

# Analysing Fronto Temporal Dementia Using Artificial Neural Networks

<sup>1</sup> Sandhya N, <sup>2</sup> Dr. Nagarajan.S

<sup>1</sup> Research Scholar, Department of MCA, Hindustan University of Technology & Sciences, Padur, Tamil Nadu, India

<sup>2</sup> Professor, Department of Information Technology, Hindustan University of Technology & Sciences, Padur, Tamil Nadu, India

\*Corresponding author Email: <sup>1</sup>sandhya.n.deepak@gmail.com, <sup>2</sup>snagarajan1960@gmail.com

## Abstract

This study aims at studying Fronto Temporal Dementia (FTD) which occurs because of neuro degeneration process. The data of a 60 year old patient including the patient's previous medical history, Neurological examination, Neuro-psychological examinations, and pathological tests along with brain images are obtained. The disintegrations in the demented brain show that neurons fail to transmit signals resulting in loss of network connectivity and reduced functionality of the brain regions. The demented brains are compared against healthy controls (HC). We propose standard back propagation algorithm to compare the demented brain with the Healthy Controls. The mathematical analysis is done.

**Keywords:** FTD, Fronto-temporal Dementia

## 1. Introduction

FTD patients show prominent personality changes. They can't handle personality, copying, computation and lack memory skills. Also, they show speech and language problems. Spelling mistakes are common and talk less. They show mutism in later stages. Vision and hearing are also impacted along with other executive problems. The patient does not recognize photos, cannot remember or name his/her acquaintances.

Patient has no interest in self-grooming, he is adamant and does not take care of personal health. He is not persistent and tractable. The patient exhibits changes in food intake. Depression, lack of insight, dullness are the common symptoms. The patient fails to conduct properly with his/her own self, with others as well as with the society properly thus shows behavioral problems.

### 1.1 Genetics

About 6-10% of patients inherit dementia but the remaining patients develop it by chance. People in the age group of 45-65 get FTD. Out of 100,000 people, approximately 15 are affected by FTD.

### 1.2 Pathology

Many patients inherit FTD. Some patients report variations in TDP-43 which is clinically called as FTLTDP (TDP-43 proteinopathy). A second reason is because of the GRN gene mutations (present on chromosome 17) or because of VCP mutations. Therefore, TAU, TDP-43 are the two proteins causing FTD. When TAU causes FTD, it is called Tauopathy (FTLD-TAU) and when huge amounts of TDP-43 assimilate and causes FTD, it is called FTLTDP. TDP-43 gene is also called as "Progranulin".

## 2. Materials and Methods

### 2.1. SUBJECTS

The data is collected from medical databases. The reports pertaining to patient's Neurological exams, Pathological tests, Neuro-Psychological exams, Scanned brain images are collected. The patient's blood test reports are also collected as these reveal the adequacies or deficiencies of various vitamins, proteins, minerals, proteins, hormones, chemicals and antibodies in the patient's body. The B12 deficiency, Thyroid, HIV AIDS, Cancer, tests are conducted as an essential routine.

**Table:** Demographics of Patient and Healthy Controls (HC)

Group	N	Sex (M/F)	Age
HC	1	1	60 Y
FTD	1	1	60 Y

### 2.2. Neurological Testing

The patient generally undergoes Ophthalmic tests for checking whether the FTD has affected the vision. Tests for hearing abilities are also done. Cardiological tests for knowing the heart functioning, tests diagnosing the physical strength, pertaining to walking, gait, balancing criteria, and co-ordination are done. The patient's responses, reflexes are also tested by various cognitive tests.

### 2.3. Neuropsychological Testing

There are various tests to examine the memory and concentration capabilities, calculations and language skills of the patient. The tests are Mini Mental State Examination (MMSE), Clock Drawing Test (CDT), Mathematical tests. All these give a measure of the magnitude of the effects of FTD. Some patients respond positively to attend

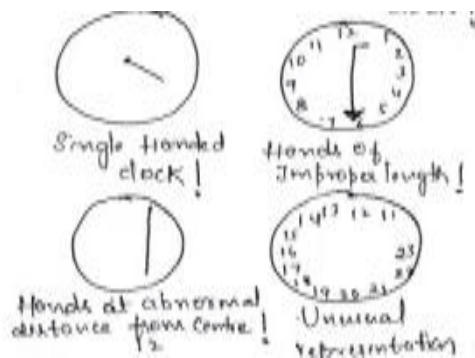


Figure 1: Clock Drawing Test

these tests but some will be reluctant and respond aggressively.

## 2.4. Imaging

Neuro Imaging techniques employed are usually MRI scanning. Fig 2a shows a healthy brain, fig 2b shows the brain with starting stages of Dementia, fig 2c shows later stages and fig 2d shows the final stages of Dementia.

In our study, the frontal, temporal regions are scanned studied. The demented brains are compared with the normally functioning brain (HC) and the deficits are found out.

## 2.5. Methods

In Supervised Learning, the demented brain is compared with the Healthy brain. The desired output or the standard output of the Actual brain is designated as D. The actual output of the Demented brain is termed as A. The difference between A and D is calculated as Error E.  $E = D - A$ . In back propagation network, with the suitable adjustments of weights, training of network is done and addition of weights goes on till the target or the desired output D is obtained.

## 2.6. Discussion

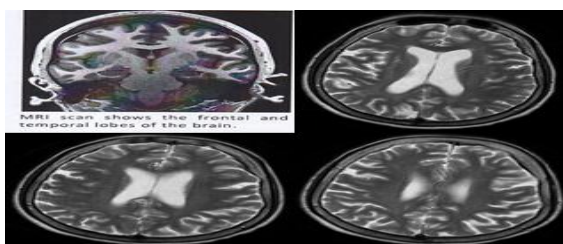


Figure 2-“a,b,c,d (top left): Stages of Dementia

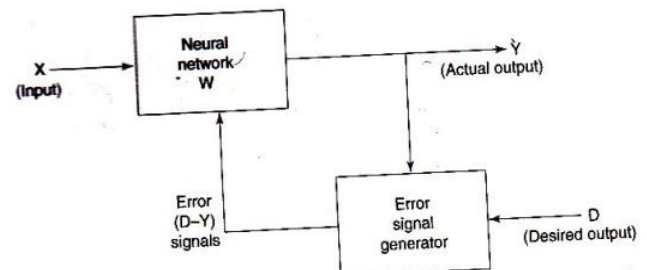
In the study, the interaction between different neurons each having unique strength performs calculations.

An Artificial Neuron may be one neuron, group or even an assembly. Neurons interact as well as have an internal knowledge representation which transforms the incoming signals. Knowledge is specified by threshold which can be adjusted by the learning algorithm to achieve the desired performance expected by the network. Neurons shoot signal when the sum of all incoming signals exceeds threshold value in a given time frame. This is when the neuron gets activated. Activation below threshold gives zero as the output and above the threshold gives output as one. Training is difficult. When the neurons saturate at high activation values, graded neurons concept comes and the output is s-shaped function (sigmoidal). The steepness gives the neuron's response. As the linear activations are being squashed at the output for ranging the outputs between 0 and a maximum value, they are termed as Squashing Functions.

Depending upon the arrangement of axons and dendrites, a simple

or a complex neuron model can be selected. Biological network has many feedback iterations and is not a feed forward one. Given many logical neurons, and an initial state, they interact till a stable state reaches where no further changes can occur (Point Attractor) or changes occurring without any pattern (cyclic attractor) resulting in a Chaotic state.

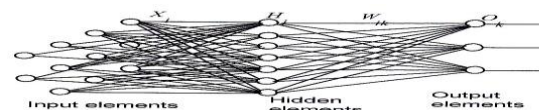
John Hopfield In 1982 proposed a two-state neuron network without self-connections, weights being symmetrical resulting in static configuration. These are called Hopfield Networks. By nature, these are very simple. In Hopfield Network,



learning is by Hebbian learning or Correlation Learning. It states that neurons with positive correlation means there are strong excitatory connections among them, neurons with negative correlation means there are greater inhibitory connections (one active and the other inactive), neurons without any correlation means they have weaker connections or have lost the connections. The study can be extended to analyze other forms of disconnectivity in the neural patterns including multi layers of transmission. Signals with information move from input unit and through various hidden layers which process them and reach the output unit in one direction. The decisions are made at the output unit. Signals can be true or false. Biologically connections can be synaptic, direct connections are called Excitatory and Inhibitory negated connections are called as Inhibitory. Signals can be changed or negated.

**Activity of Neuron = Total Number of true inputs - Total Number of false inputs**

Threshold is compared with the activity and a decision is made whether the neuron should give a true signal or a false signal. There should be a “Majority” level which evaluates that at least half of the inputs should be true to output a true signal. Multi-Layer Perceptron's make use of graded neurons where there is a feed forward flow of information between different layers of neurons.



Network has the strength of the signals as the information and neurons hold activations as the threshold. So the network training is easy, thresholds, strength of connections between neuron pairs will be simplified. If there are many inputs and outputs, MLPs are best suited as they set connections and manage interactions between nodes and knowledge of the nodes to perform hetero associations of input and output layers. Learning algorithm depends on the errors which will be sent from the output layer to the input layer. MLPs are significant as they lessen decision making information to a lesser volume.

## 3. The Ann Approach

The Back propagation algorithm also called as (Back Propagation Network) was developed by Bryson later rediscovered by) Parker can be applied to the study. For feed forward multilayer neural networks, this can be used for training which operates in iterations. For weight calculations, it makes use of Gradient Descent Method. The specialty of the algorithm lies in the fact that

it changes weights to classify-recognize, to respond-memorize, to respond to inputs (same as given in the training)-to generalize. BPN has 3 layers-Input, hidden, Output layer. The hidden and output layers have connections from units with activation value and these connections are called as biases. The bias is called as weights, inputs are sent to BPN and the network could provide an output which is binary (0, 1), bipolar (-1, +1).The activation function increases.

### 4. Mathematical Model

Study keeps the normally functioning brain (Healthy Control – HC) with the demented (FTD) brain images. The white matter/grey matter disintegration analyzed in the image processing clearly shows that there is a difference in the pattern and concentration of the white/grey matter and it is higher in HC when compared to the FTD brain. When the patterns of the network are given to network for training, using Back Propagation, functioning will be as mentioned below.

For training a pattern (x, t) where x being the input and t is the desired or target is given. 'x' produces output at each neuron and an actual output which is termed as 'o'.

A comparison will be made with the targeted output t and error is found as e=t-o. (i.e., difference between obtained output and desired output). BP algorithm finds the rate of error with neuron's activity level. This marks phase-I as the transmission is in a forward direction and now the algorithm goes back to previous layer of the output layer and calculates the weights (the weight between output and previous layer) such that the error is reduced, next algorithm steps back to the previous layer and finds the weights of last hidden layer and its previous layer (next to last layer). Errors are found, new weight values are found proceeding backwards from output layer to the input layer. When the input layer does not show any change, a constant (steady) state is arrived at and the algorithm continues the process with following pair of (x,t). Response will be in forward direction but weights will be in backward direction. Therefore, it gets the name Back Propagation Network (BPN). Mathematically, the description of how the connection strengths will emerge during the training session forms the learning algorithm.

This error depends on the weights value. Weight updation will be based on the learning rate. The learning factors of BPN are listed as Initial Weights, Learning Rate, Momentum, Generalization, Hidden nodes, training data. Three levels of training involved are - giving patterns, finding error and transmitting error back to previous layer, upgradation of weights (t).

#### Algorithm

- The algorithm uses some terms:
- x: input training pattern (x<sub>1</sub>, ...x<sub>i</sub>... x<sub>n</sub>)
- t: target output pattern (t<sub>1</sub>...t<sub>k</sub>...t<sub>m</sub>)
- α: learning parameter
- x<sub>i</sub>: i<sup>th</sup> input unit
- v<sub>0j</sub> : layer j<sup>th</sup> bias (hidden layer)
- w<sub>0k</sub> : layer k<sup>th</sup> bias (output unit)
- z<sub>j</sub> : a hidden unit
- δ<sub>k</sub> : weight adjusted for w<sub>jk</sub> because of error at y<sub>k</sub> which would again be sent back to hidden units and connected to y<sub>k</sub>
- δ<sub>j</sub> : weight adjusted for v<sub>ij</sub> due to error sent back to unit z<sub>j</sub>

- Step 0: Initialize learning rate, weights.
- Step 1: Steps 2 to 9 shall be repeated when stopping condition becomes false.
- Step 2: For each pair (x, t), steps 3 to 8 shall be repeated.

#### Phase 1:

Step 3: Give input x<sub>i</sub> (i varying from 1 to n) is obtained by input unit and transferred to the hidden unit.

Step 4: Unit z<sub>j</sub> (j varying from 1 to p) integrates the weighted input and computes total input:

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

Output is calculated by activation function z<sub>inj</sub> [(0,1) or (-1,+1)]

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

Output goes to output layer from hidden layer.

Step 5: Compute total input y<sub>k</sub> (k varying from 1 to m)

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

Output is measured using activation function

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

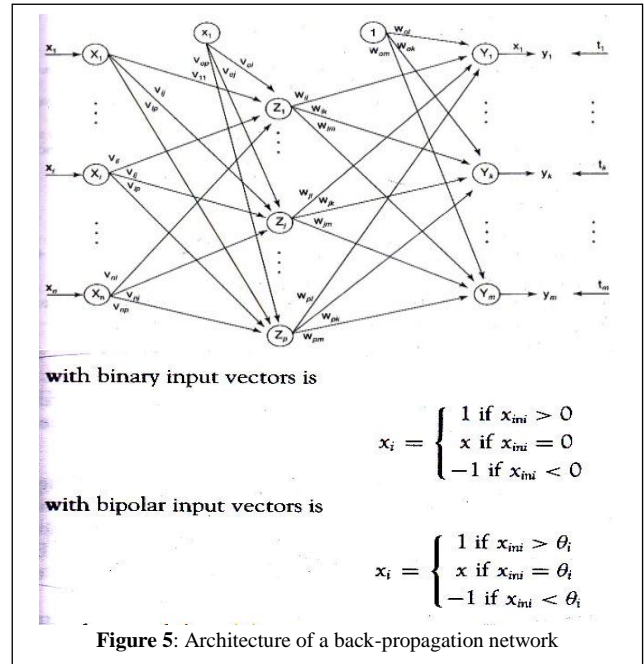


Figure 5: Architecture of a back-propagation network

#### Phase 2:

Step 6: Correction of error is interpreted as δ<sub>k</sub> (k varying from 1 to m)

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

After correcting errors, there will be a change and updation of weights and bias:

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

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

Send the corrected error δ<sub>k</sub> to previous layer in the backward direction.

Step 7: Inputs are summated at the hidden unit:

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

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

Based on δ<sub>j</sub>, weights and bias are updated:

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

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

#### Phase 3:

Step 8: Weights and Bias are updated at y<sub>k</sub>:

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

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

Bias, weights updation occur in each hidden unit:

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

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

Step 9: Process goes on until actual output matches with expected output.

### 4 Conclusion

The difficulty with Multi-Layer Perceptron is that the process of

calculating the weights to obtain a small or a no output error is very tough particularly for the hidden layers. More number of hidden layers will increase complexity of training. This issue is solved by back propagation network which is a speedy, accurate and capable algorithm for the analysis of brain network having multiple layers. A suitable mathematical model is proposed for a complex multi-layer network patterns with BPN.

#### 4.1. Scope for Future Study

The future studies may focus on handling cases with more complex brain atrophy. Patients in last stages of dementia may have complex brain network structures with severely damaged network. They are very cumbersome to analyze. Algorithm handling multiple layer data transmission with complexities and breakdown are needed. Studies may be carried out on such issues.

### 5. Limitations

Various researches have been going on across the world to discover the complex intra and inter physiological connectivity aspects of the brain. This study is completed in a short time span and on a single patient. Data sets places a major constraint. These findings need to be repeated on a higher, independent sample. Here, a single layer network is fast. As the number of hidden layer increases, time taken will be more as with multi-layer networks as it should calculate the error and send error back to the previous layers. The limitation of this study is the small sample size and it is image specific. In cases of patients who are in the later stages of dementia, the demented brain scan shows not so clear network atrophies or almost disintegrated images that will be tough to analyze.

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