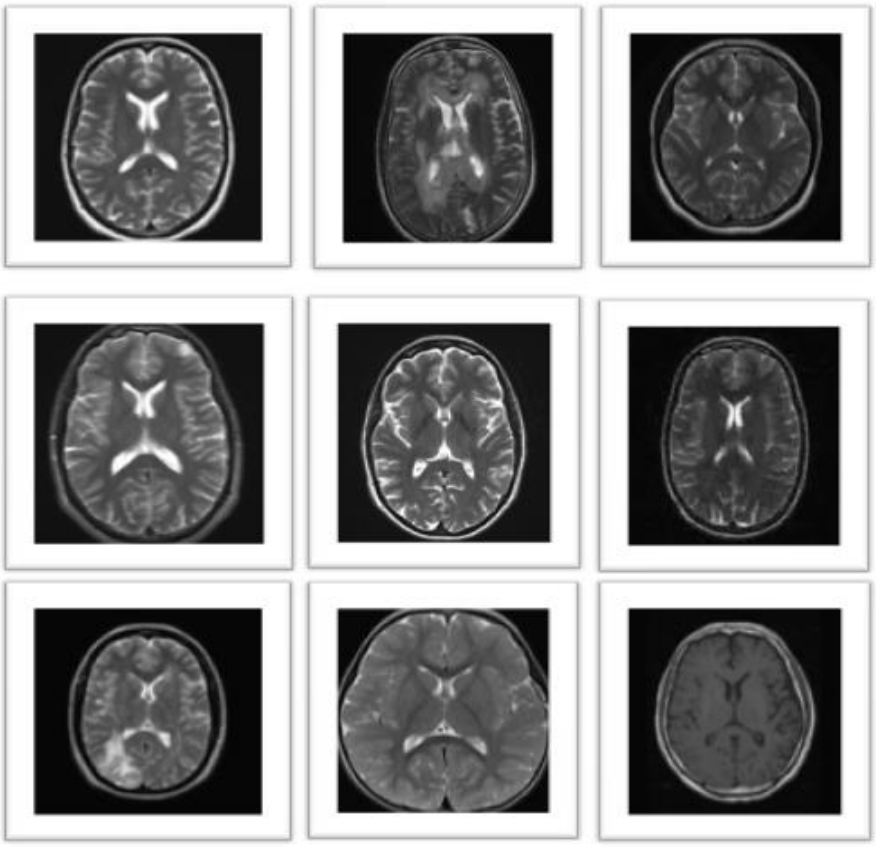

Fig 5. Top images retrieved for normal brain images using proposed CBMIR System

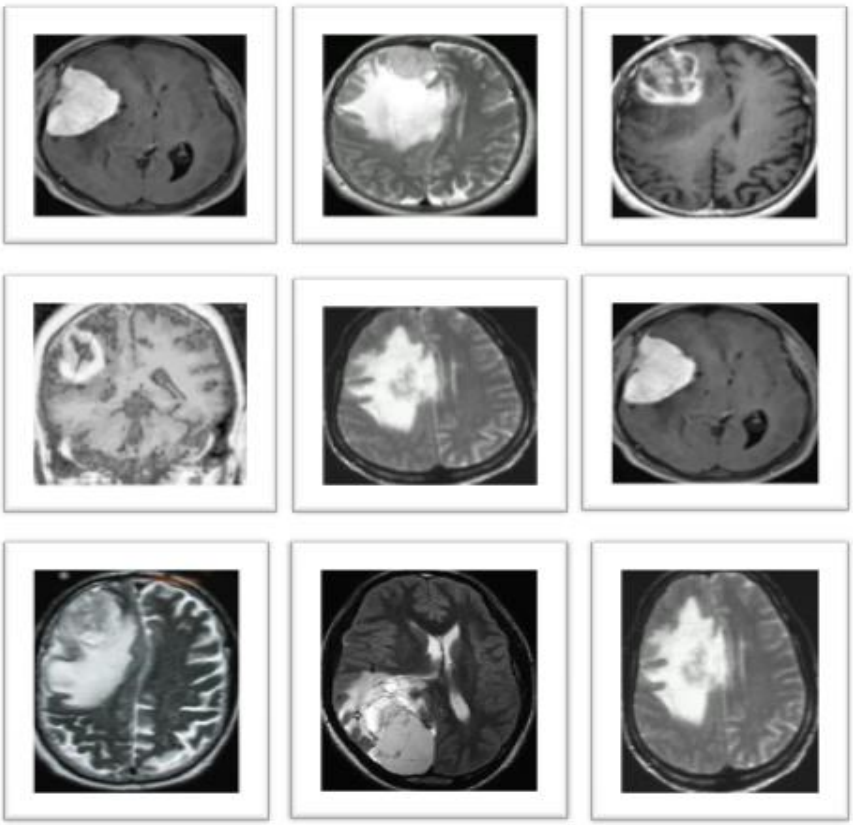

Fig 6. Top images retrieved for brain tumor images using proposed CBMIR System

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