BULGARIAN
ACADEMY
of SCIENCES
1869

IICT
Institute of Information and
Communication Technologies

Biomedical Signal Processing Experiences

Ayyoob Jafari

Biomedical Signal Processing Experiences

- Parkinson Gate Signal Processing
  - A gray box model for Gait signal generation
  - Spectral Analysis of Parkinson Gait Signal
  - Chaotic Features of Gait in Parkinson?
- Parkinson Voice Signal Processing
- Retinal Images Based Human Identification
- Ultrasound Vessels Image Processing
- Emboli detection from artifact in TCD signal
- VLP Detection

Parkinson Gate Signal processing

(Gray Box Neural Network Model)

- In this study, we focused on the gait of Parkinson’s disease (PD) and presented a gray box model for it. We tried to present a model for basal ganglia structure in order to generate stride time interval signal in model output for healthy and PD states. Because of feedback role of dopamine neurotransmitter in basal ganglia, this part is modelled by “Elman Network”, which is a neural network structure based on a feedback relation between each layer. Remaining parts of the basal ganglia are modelled with feed-forward neural networks. We first trained the model with a healthy person and a PD patient separately. Then, in order to extend the model generality, we tried to generate the behaviour of all subjects of our database in the model.

Parkinson Gate Signal processing

(Gray Box Neural Network Model)

- Hence, we extracted some features of stride signal including mean, variance, fractal dimension and five coefficients from spectral domain. With adding 10% tolerance to above mentioned neural network weights and using genetic algorithm, we found proper parameters to model every person in the used database. The following points may be regarded as clues for the acceptability of our model in simulating the stride signal: the high power of the network for simulating normal and patient states, high ability of the model in producing the behaviour of different persons in normal and patient cases, and the similarities between the model and physiological structure of basal ganglia.

Parkinson Gate Signal processing
(Gray Box Neural Network Model)

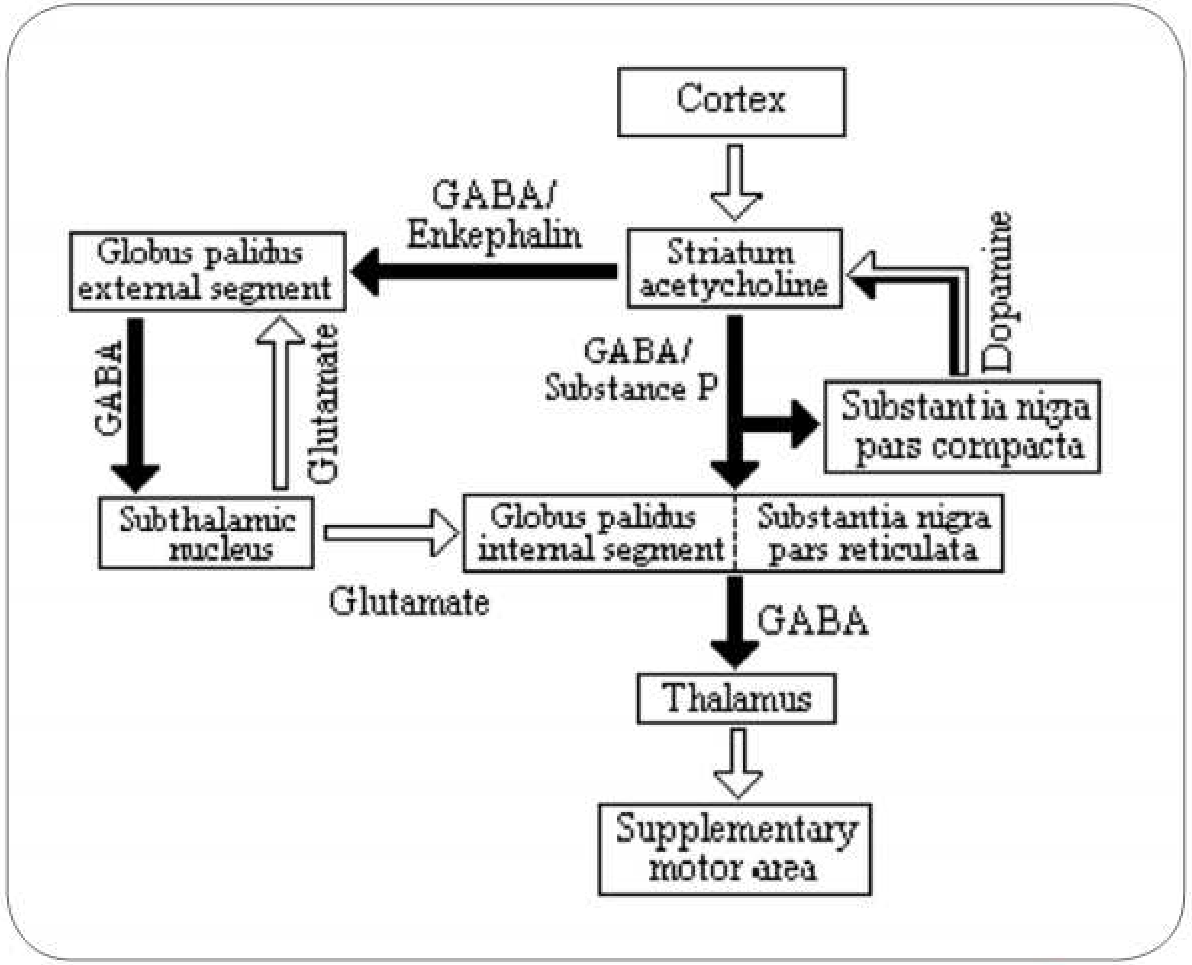
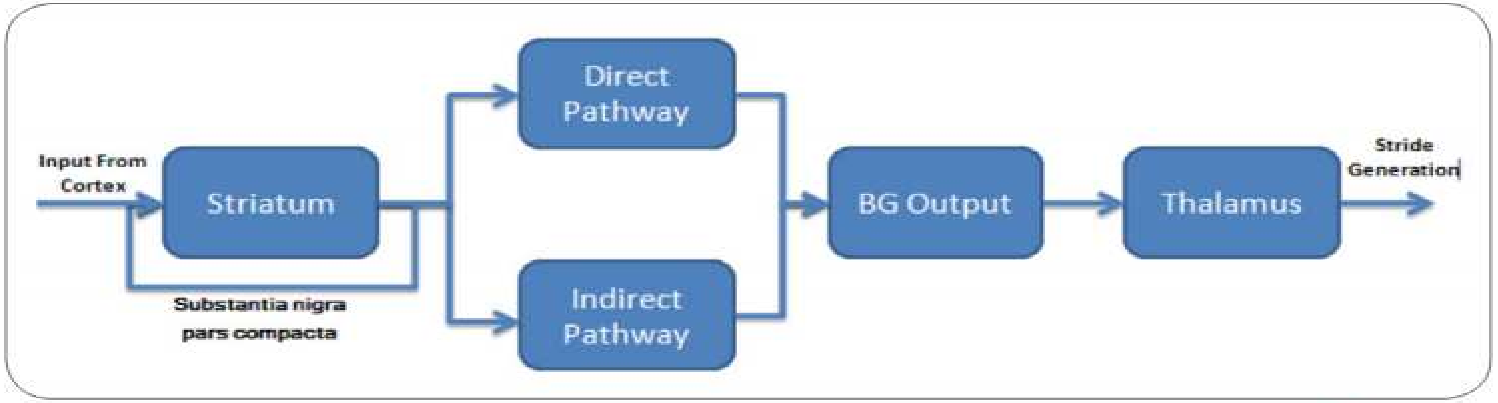


Figure 1. Basal ganglia and their components [6].

NEUROSCIENCE

Parkinson Gate Signal processing
(Gray Box Neural Network Model)



Figu

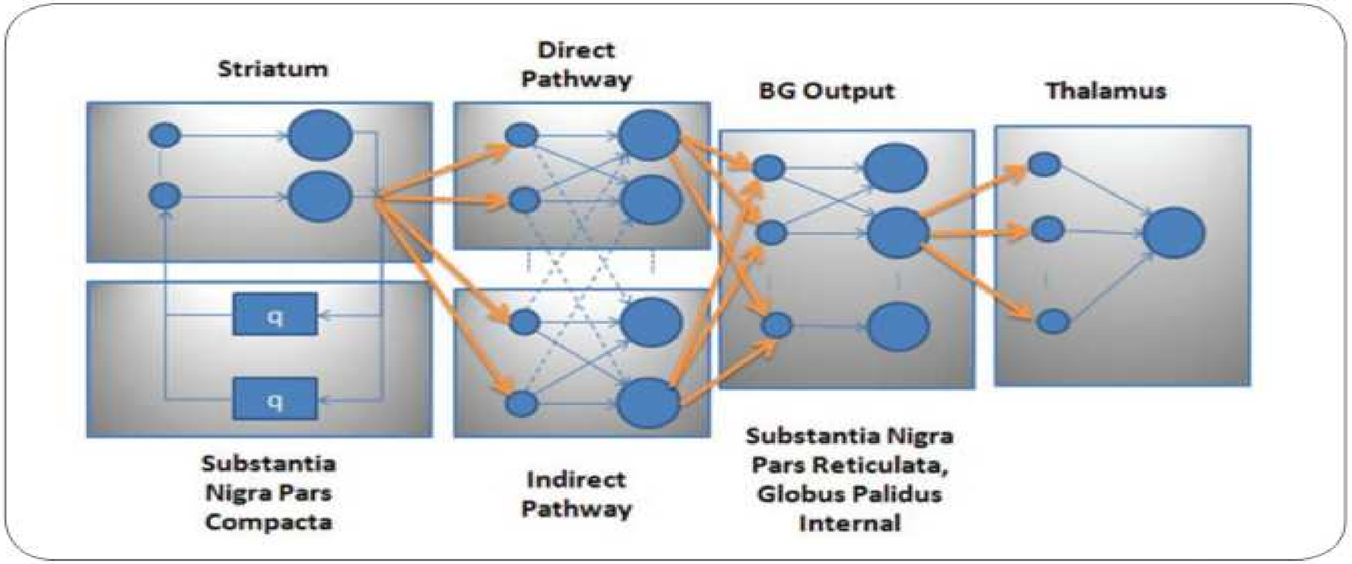


Figure 3. Schematic representation of the presented model.

Parkinson Gate Signal processing
(Gray Box Neural Network Model)

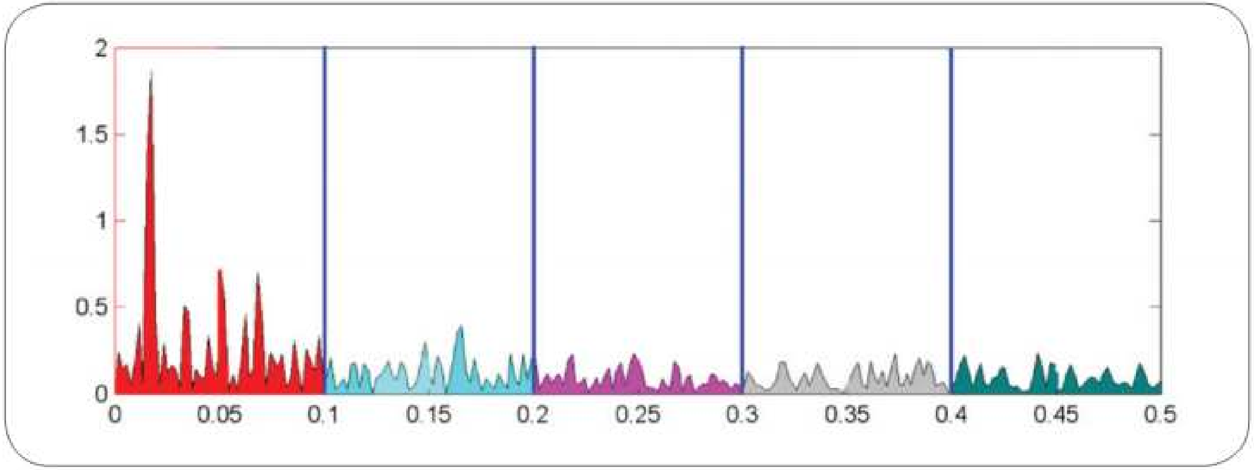
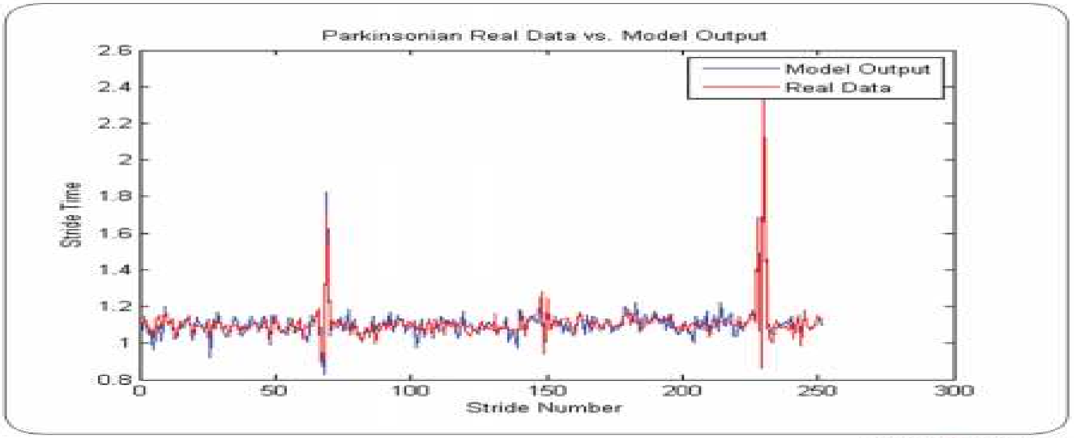


Figure 5. Feature extraction from spectral analysis.

NEUROSCIENCE



NEUROSCIENCE

Figure 9. Representation of real and simulated signals of a PD patient simultaneously.

Parkinson Gate Signal processing

(Spectral Analysis of Gait Signal)

At present, there is no quantitative test to definitely diagnose Parkinson's Disease. For this purpose, we computed the power spectra of stride and swing signals of normal persons and patients. The evaluation of power spectra in stride on normal group shows that the main peak of the frequency range is in the rangeof0.018to0.02 Hz. In contrast, the main peak frequency is different between different PD patients..

Parkinson Gate Signal processing (Spectral Analysis of Gait Signal)

- Our studies on swing signal and its power spectra show that there is a significant difference between the amplitude of frequency components between normal and PD groups. Patients show power spectra amplitude even more than 10 times greater than that of normal patients. The clinical data were obtained from physionet.org. Power spectra of left stride, right stride, and left swing were computed. Frequency domain of power spectra was divided into ten parts and then the surface area under each part was calculated. We used artificial neural network for classification of these groups. The clinical data was divided into two parts, training and test sets. An accuracy of 93.75%was obtained during training.

Chaotic Features of Gait in Parkinson

- t seems that considering PD from dynamical systems perspective is a relevant method that may lead to better understanding of the disease. There is some ambiguity about chaotic nature in PD symptoms and normal behaviour. Some studies claim that normal gait has somehow a chaotic behaviour and disturbed gait in PD has decreased chaotic nature. However, it is worth noting that the basis of this idea is the difference of fractal behaviour in gait of normal and PD patients, which is concluded from Long Range Correlation (LRC) indices. Our primary calculations show that a large number of normal persons and patients have similar LRC. It seems that chaotic studies on PD need a different view.

Chaotic Features of Gait in Parkinson

Because of short time recording of symptoms, accurate calculation of chaotic features is tough. On the other hand, long time recording of symptoms is experimentally difficult. In this research, we have first designed a physiologically plausible model for normal and PD gait. Then, after validating the model with neural network classifier, we used the model for extracting long time simulation of stride in normal and PD persons. These long time simulations were then used for calculating the chaotic features of gait. According to change of phase space behaviour and alteration of three largest lyapunov exponents, it was observed that simulated normal persons act as chaotic systems in stride production, but simulated PD does not have chaotic dynamics and is stochastic. Based on our results, it may be claimed that normal gait has chaotic nature which is disturbed in PD state. Surely, long time real recordings from gait signal in normal persons and PD patients are necessary to warranty this hypothesis.

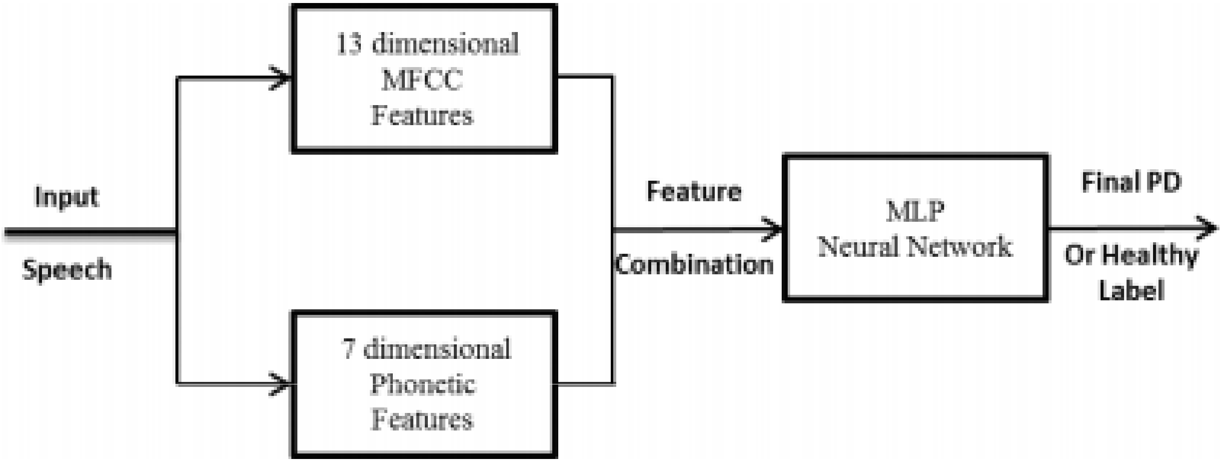
Parkinson Voice Signal Processing

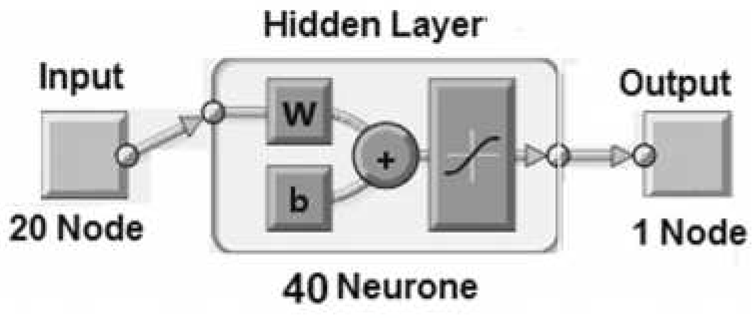
- This research presents a combinational feature extraction approach using voice utterances for discriminating Parkinson's disease (PD) patients from healthy people. The proposed feature set consists of seven nonlinear phonetic features and 13 usual Mel-frequency cepstral coefficients (MFCCs). In this research, two new features EDC-PIS (energy distribution coefficient of peak index series) and EDC-PMS (energy distribution coefficient of peak magnitude series)
- were introduced, which are robust to many uncontrollable confounding effects such as noisy environments. The nonlinear phonetic features comprise recurrent period density entropy (RPDE), detrended fluctuation analysis (DFA),noise-to-harmonic ratio (NHR), fractal dimension (FD), pitch period entropy (PPE), EDC-PIS, and EDC-PMS.

Parkinson Voice Signal Processing

MFCC features have been widely used in voice processing tasks and therefore are good candidates to be used for the voice processing of PD subjects. The dataset used was composed of a range of 200 voice utterances from 25 PD subjects with different severity levels, and 10 normal persons. Using voice utterances from healthy and PD subjects, a 20-dimensional final feature set using MFCCs and nonlinear features is composed. Finally, a multilayer perceptron (MLP) neural network classifier with one hidden layer was used to discriminate PD subjects. Also, the proposed system was used for classification of mild and severe PD subjects. We obtained 97.5% overall correct classification performance for the discrimination of PD. In addition, we obtained 95.5% overall accuracy for the discrimination of mild and severe PD subjects.

Parkinson Voice Signal Processing





(B)

Fig. 6 (**A**) MLP neural network with a [3-4-1] topology. (**B**) Final MLP classifier topology.

Parkinson Voice Signal Processing

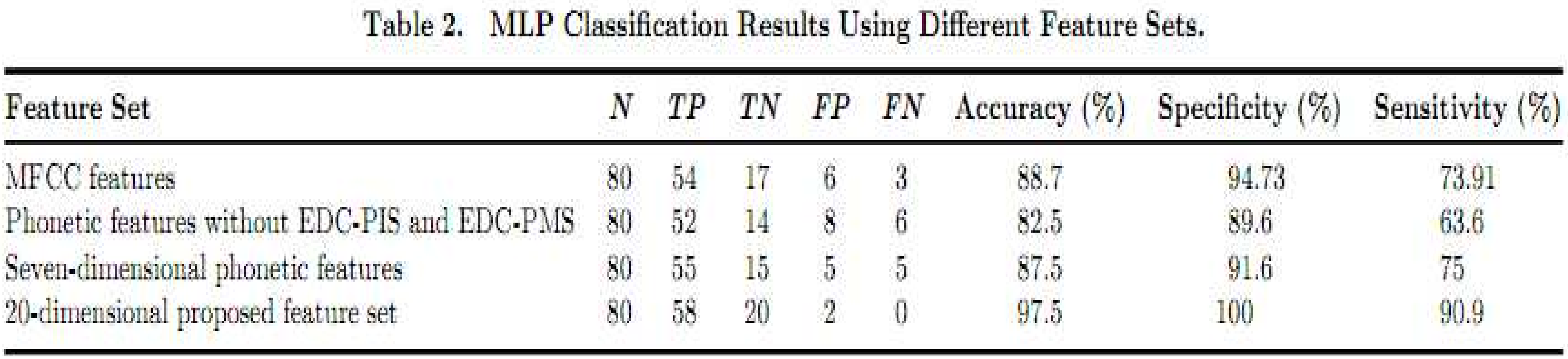


Table 2. MLP Classification Results Using Different Feature Sets.

Feature Set	*N*	*TP*	*TN*	*FP*	*FN*	Accuracy (%)	Specificity (%)	Sensitivity (%)
MFCC features	80	54	17	6	3	88.7	94.73	73.91
Phonetic features without EDC-PIS and EDC-PMS	80	52	14	8	6	82.5	89.6	63.6
Seven-dimensional phonetic features	80	55	15	5	5	87.5	91.6	75
20-dimensional proposed feature set	80	58	20	2	0	97.5	100	90.9

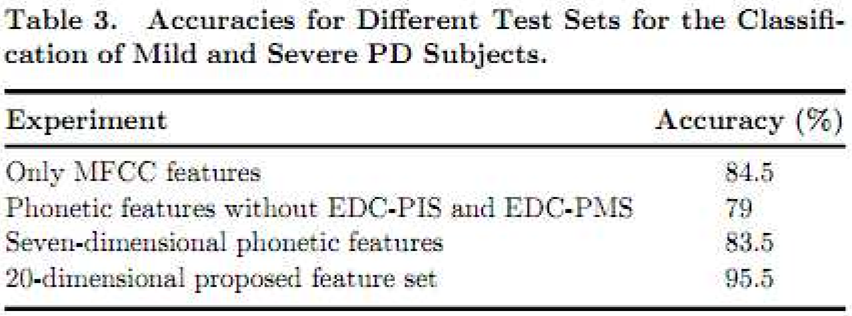


Table 3. Accuracies for Different Test Sets for the Classification of Mild and Severe PD Subjects.

Experiment	Accuracy (%)
Only MFCC features	84.5
Phonetic features without EDC-PIS and EDC-PMS	79
Seven-dimensional phonetic features	83.5
20-dimensional proposed feature set	95.5