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Framework for Predicting Alzheimer's Disease using CNN Machine Learning Classification Techniques

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ABSTRACT

The world's population is promptly aging, and the number of persons with dementia is predictable to propagate from 35 million today to 65 million by the year 2030. Alzheimer's Disease (AD) is the widespread origin of dementia. Dementia is an unceasing deterioration of our day to day activity like intellectual, behavioral and social aids that interrupts a human's ability to function independently and actively. The initial signs and indications of the disease that forgetting past and present events and communications. If the disease progresses, a person with AD will have unembellished memory impairment and finally the person lose his/her ability to carry out the day to day works. In present days, no treatment is available that can predict and cure the Alzheimer's disease in early stages. Nearly 44 million people in global living with AD. Therefore, this has become the research direction of our proposed work. In existing model, likely 18F-FDG PET brain images from the AD Neuroimaging Initiative (ADNI) were collected. But, F-FDG itself is not a conclusive imaging biomarker for AD. The former era has produced numerous tools for the early analysis of AD, but major drawbacks of existing system is that the biomarkers are expensive, less accuracy to classify the disease and high time complexity. To overcome the above drawbacks, the predictive modeling system need to be developed for accurate prediction of Alzheimer's disease. This proposed model focuses on prediction of the disease in the early stage. A combination of ensemble learning and deep learning techniques are used to implement and develop the model. The proposed model improves classification accuracy and reduces time complexity due to Convolutional Neural Network (CNN) classification algorithm.

Keywords *– CNN Classifier; Prediction; Classification accuracy; Machine Learning;*

1. INTRODUCTION

The ecosphere's population is promptly increasing, the number of people with dementia are also increasing in vertical manner. In the year 2030, around 65 million people are expected to reach with AD. Today they are around 35 million are with AD. In US, out of 5 million people, 1 in 9 people are with AD. Dementia is a disease with collective and various symptoms of forgetfulness and brain disorders. It is not a single disease, in general it describes symptoms of deficiency in thinking, communication, and memory. Now a days, the older adults with dementia at an increasing frequency. According to the Research & Development by CDCP (Centers for Disease Control and Prevention), presently, 20 million people are with arthritis, 25 million people are having hypertension, 10 million have diabetes, and 3 million older adults are with asthma.

1.1 Motivation

AD is one form the disease called dementia. The dementia is a continuous decline and affects the day to day life activities like thinking, memory power, behavioral skills that disrupts one person's

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capability to function individualistically. The early symptoms and signs of the AD are forgetting recent activities or discussions. Without proper assistance and recalling, the adult people with AD have server memory disfigurement and mislay the ability to carry out day to day tasks. In the final stages of the dementia disease are impediments from severe loss of brain activities such as dehydration, malnourishment or infection result in final calls of death. Recent survey study shows that, nearly 45 million people in universe alive with AD or allied form of dementia. In current technological world, there is no treatment that can analyze and cure the disease in early stages or slow down the disease functionality in brain. Therefore, this is problem statement becomes our research direction and even though for many number researchers.

1.2 Machine Learning

In recent days, in fast growing technological world, Machine Learning (ML) becomes popular among many of researchers, industries and government sectors. It is the contrivance of automating and cultivating the learning process of systems/computers based on their capabilities/understanding capabilities without being actually programmed by the human beings assistance. The ML process starts with feeding the raw data as an input to train the machines by creating/building machine learning models or learning tasks. Using the different ML algorithms or methods uses the input data and targeted output builds ML models or ML tasks. The ML algorithms are based on type of data and kind of task which are trying to automate the machine learning models.

1.2.1 Issues in ML

- Understanding which processes need mechanization
- Nonexistence of excellence data
- Inadequate infrastructure and implementation
- Deficiency of skilled possessions or assets (both man and machines)

1.3 Pre-Processing

Mass screening retinal pictures may have different picture resolution, illumination, and contrast. Standardizing these variables enables to encourage the process of profound learning. The picture preprocessing is applied to all retinal images and that are resized to the same Field Of View (FOV) radius size. After that, the radius size is set into r=384 pixels that to get an image size close to that is used previously. The methodologies are like illumination equalization and enhancement of contrast is then use in pre-processed images.

1.4 Segmentation

The process of partitions the image pictures with comparable characteristics into different areas which comprises of each pixel values is called as segmentation. The areas should be heavily related to depicted objects or characteristics in order to be relevant and helpful for picture assessment and interpretation. Significant segmentation is the first step from low-level picture processing to transform a gray or color picture into one or more other pictures into a high-level picture description of characteristics, items, and scenes. Successful image analysis relies on segmentation reliability, but precise picture partitioning is usually a very difficult issue.

1.5 Feature Extraction

The progression of which an initial data set is reduced into more manageable groups for processing the image data is known as feature extraction. The larger data set requires lot of processing time to compute the entire process. The feature extraction concepts includes like traditional transformed and non-transformed signal characteristics and texture and graph descriptors methods.

1.6 Classification

In ML, the process to identify which set of categories are belongs to one group based on the relevant observations is called as classification method. The classification algorithm classifies the data into each corresponding classes. The plotted is processed as a function with band the result is a spectral signature or spectral response curve for that class.

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1.7 Prediction

The method that usages the data mining methods and probability techniques to get the predicted outcomes is stated as predictive modeling in machine learning algorithms. Each model development is prepared with number of predictors, which are attributes or variable that are prospective to manipulate the future results. Now a days, pe predictive modeling methods have many applications development in business and medical sectors.

2. RELATED WORK

Ding Y, Sohn J H, Kawczynski M G, Trivedi H, Harnish R, Jenkins NW, Lituiev D, Copeland T P, Aboian M S, Mari Aparici C, Behr S C, Flavell R R, Huang S Y, Zalocusky K A, Nardo L, Seo Y, Hawkins RA, Hernandez Pampaloni M, Hadley D, Franc BL [1] proposes the concept as A Deep Learning Model to Predict a Diagnosis of Alzheimer Disease by Using 18F-FDG PET of the Brain. The stated paper concepts proposes a work on Prospective 18F-FDG PET images of brain from the AD Neuro imaging Initiative (ADNI) imaging studies from 2005 to 2017 (1002 patients) and reflective autonomous test set (40 imaging studies from 2006 to 2016). The mentioned data are collected for their experimental analyzes. Using CNN of InceptionV3 architecture, the medical data sets are trained on 90% of ADNI data set and remaining 10% of data sets are tested on continuing autonomous data set. Finally, the performance of the system is compared to radiologic readers and relevant tools and techniques. This existing system implemented and analyzed with the performance measures like specificity, sensitivity, and ROC. For early prediction of AD, the deep learning procedure was developed by using fluorine 18 fluorodeoxyglucose PET of the brain images from MRI scan. And the system model accomplishes an average of 75.8 months prior to the final diagnosis with 100% of sensitivity at 82% of specificity. For AD disease, F-FDG themself is not a conclusive imaging biomarker. In earlier decades, several tools were used to diagonals the AD.

Syed Asif Hassan, Tabrej Khan [2] proposed the research paper titled on A Machine Learning Model to Predict the Onset of Alzheimer Disease using Potential Cerebrospinal Fluid (CSF) Biomarkers. The paper proposes the determination on J48 algorithm based taxonomy model. That can be effectively applicable for organizing cognitive impaired AD patient from normal strong individuals, includes area under curve (AUC) value of 0.992 and sensitivity & specificity of 99.19% and 97.87%, respectively with an accuracy of 98.82%. The 60% of training and 40% of testing independent data shows the significant improvement in T-test with J48 algorithm when analyzed with other existing classifiers on AD dataset. Using feature selection method, this proposed model predict the patient with early stages of sign of the AD. The various statistical performance evaluators are compared to produce the efficient predictive model based on NB, J48 and SMO. To diagnosis the early stages of AD, neuroimaging data are expansively used to organize the image subjects. This approach customs low-cost CSF biomarker to perceive AD in its early stages. Therefore, the present research study infers a novel CSF biomarker-based classification tool to capably organize a patient with an early stage of perceptive impairment from strong person with higher accuracy and sensitivity.

Wang, T., Qiu R.G. & Yu M [3] the authors proposed the concepts like Predictive Modeling of the Progression of Alzheimer's Disease with Recurrent Neural Networks. The paper deals with the contributions on Recurrent Neural Network (RNN) model of two hidden units with hundred hidden units at each layer was implemented to predict the AD in early stages. During the training procedure, the learning rate and moving average rate contrivances were applied to analyze the dataset. For loss function optimization, L2 regularization was added to the loss function with Adam optimizer. In addition to this, 10-fold cross validation process is used during experiments. The appropriate intervention comprises the ways in which to facilitate the AD patients with operative and right levels of lifestyle changes. Therefore, considerate and predicting how AD advances in an specific patient over the time period is the significant to the success of supporting the interference of AD accordingly providing custom-made healthcare services in an operative manner during their period endurance.

3. EXISTING SYSTEM

The existing system concepts deals with 18F-FDG PET brain images from the AD Neuro imaging Initiative (ADNI) and retrospective independent training and test set were collected for analyzes. At

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final stage, the clinical identification at follow-up was recorded simultaneously. In existing system also implements the CNN architecture on both training and testing data. (90% training data and 10% testing data). The data sets were considered as independent data set. The existing model was analyzed with the performance metrics like sensitivity, specificity, and ROC. The deep learning algorithms also applied to analyze the disease that whether the patient has AD or not.

3.1 Issues in existing system

The existing system considers F-FDG, it is not a decisive imaging biomarker for AD. In past decades numerous tools were developed already to analysis the AD and is perceived in the cerebral spinal fluid.

3.2 Drawbacks in existing system

The major limitations of existing F-FDG scheme are as follows:

- The biomarkers used here are expensive
- Less accuracy and high time complexity

4. PROPOSED SYSTEM

The proposed system develops classification and predictive model that can account for accurate classification grouping and prediction of Alzheimer's disease [4] [5]. This proposed approach will focus on prediction of the disease in the early stage. A combination of ensemble learning and deep learning techniques are used to implement and develop the proposed model.

4.1 Advantages of Proposed System

- The accuracy will be more and the time complexity will be less due to the CNN algorithm implementation.
- Inexpensive when compared to the existing model where biomarkers are used as the indicators.

4.2 Proposed System Design

The Fig.1 describes the proposed system design for predictive modelling of AD. The proposed system contemplates mechanized diagnosis of Alzheimer's Disease [6] in three dimensional operational MRI brain scans. We use a deep convolution neural network based classifier to examine the brain MRI images from scans. The system extracts the needed information from MRI scan three dimensional images and learns & trains the significant information related AD. We perform Gaussian filtering and gray scale conversion in the raw MRI scans. Then the segmentation process is used as Fuzzy C Means techniques to segment the image into several pixels. Then the pixels or image objects has been sent into feature extraction and the module applied with DWT & GLCM techniques previously transient them to the CNN classifier. The proposed system also includes predicative modelling with ensemble and deep learning mechanisms. We use the datasets of ADNI [7] for classification of the AD between normal or healthy persona to evaluate the proposed model.

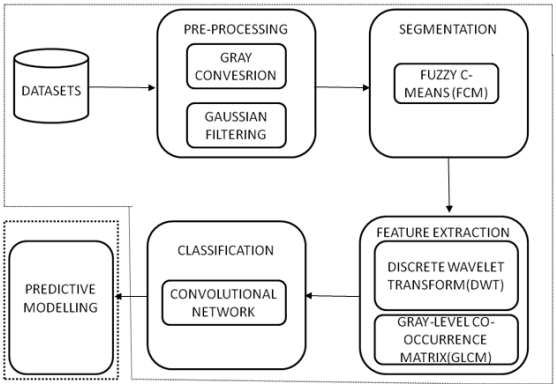

Fig 1. Proposed System Design

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4.3 Ensemble Learning

Ensemble learning methods combines different machine learning techniques into single predictive model. The developed model decreases the bias, variance and improve the prediction of the disease. The learning methods are divided into two methods like sequential ensemble methods and parallel ensemble methods. In our proposed system implements both the methods to increase the predictions on input data analyse.

4.4 Deep Learning

Deep learning approach is applied into multiple layer to increasingly extract higher level features from the supplied raw input data. It is a class of ML algorithms. For example, in image processing applications, the lower level layers identify the edges in the images and then the higher level layers are to identify the concepts appropriate to the human brain image pixels.

4.5 Pre-Processing

The proposed system, overwhelms unwanted misrepresentations and enhances the image features for further processing using pre-processing techniques. The pre-processing module consists of the following techniques to pre-process the data.

- Gray scale conversion
- Gaussian Filtering

The Gray scale conversion technique considers the input brain images and converts the RGB images into Gray scale images. The Gaussian filtering process reduces noise and distortions in converted Gray scale images. Fig.2 shows the process of pre-processing.

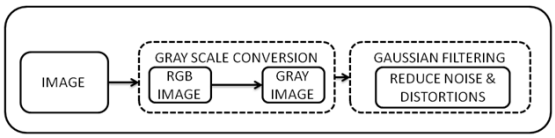

Fig 2. Pre-Processing

4.5.1 Gray scale conversion

Initially, the RGB images are viewed as three colour images (as red, green and blue scale images). At a specified spatial location in the brain images, where each colour pixel is a threesome which corresponds to colour components. The colour pixels are represented in MATLAB with M*N*3 array. Correspondingly, the grayscale images can be viewed as a single layered image. The grayscale image is M*N array values that represents the scale intensities in MATLAB environment.

Algorithm – To convert RGB image into Grayscale image

Step 1: Red, green, and blue standards of a pixel are taken as input from the RGB brain image

Step 2: Use the mathematical function to convert the colour images into single gray image values.

Step 3: Interchange the creative Red (R_Value), Green (G_Value), and Blue (B_Value) values with new Gray (GR_Value) value

```
In RGB image, for each pixel, perform {
    R_Value= Pixel.R_Value
    G_Value= Pixel.G_Value
    B_Value = Pixel.B_Value
    GR_Value=(R_Value+G_Value+B_Value)/3
    Pixel.R_Value = R_Value
    Pixel.G_Value = G_Value
    Pixel.B_Value = B_Value
}
```

4.5.2 Gaussian Filtering

To reduce the noise and blur the images, the gaussian filtering method is used. The Gaussian smoothening process practices the two dimensional dissemination function as a point-spread utility.

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The same can be achieved by using convolutional technique. Before to perform the convolution, the gaussian function is applied in a collection of discrete pixels. Truncate the gaussian with a σ of 1.0. Use this Gaussian value at the center of a pixel. But the gaussian varies non-linearly diagonally through the pixel. Sum the gaussian at 0.001 increments.

4.6 Segmentation

Partition the digital image into numerous sectors is the process of image segmentation. The segmentation process is to shorten or change the depiction of an image into more evocative and easier to analyse. For image segmentation, our proposed system uses Fuzzy C- Means algorithm.

Segmentation process partitions a picture with comparable characteristics into different areas comprising each pixel. The areas should be heavily related to depicted objects or characteristics of interest in order to be relevant and helpful for picture assessment and interpretation. Significant segmentation is the first step from low-level picture processing to transform a gray or color picture into one or more other pictures into a high-level picture description of characteristics, items, and scenes. Successful image analysis relies on segmentation reliability, but precise picture partitioning is usually a very difficult issue. Fig. 3 depicts the process of segmentation.

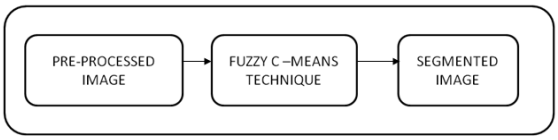

Fig 3. Segmentation

4.6.1 Fuzzy C-Means Technique

Fuzzy C-Means segmentation algorithm mainly useful for clustering concepts. The algorithm mainly focuses on two more than clusters. The technique mainly used in pattern recognition, classification and change detection methodologies. The technique minimizes the objective function that is defined in the equation (1)

$$A_m = \sum_{i=1}^{N} \sum_{j=1}^{C} a_{ij}^{m} \left\| x_j - c_i \right\|^2, \quad 1 \le m < \infty \tag{1}$$

The FCM program applies to a broad range of issues in the assessment of geo-statistical information. For any set of numerical data, this program produces fuzzy partitions and prototypes. These partitions are helpful to support recognized substructures or to suggest substructure in unexplored information. A generalized minimum-square objective function is the clustering criterion used to aggregate subsets. This program features a choice of three standards (Euclidean, Diagonal, or Mahalonobis), an adaptive weighting factor that fundamentally regulates noise sensitivity, recognition of variable cluster numbers, and outputs that include multiple cluster validity measurements.

Algorithm - Fuzzy C-Means Technique

Let $X = \{x_1, x_2, x_3, ..., x_n\}$ are the set of data points and $V = \{v_1, v_2, v_3 ..., v_c\}$ are the set of centers

Step 1: Initially, chose the 'c' clusters randomly

Step 2: Next, measure the fuzzy membership as μ_{ij} using equation (2)

$$\mu_{ij} = 1 / \sum_{k=1}^{c} (d_{ij} / d_{ik})^{(2/m-1)} \tag{2}$$

Step 3: Compute the fuzzy centers v_j using equation (3)

$$v_j = (\sum_{i=1}^{n} (\mu_{ij})^m x_i) / (\sum_{i=1}^{n} (\mu_{ij})^m), \forall j = 1, 2, ...c \tag{3}$$

Step 4: Perform the steps 2) and 3) until the minimum 'j' value is accomplished

4.7 Feature Extraction

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The feature extraction method is one category of dimensionality reduction that proficiently signifies the fascinating sections of an image as a condensed feature vectors. This method is very convenient when the image size is actually huge. For image matching and image retrieval processes, the reduced feature representation is required to rapidly ample the tasks. DWT and GLCM techniques are used efficiently in feature extraction process. In feature extraction process, the segmented image is decomposed using DWT to deliver the sub-band images. Then, the GLCM technique is applied to sub-band images to extract the textural features from the decomposed image. The final extracted images will become the input for the CNN classification. The Fig. 4 depicts the process of feature extraction.

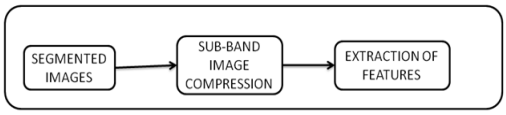

Fig 4. Feature Extraction

4.7.1 DWT and GLCM

DWT is one type of numerical and functional analysis in which the wavelets are discretely sampled and used in our proposed system to analyse the brain images. This technique uses Fourier transforms, that captures both frequency and location information in images. GLCM is a statistical process that examines the textures and deliberates the spatial relationship of pixels in images. It also characterize the texture of an brain MRI image by measuring pairs of pixels with precise values and then extracts the statistical measures.

Algorithm- GLCM

Step 1: Initially, total all the pairs of the pixels and in which the first pixel with the value ‘i’ and the matching pair of the first pixel denoted by‘d’ and has the value of ‘j’.

Step 2: The initial amount value in step 1, is arrived in the ith row and jth column of the matrix as pd[i,j]

Step 3: Mention the amount of pairs of pixels as gray levels as [i,j] and that equals the pairs of pixels as gray levels as [j,i]

Step 4: Matrix values in pd[i,j] normalized by separating each entry of the pixel values by the amount of pixel sets.

Step 5: The normalized n[i,j] value is defined by using the equation (4):

$$N[i,j]=\frac{P[i,j]}{\sum_i \sum_j P[i,j]} \quad (4)$$

4.8 Classification

The classes are identified from the specific training sites on the images is known as classification process. Mean and variances values of the each training sites are used to classify all the pixels. In classification process, initially build the image representation from all the features mentioned, then train the model with representations. Finally, obtain the class predictions for the input images.

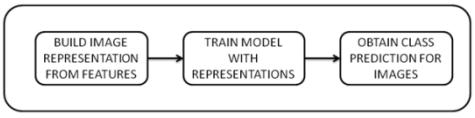

Fig 5. Classification

4.8.1 CNN

The CNN process mentions the following processes such as input image, feature detector and feature map. A convolution is the combination of two functions that represents that one function modifies another function. The equation (5) shows the function of convolution:

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$$(f * g)(t) \stackrel{\text{def}}{=} \int_{-\infty}^{\infty} f(\tau) g(t-\tau)\, d\tau = \int_{-\infty}^{\infty} f(t-\tau) g(\tau)\, d\tau. \quad (5)$$

The input image process contains image for initial process. The feature detector process normally develops the matrix with 3x3 and could also be 7x7. The feature map is also known as kernel or a filter to detect the known features. Initially, the feature detector produces feature map with the matrix representation of the input image. This is also called as an activation map. The main objective of the CNN classification is to reduce the size of the image and makes the processing faster and smoother. Unfortunately, some of the features of a classified images are lost in this classification process. But, however the important features of the images are retained for image detection. These features are very unique to identify the specific image object.

4.9 Proposed System Design

The Fig. 6 depicts proposed system design. In our system we considers the automated analysis of AD in three dimensional structural brain MRI scans. This system develops an efficient deep CNN classifier by investigating three dimensional brain images from MRI. Initially, the system performs pre-processing using gaussian filtering and gray scale conversion in the raw MRI scans. Afterward, Fuzzy C-Means technique is performed to segment the images using DWT and GLCM techniques that are implemented for feature extraction and finally CNN classification is performed for classification process. To evaluate the proposed model, we use datasets of AD from ADNI.

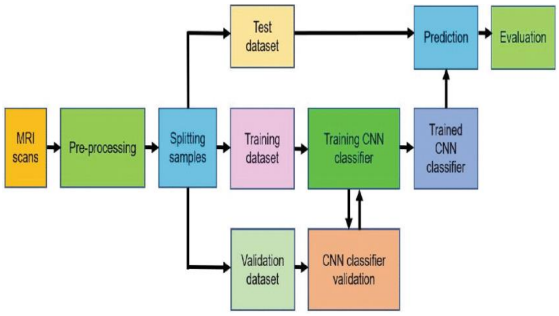

Fig 6. Proposed System Design

5. RESULT DISCUSSION AND ANALYSIS

5.1 Performance Metrics

The relevant performance metrics processes and examination the process involved in creating, testing and providing an efficient model for Alzheimer's Disease prediction. The metrics are compared with the existing techniques of classification and prediction models of AD.

- **Classification Accuracy:** It is the ratio of number of correct predictions to the total number of input image samples.
- **True Positive Rate (Sensitivity):** True Positive Rate mentions the percentage of positive data input points that are suitably classified as positive, with reverence to all positive input data points.
- **False Positive Rate (Specificity):** False Positive Rate indications the percentage of negative data input points that are fallaciously considered as positive, with reverence to all negative data points.

5.2 Pre-processing

The Fig. 7 depicts the initial input image data sets.

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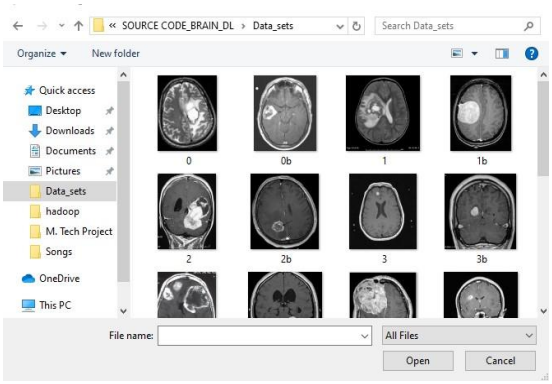

Fig 7. initial input image data sets

Mass screening retinal pictures may have different picture resolution, illumination, and contrast. Standardizing these variables enables to encourage the process of profound learning. The picture preprocessing is applied here as follows. Initially, all the brain images are resized to the same field of view (FOV) radius size. Set the radius size r= 384 pixels to get an image size close to the initial. Then, techniques for illumination equalization and improvement of contrast are used. The input images are pre-processed using Gray scale conversion and Gaussian filtering techniques.The Fig. 8 depicts the pre-processed images.

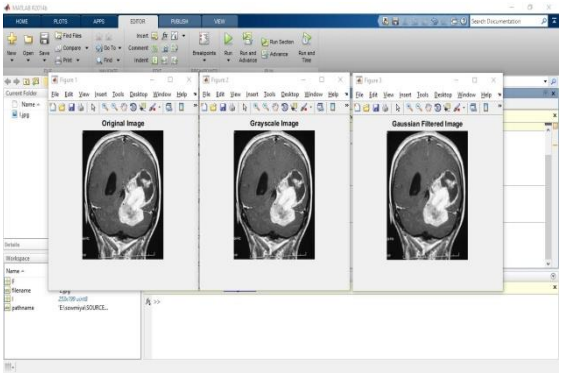

Fig 8. Pre-processed Images

5.3 Segmentation

Segmentation partitions a picture with comparable characteristics into different areas comprising each pixel. The areas should be heavily related to depicted objects or characteristics of interest in order to be relevant and helpful for picture assessment and interpretation. Significant segmentation is the first step from low-level picture processing to transform a gray or color picture into one or more other pictures into a high-level picture description of characteristics, items, and scenes. Successful image analysis relies on segmentation reliability, but precise picture partitioning is usually a very difficult issue. Fuzzy C-Means technique is cast-off to segment the images. The Fig. 9 depicts the segmented images.

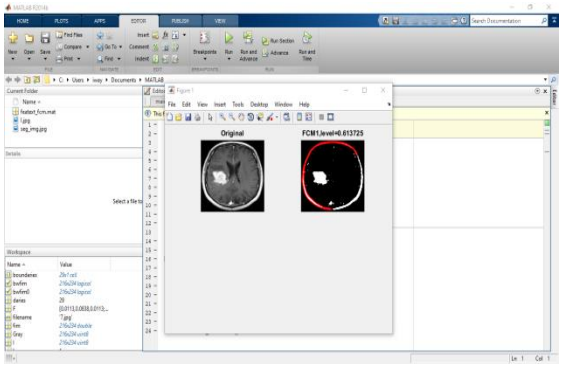

Fig 9. Segmented Images

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5.4 Feature Extraction

Feature extraction encompasses both the traditional transformed and non-transformed signals. Advanced feature representation methods are becoming necessary when it comes to dealing with the local image content or with spatio-temporal characteristics or with the statistical image content. DWT and GLCM techniques are implemented for feature extraction. The Fig. 10 depicts the feature extracted images.

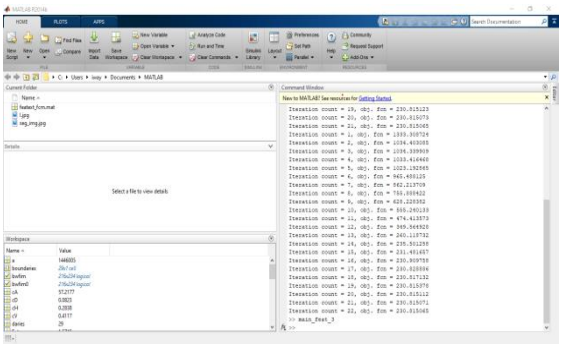

Fig 10. Feature extracted images

5.5 Classification

The Fig. 11 shows the classified images from the brain images. The proposed CNN classification process then acts to classify the data representing each class. The mean and variance values are used to classify all the pixels.

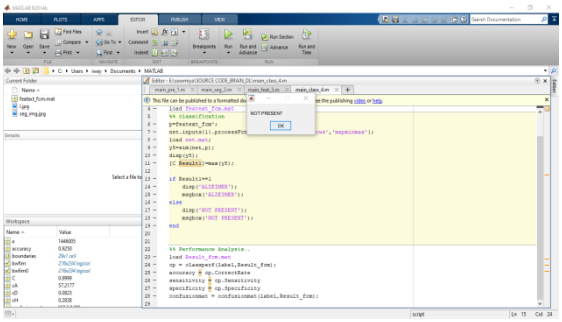

Fig 11. Classified images

6. CONCLUSION AND FUTURE WORK

6.1 Conclusion

The work proposed in the system focuses on the important challenge of classifying the Alzheimer's disease and develops intelligent classifiers, which can successfully classify that whether the patient have Alzheimer's Disease or not. Meanwhile the system also proposes to predict the disease in future based on the brain images and history of the patient. The proposed work implements the concepts called DWT and GLCM for feature extraction and CNN classification technique and results obtained have shown to be promising.

6.2 Future Work

The future works as follows:

- Predict the Alzheimer's disease early in the patients
- Perform the classification efficiently
- Using multiple datasets which could attain the optimum prediction.
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