

Performance Analysis of various Neural Network functions for Parkinson's disease Classification using EEG and EMG

Angana Saikia, Masaraf Hussain, Amit Ranjan Barua, Sudip Paul

Abstract: Artificial neural network (ANN) is a significant tool for classification of various types of disease using either Biosignals/images or may be any kind of physical parameters. Establishment of appropriate combination of learning, transfer function and training function is a very tedious task. Here, we compared the performance of different training parameters in feed forward neural network for differentiating of Parkinson's disease using human brain (Electroencephalogram) and muscle signals (Electromyogram) features as the input vector. 3 different types of training algorithm with six training functions is used. They are Gradient Descent algorithms (traingd, traingdm), Conjugate Gradient algorithms (traincgb, traingcp) and Quasi-Newton algorithms (trainbfg, trainlm). Proposed work compared the mentioned algorithm in terms of mean square error, classification rate (%), R-value and the elapsed time.

Study showed that trainlm (Levenberg-Marquardt) best fits for larger data set. It showed the highest accuracy rate of 100% with 0 mismatch classification with a best validation mean square error of 0.0040254 in 3 epochs with a elapsed time of 1.12 seconds. The R-value found was 0.9998 which is in nearly equals to 1. Hence, Levenberg-Marquardt can be used as a training function for the classification of any brain disorder

Keywords : Artificial neural network (ANN), Electroencephalogram (EEG), Electromyogram (EMG), Parkinson's disease (PD), Neural Network Classification.

I. INTRODUCTION

Parkinson's disease is a brain impairment which is affected due to insufficient and low formation of dopamine in the human brain. It initially starts with tremor of the hands and slowly increases to the other limbs (1) (2). One suffering from PD losses its control of limb movements. They suffer from muscle rigidity and does not have a proper standing, walking or sitting posture (3). They also come across Sleep disturbances, and many other neuropsychiatric problems (3). PD also results due to continuous contact with toxic drugs like MPTP which is mostly affected in people working in mines. Also the fields workers working in farming sector get exposed to different types chemicals have risk of PD. Many

Revised Manuscript Received on July 22, 2019.

* Correspondence Author: **Sudip Paul**, Department of Biomedical Engineering, North-Eastern Hill University, Shillong, India.

Angana Saikia, Department of Biomedical Engineering, North-Eastern Hill University, Shillong, India.

Masaraf Hussain, Department of Neurology, North Eastern Indira Gandhi Regional Institute of Health and Medical Science, Shillong, India

Amit Ranjan Barua, Department of Neurology, GNRC Hospitals, Guwahati, India

types gene studies are been carried out by researchers to find the genetic causes of PD (4).

Diagnosis of PD brain and muscle signal is a very much essential parameter to find the functional neuronal changes of PD (5). During Parkinson's disease a person muscle and brain coordination gets disturbed. Hence, study of EEG and EMG patterns is a effective tool (6).

Artificial neural network classification is technique to classify various types of system. Most of the disease diagnostic systems are nowadays modeled and designed using neural network classification. ANN is same as that of the biological neurons of our body which consists of inputs, transfer and training functions and the desired output. ANN can be of single-layer or multiple layer neurons. Most of the disease detection system, which is complex dataset, multilayer perceptron (MLP) is used. In MLP network, back propagation (BP) learning algorithm is used (7).

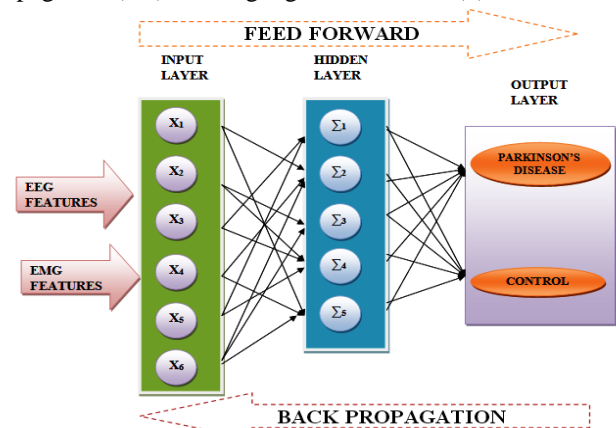


Fig I: ANN Architecture

Some work done in this field is:

Loconsole et al (8) designed a model to classify the PD from healthy subjects on the basis of handwriting on computer vision and sEMG processing. The classification was done using ANN and SVM tools and found that various features on handwriting patterns and classification tools with the sEMG signals acts as effective technique for neurodegenerative disease classification. Berus et. al (9) worked on the classification of PD, using multiple feed-forward ANNs. Features were extracted from 26 voice recordings from each individual. Kendall's correlation coefficient based feature selection technique outperformed among all others which recognized the most effective and accurate voice.

Performance Analysis of various Neural Network functions for Parkinson's disease Classification using EEG and EMG

Multiple ANNs showed higher accuracy of 86.47% during the classification without use of the feature selection.

Srinivasan et. al (10) studied different pre-processing techniques that can be used to classify PD. Classification was done using ANN using PD datasets collected online database. They concluded that combination of different types of processing techniques like Discretization, Resampling, and SMOTE can be effective for classification of the disease.

Orhan et. al (11) compared some techniques such as artificial immune system, feed forward, learning vector quantization and probabilistic neural network algorithms for detection of PD. 10-fold cross validation method was employed for disease detection. The accuracy was 95.6% from artificial immune system, 95.4% from feed forward, 91.4% from learning vector quantization and 96.5% from probabilistic neural networks where probabilistic neural networks showed the highest accuracy rate.

Training Algorithm

Some of the training algorithm used to evaluate for classification of Parkinson's disease from the control subjects are as follows: (12).

Gradient Descent algorithms

This technique updates weights and biases in negative gradient direction of the performance function. Some of them used are: Gradient Descent back propagation algorithm (traingd) and Gradient Descent with Momentum (traindm) algorithm(13).

Conjugate Gradient algorithms

It mostly adjusts the weights where the performance function is decreasing quickly (14). Some are: Scaled Conjugate Gradient (trainscg) (15) and Conjugate Gradient back propagation with Polak-Ribere (16).

Quasi-Newton algorithms

The initiation of this technique is finding of the second derivatives of the performance index at the present values of the weights and biases. They are: BFGS (Broyden– Fletcher – Goldfarb– Shanno) (trainbfg) algorithm and Levenberg– Marquardt back propagation (trainlm) algorithm (17)

II. METHODOLOGY

EEG and EMG was acquired from a signal acquisition system designed by AD instruments, Australia loaded with the Lab Chart software for the signal amplification and filtration. 200 subjects participated in the study from health centers around Meghalaya and Assam. Among the participants, 100 subjects were in the initial illness (1 and 1.5 Stage) of PD and 100 subjects were control (no symptoms of PD). The participants were between the age of 50-70 years. Study was initiated by taking written consent from each subject or their guardian. Signals were acquired for a period of 30 minutes in the morning session of the hospital OPD. The exclusion parameters of the PD patients were:

- Later stages (stage 2-5) of the disease
- Age < 50 years and > 70 years
- Patients with major surgeries and having any implants (metallic) on their body

Placement of electrodes was as follows (Table no 1):

Table 1: Placement of Electrodes

Parameter	Channel 1	Channel 2	Ground
EEG	Frontal brain	Temporal brain	Forehead bone
EMG	Extension carpal ulnaris	Flexor digitorum superficialis	Elbow bone

Features analyzed from EEG are (18) (19): Lyapunov Exponent and Inverse Lyapunov Exponent, Shannon Entropy and EMG were (20): Power, Standard deviation, Root mean square, Variance, Waveform length, Modified median and mean frequency.

The flowchart of the methodology carried out is given in Fig II.

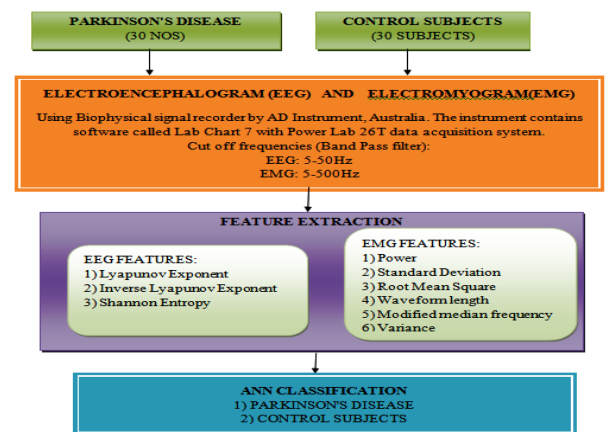


Fig II: Flowchart of Methodology

III. RESULTS AND DISCUSSION

ANN classification and training were carried out in MATLAB 2015(a) using sigmoid function in the hidden layer. The input datasets were the features of EEG (Lyapunov Exponent, Inverse Lyapunov Exponent, Shannon Entropy) and EMG(Power, Standard deviation, Waveform length, Modified median Frequency, Variance and Root Mean Square) extracted from 200 individuals (100 PD and 100 control subjects) and the output datasets were two different classes (PD and Control subjects). During learning, all the inputs were categorized as training (70%), validation (15%) and for testing (15%) sets.

Some of the fixed parameters used are: max_epochs=10000, show=50, performance goal=0.02. The system is compared in terms of elapsed time, no of epoch,

Classification percentage, R on validation. Hidden neurons depend on the size of the input and the output layer. Here we have 9 inputs and 2 outputs. So number of neurons was checked for 5, 7, and 9,10,20,30.

The network is trained till the mean squared error was found to be less than 0.0. It was found that trainscg and trainlm are almost the fastest which outperformed among all other training functions. Table 1 below shows the overall classification percentage and all other parameters for each training function. Trainlm showed the highest classification rate of 100% and also an R value of 0.9998 which signifies a accurate network response with an epoch time of 1.12 seconds.



Table 1: Overall classification percentage

ALGORITHM	TRAINING FUNCTION	NEURONS	BEST VALIDATION MSE	EPOCH	CLASSIFICATION	ELAPSED TIME	MISMATCH	R VALUE
Gradient Descent	traingd	5	0.098733	387	62	120.54	38	0.349
		7	0.028972	29	55	23.98	45	0.9872
		9	0.984022	80	66	9867	34	0.5768
		10	0.016814	49746	65	140.59	35	0.3385
		20	0.038248	615	59	2.43	41	0.3451
		30	0.11569	27	62	1.803	38	0.4563
	traingdm	5	0.30489	34	70	1.879	30	0.8799
		7	0.67392	98	65	23.97	35	0.5647
		9	0.45729	109	50	45.92	50	0.3987
		10	0.023574	1339	81	3.97	19	0.5643
		20	0.063293	10	62	1.582	38	0.3452
		30	0.21658	39	79.31	1.62	20.68	0.35214
Conjugate Gradient	trainseg	5	0.45922	67	77.7	3.45	22.3	0.9874
		7	0.76845	56	79	5.45	21	0.786
		9	0.67368	89	80	4.56	20	0.8675
		10	0.05474	31	80	0.797	20	0.8976
		20	0.009897	37	78	0.703	22	0.8776
		30	0.85889	34	83	0.859	17	0.6578
	traincgp	5	0.98679	45	56	0.879	44	0.9876
		7	0.34562	67	65	0.987	33	0.8758
		9	0.45638	1200	70	2.99	30	0.9864
		10	0.10601	7	79	2.979	21	0.79643
		20	0.33333	10	50	1.737	50	0.57735
		30	0.045124	4	76	1.727	24	-0.4563
Quasi Newton	trainbfg	5	0.93839	5	55	2.678	45	0.7863
		7	0.85639	25	69	1.77	31	0.7689
		9	0.76835	89	75	0.99	25	0.98753
		10	0.012399	5	78	2.28	22	0.5637
		20	0.010487	5	56	1.88	44	0.6574
		30	0.27778	4	50	1.911	50	0.57733
	trainlm	5	0.000234	6	96	1.88	4	0.1259
		7	0.000215	10	98	0.78	2	0.9856
		9	0.000012	15	100	0.02	0	0.9879
		10	0.0040254	3	100	1.12	0	0.9998
		20	0.027757	30	89	1.928	11	0.9968
		30	0.0048949	25	90	1.14	10	0.9876

Performance Analysis of various Neural Network functions for Parkinson's disease Classification using EEG and EMG

IV. CONCLUSION

Feed-forward back propagation neural network is a significant tool for classification of neurodegenerative disorders like PD, Alzheimer's disease etc. with effective combination of training, transfer and learning functions. In our study, it was found that there was no differences between the recognition rates for trainscg and trainlm. On the other hand, it was seen that the training speed of trainlm is much greater. If we see the overall network performance considering all the parameters, trainlm outperforms as compared to other training functions with respect to classification of brain disorders using EEG and EMG. Hence, it can be concluded that trainlm is the effective function for the classification of any kind of neurodegenerative disorders with respect to both less time for execution with more number of input data.

CONFLICT OF INTEREST

Authors confirm that there is no conflict of interest.

ACKNOWLEDGEMENT

Ethically approved by:

- a) Institutional Ethical Committee (NEHU), Sanction order no: IECHSP/2017/42 and NEIGR/IEC/M6/F13/18.

REFERENCES

1. H. Checkoway, L.M. Nelson, "Epidemiologic approaches to the study of Parkinson's disease etiology," *Epidemiology*, 1999, pp.327-36.
2. A. Saikia, V. Majhi, M.Hussain, S.Paul, A.Datta, "Tremor Identification Using Machine Learning in Parkinson's Disease," *Early Detection of Neurological Disorders Using Machine Learning Systems: IGI Global*, 2019, pp.128-51.
3. I. Boersma, J. Jones, C. Coughlan, J. Carter, D. Bekelman, J. Miyasaki, "Palliative care and Parkinson's disease: caregiver perspectives," *Journal of Palliative Medicine*, 2017;20(9):930-8.
4. De Rijk M, Breteler M, Graveland G, Ott A, Grobbee D, Van der Meche F, et al. Prevalence of Parkinson's disease in the elderly: the Rotterdam Study. *Neurology*. Vol. 45, no.12,1995, pp.2143-6.
5. G. Pfurtscheller, Da Silva FL, "Event-related EEG/MEG synchronization and desynchronization: basic principles," *Clinical neurophysiology*, Vol. 110, no. 11 1999, pp.1842-57.
6. Y.Z.Huang, F.Y. Chang, W.C. Liu, Y.F.Chuang, L.L.Chuang, Y.J. Chang, "Fatigue and muscle strength involving walking speed in Parkinson's disease: insights for developing rehabilitation strategy for PD," *Neural plasticity*. 2017.
7. R.Sathya, A. Abraham, "Comparison of supervised and unsupervised learning algorithms for pattern classification," *International Journal of Advanced Research in Artificial Intelligence*, Vol. 2, no. 2, 2013, pp.34-8.
8. C. Loconsole, G.D. Cascarano, A. Brunetti, G.F. Trotta, G. Losavio, V. Bevilacqua, "A model-free technique based on computer vision and sEMG for classification in Parkinson's disease by using computer-assisted handwriting analysis," *Pattern Recognition Letters*, Vol.121, 2019, pp.28-36.
9. L. Berus, S. Klancnik, M. Brezocnik, M. Ficko, "Classifying Parkinson's Disease Based on Acoustic Measures Using Artificial Neural Networks", *Sensors*, Vol. 19, no.1, 2019, pp.16.
10. S.M. Srinivasan, M. Martin, A. Tripathi, "ANN based Data Mining Analysis of the Parkinson's Disease," *International Journal of Computer Applications*, Vol.168, no.1, 2017.
11. O. Er, O. Cetin, M.S. Bascil, F.A. Temurtas, "Comparative study on parkinson's disease diagnosis using neural networks and artificial immune system," *Journal of Medical Imaging and Health Informatics*, Vol. 6, no.1, pp. 264-8.

12. M.K.S. Alsmadi, K.B. Omar, S.A.Noah, "Back propagation algorithm: the best algorithm among the multi-layer perceptron algorithm," *International Journal of Computer Science and Network Security*, Vol.9, no.4, 2009, pp. 378-83.
13. S. Ali, K.A. Smith, "On learning algorithm selection for classification," *Applied Soft Computing*, Vol. 2, no, 2, pp. 119-38.
14. M.H. Beale, M.T. Hagan, H.B. Demuth, "Neural network toolbox," *User's Guide*, MathWorks, Vol. 2, 2010, pp. 77-81.
15. W.W. Hager, H.A. Zhang, "Survey of nonlinear conjugate gradient methods," *Pacific journal of Optimization*, Vol. 2, no. 1, 2006, pp. 5-58.
16. M.F. Møller, "A scaled conjugate gradient algorithm for fast supervised learning," *Neural networks*, Vol. 6, no. 4, 1993, pp. 525-33.
17. M.H. Beale, M.T. Hagan, H.B. Demuth, "Neural network toolbox user's guide," *The MathWorks Inc*, 1992.
18. A. Saikia, M. Hussain, A.R. Barua, S.Paul, "EEG-EMG correlation for parkinson's disease," *International Journal of Engineering and Advanced Technology*, Vol. 8, no.6,2019, pp.1179-85.
19. A. Saikia, M. Hussain, A.R. Barua, S. Paul, "Significance of Lyapunov Exponent in Parkinson's Disease Using Electroencephalography," 2019 6th International Conference on Signal Processing and Integrated Networks (SPIN); 2019: IEEE.
20. A. Andrews, E. Morin, L. McLean, "Finger movement classification using forearm EMG signals," 2008.

AUTHORS PROFILE



Angana Saikia: She is currently working as Research Associate in the dept of BME, NEHU. Previously she was working as a Senior Research Fellow (SRF) Department of Biomedical Engineering, NEHU, Shillong. She completed her B.E from Guwahati University, Assam and her M-Tech in Bioelectronics from Tezpur Central University. She is currently also pursuing her PhD in the Department of Biomedical Engineering, NEHU, Shillong. She has many research publications in reputed journals and attended various international conferences in USA. Recently she wrote a book on "Overview of Parkinson's disease and its Relevance" published by LAP LAMBERT Academic Publishing, Germany. She also has many research publications and attended many International conferences.



Masaraf Hussain: Dr. Hussain is presently working as a assistant Professor in department of Neurology, North Eastern Indira Gandhi Institute of Health and Medical Science, Shillong. He completed his MBBS in the year 1998 and MD in Medicine in the year 2002 from NSCB Medical college, Jabalpur(MP). In 2012 he completed his DM in Neurology from Guwahati Medical College. His specialization is mainly with various movement disorders. He has many research publications in reputed journals. In was associated to NEIGRIHMS, shillong since 2003, where he joined as a senior resident doctor and has been promoted to Assistant Professor in Department of Medicine in the year 2007.



Amit Ranjan Barua: Dr. Barua is presently working a neurologist in Guwahati Neurological Research Center (GNRC hospitals), Guwahati. His specialization is mainly movement disorder and Parkinson's disease. He is also specialized in motor and cognitive disorders. He completed his MBBS and MD from Guwahati Medical College, Guwahati. Later he completed DNB in Neurology from Guwahati Medical College, Guwahati.

He has attended various international conferences in India as well as abroad. His publications can also be seen in the various reputed journals related to medical and health care sector. He has also been an active member of various medical society and known for his immense contribution s in various movement disorders.





Sudip Paul: Dr Paul is the Assistant Professor in Dept of BME, NEHU, and Shillong. His B-Tech and M-tech both were specialized in Biomedical Engineering from Banaras Hindu University, India. He completed his PhD from IIT (BHU). His expert areas are Electrophysiology, Biomedical Instrumentation, Biomedical Signal Processing,

Artificial Organ and Rehabilitation System. He also completed his Post Doc in Computer Science and Software Engineering from The University of Western Australia, Perth. He has several research papers in reputed journals in the field of Electrophysiology, Biomedical Instrumentation, Biomedical Signal Processing, Artificial Organ Rehabilitation System, Machine learning and ANN, Neural mechanism and Cognitive disorders.