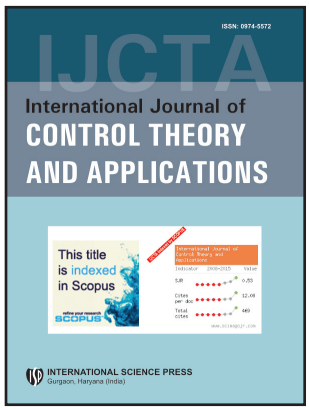

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Fronto Temporal Dementia – Supervised and Unsupervised Learning Approaches

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Abstract: Fronto Temporal Dementia (FTD) occurs because of progressive degeneration criteria of frontal and temporal lobes of the brain. These brain areas are prominent in memory, decision, linguistic abilities, emotion, calculation, inter-personal conduct, and behavior. This study aims at understanding how supervised and unsupversised learning approaches can be applied to determine the brain deterioration.

The data of patients including the previous medical history, Neurological examination, Neuro-psychological examinations, and pathological tests along with brain images are obtained. Segmentation of brain is done and different approaches like Supervised Learning or Unsupervised Learning methods are employed. The results from both methods will be evaluated and the magnitude of deterioration is determined. A comparative study of both supervised and unsupervised learning approaches is made to determine the deterioration of the demented areas. The proposed study makes use of *k*-means Clustering technique and Back Propagation Network. Other advanced unsupervised and supervised learning algorithms may be applied and suitable mathematical models may be developed.

Keywords: Fronto Temporal Dementia (FTD), Mini Mental State Examination (MMSE), Back Propagation Network (BPN),MRI, Supervised Learning, Unsupervised Learning.

1. INTRODUCTION

Fronto Temporal Dementia patient shows changes in personality and Executive Behaviour. Memory of a patient is severely impaired, has problems in recognition of people of his relative and friend circle. Numerical calculations slowly decline, he talks less. Clinically shows Disinhibition. He becomes tactless and impulsive. Progressive aphasia with non-fluent verbal output, Semantic aphasia with visual Agnosia is observed[1].

Patient exhibits rigid mental attitude, is depressed and socially does not mingle with people and interpersonal conduct. During advanced stages, severe degeneration in functionality will be seen.

Genetics and Pathology

Some of the patients inherit FTD but many patients get it by chance. Changes in a protein called TDP-43 (TAR-DNA-binding protein 43) result in a type of FTD called FTD-TDP.

Mutation of GRN gene present on chromosome 17 causes another type of FTD called FTLD-TAU (tau-positive inclusions (tauopathies)).

2. MATERIALS AND METHODS

Details of patient are collected as shown in Table I. The patients undergo the following types of tests as a part of the diagnosis.

Clinical Examination

Blood tests are done to check the proper functioning of Thyroid gland. Blood tests are done for checking B12 deficiency, presence of Syphilis, HIV, and Cancer.

Table 1
Patient Demographics

Demographics of Patient and Healthy Controls (HC)			
Group	*Number*	*Sex (M/F)*	*Age*
HC	1	M	60 Y
FTD	1	M	60 Y

Neurological Testing

The patient would have undergone many neurological tests to check for the functioning of various parts of the body including walking, strength, stamina, and gait, co-ordination of different organs of the body, hearing capacity, wellness of eye sight, functioning of heart[2].

Neuropsychological Testing

For evaluating this problem solving techniques, pencil and paper tests like MMSE[3] (Mini Mental State Examination) are conducted by the clinical experts. This also gives experts a measure of patient's memory abilities, linguistic skills, and computational capabilities.

A sample questionnaire of the MMSE is given in Table 2.

Table 2
Mini Mental State Examination Questions

Mini Mental State Examination Sample		
MMSE Questions	*Maximum Score*	*Actual Score*
Orientation – Which country you belong to?	5	( )
Orientation - Which Organization you are working for?	5	( )
Registration – Name 3 objects: 1 second to say each. Then ask the patient all 3 after you have said them. Give 1 point for each correct answer. Then repeat them until he/she learns all 3. Count the trials and record the Trials.	3	( )

Mini Mental State Examination Sample		
MMSE Questions	*Maximum Score*	*Actual Score*
Attention and Calculation – Multiple of 2s. 1 point for each correct answer. Stop after 5 answers. Alternatively spell "India" backwards.	5	( )
Recall – Ask for the 3 objects repeated above. Give 1 point for each correct answer.	3	( )
Language – Dictate a word and ask the patient to spell.	2	( )
Language - Dictate a paragraph and make the patient to write.	1	( )
Copy the design of circle, square, rectangle, rhombus, triangle from charts etc.	3	( )

A patient who scores in the range of 27-30 has normal cognitive function, any score in the range 21-26 shows mild cognitive impairment, any score in the range 11-20 shows moderate cognitive impairment, and any score in the range 0-10 shows severe cognitive impairment.

Image Acquisition

MRI makes use of magnetic fields and radio waves to form the images and is a widely used technique in medical image processing for imaging the anatomy and physiological process of the body in disease related cases. It has No. ill effects of exposing the body to ionizing radiation[4].

It is used for study of neurological disorders like neurological cancer because of the contrast between grey and white matter for neurological aspects of Central Nervous System, demyelinating diseases, Dementia, epilepsy, cerebrovascular diseases. Images are taken in fractions of milliseconds; brain's responses to different stimuli can be analyzed. Structural abnormalities can be studied. Over 25,000 MRI scanners are used worldwide.

MRI scanned images are obtained. The images are subjected to Segmentation. Segmentation is carried out based on the prior knowledge of pixels in the slices. Pre-processing is a significant step in medical image processing. Noise removal techniques are used to remove the noise from the images.

Given in Figure 1 is the set of MRI images that shows the progression of the human brain affected by the Fronto Temporal Dementia.

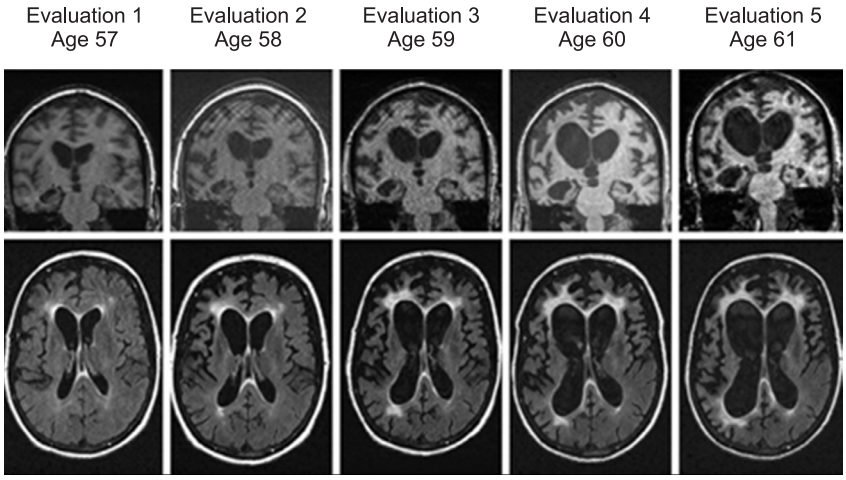

Figure 1: Progression of the FTD affected human brain - Longitudinal coronal T1-weighted images (top row) and axial fluid attenuation inversion recovery (FLAIR) images (bottom row) of the proband at Evaluations 1–5 (ages 57–61), demonstrating progressive right >> left frontotemporoparietal cortical and right hippocampal atrophy with progressive increased signal changes in the subcortical/periventricular white matter[5]

3. PROPOSED METHODOLOGY

Segmentation

It is the process of partitioning a given digital image into various segments/sets of pixels/super pixels. Segmentation makes the image more meaningful and easy to analyze. It helps to locate lines, curves, boundaries. Segmentation produces a set of segments that totally cover the entire image. In FTD cases, the demented regions can be segmented from the image accurately. FTD can be detected in earlier stages.

Approach 1: Using Unsupervised Learning like Clustering techniques

Unsupervised neural networks are given data in an undivided form-simply a set of examples $\{x\}$. Some learning algorithms are intended simply to memorize these data in such a way that the examples can be recalled in the future. Other algorithms are intended to 'generalize', to 'discover patterns' in the data, or extract the underlying 'features' from them.

Clustering – A cluster is a collection of entities which are "alike" between them but "different" from the objects belonging to other clusters[6]. K-Means Clustering – It analyzes and discovers useful information from numerous data. The data is grouped into classes or clusters so that entities of the same cluster have greater similarity when compared to one another but different when compared to objects in the other clusters[7].

K-means[8] is an unsupervised algorithm to solve the clustering problem. It follows a method of classifying the data by means of 'k' clusters'. It defines k centers, one for each cluster. These centres will be in different locations cause different result hence the centers should be placed far away from each other.

Then we take each point which belongs to a given data set and allocate it to the close by center. When No. point due, first step is finished and early group age is done. Recalculation of k new centroids as barcenter of the cluster yielding from the previous step.

After having k new centroids, binding should be done between the same data set points and nearest new center. A loop has been formed. K centers change their location step by step until No. more changes are done or centers make No. movement. This algorithm aims at minimizing an objective function known as square error function which is stated below:

$$J(V) = \sum_{i=1}^{C} \sum_{j=1}^{C_i} (\| x_i - v_j \|)^2$$

where, '$\| x_i - v_j \|$' is the Euclidean distance between x_i and v_j.

'c_i' is the number of data points in i^{th} cluster.

'c' is the number of cluster centers.

Standard k-Means Algorithm

Let $X = \{x_1, x_2, x_3, ..., x_n\}$ be the set of data points

$V = \{v_1, v_2, ..., v_c\}$ be the set of centers.

1. We need to select 'c' cluster centers randomly
2. Find out the distance between each data point and cluster centers.
3. Allocate the data point to the cluster center with minimum distance of available cluster centres.

4. Need to recalculate the new cluster center using:

$$v_i = \frac{1}{c_i} \sum_{j=1}^{c_i} x_i$$

where, 'c_i' *shows* the number of data points in i^{th} cluster.

5. Again calculate the distance between each data point and new cluster centers.

6. If No. data point was reassigned then stop, otherwise repeat from step 3.

Approach 2: Using Supervised Learning methods like Back Propagation Algorithm

Supervised neural networks are given data in the form of inputs and targets, the targets being a teacher's specification of what the neural network's input should be[9].

A back propagation neural network is a multi-layer feed-forward neural network consisting of an input layer, a hidden layer and an output layer. The neurons presents in the hidden and output layers have biases, which are connections from the units whose activation is always one.

It uses supervised method for measuring minimum error value and gradient-descent method to examine a global minimum. The training of the back propagation network[10] is done in three stages.

1. Input training pattern.
2. Error calculation.
3. Updation of weights.

BPN Algorithm

The terminologies used are:

x is input training pattern $(x_1, ..., x_i, ..., x_n)$

t is target output pattern $(t_1, ..., t_k, ..., t_m)$ [considering HC output as the golden standard]

α is learning parameter

x_i is ith input unit

v_{0j} is layer jth bias (hidden layer)

w_{0k} is layer kth bias (output unit)

z_j is a hidden unit

d_k is weight adjusted for w_{jk} because of error at y_k which will be sent back to units hidden connected to y_k

d_j is weight adjusted for v_{ij} because of error sent back to unit z_j

Step 0: Initializing learning rate and weights.

Step 1: Repeat Steps 2-9 when stopping condition is false.

Step 2: Repeat Steps 3-8 for pair (x, t).

Phase 1:

Step 3: Input x_i(i varies from 1 to n) is received by input unit and sent to hidden unit.

Step 4: Unit z_j(j varies from 1 to p) summates the weighted input and computes total input:

$$z_{inj} = v_{0j} + \sum_i x_i v_{ij}$$

Output is computed by activation function z_{inj} [(0, 1) or (–1, +1)]

$$z_j = f(z_{inj})$$

Output propagated from hidden layer to output layer.

Step 5: Compute total input y_k(k varies from 1 to m)

$$y_{ink} = w_{0k} + \sum_{j=1}^{p} z_j w_{jk}$$

Output is calculated using activation function

$$y_k = f(y_{ink})$$

Phase 2:

Step 6: Error correction is calculated as δ_k(k varies from 1 to m)

$$\delta_k = (t_k - y_k) f'(y_{ink})$$

Based on error correction, bias and weights are changed and updated:

$$\Delta w_{jk} = \alpha d_k z_j$$

$$\Delta w_{0k} = \alpha d_k$$

Send the error correction δ_k to the previous layer in the backward direction.

Step 7: At hidden unit, inputs are summated:

$$\delta_{inj} = \sum_{k=1}^{m} \delta_k w_{jk}$$

$$\delta_j = \delta_{inj} f'(z_{inj})$$

Based on δ_j, weights, bias are updated:

$$\Delta v_{ij} = \alpha \delta_j x_i$$

$$\Delta v_{0j} = \alpha \delta_j$$

Phase 3:

Step 8: Bias, weights are updated at y_k:

$$w_{jk}(\text{new}) = w_{jk}(\text{old}) + \Delta w_{jk}$$

$$w_{0k}(\text{new}) = w_{0k}(\text{old}) + \Delta w_{0k}$$

Updation of bias and weights happen in each hidden unit:

$$v_{ij}(\text{new}) = v_{ij}(\text{old}) + \Delta v_{ij}$$

$$v_{0j}(\text{new}) = v_{0j}(\text{old}) + \Delta v_{0j}$$

Step 9: Continue the process till actual output tallies with the desired output. Final steady state value shows that the Normal HC brain output which was targeted is arrived at.

4. SCOPE FOR FUTURE STUDY

This study aims at analysing fronto temporal dementia, the magnitude of deterioration using both supervised and unsupervised techniques and performing a comparative study of both approaches by developing mathematical models for the same. The feasibility analysis has to be carried out and implementation of the proposed work is to be carried out using MATLAB software.

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