Data Segments with Different Wavelet Bands and Stages of Voting for the Discrimination of Parkinson Tremor from Essential Tremor Using Accelerometer and EMG Signals

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***Abstract*—A new idea for the identification of Parkinson tremor from essential tremor is presented in this paper. Segments of data of accelerometer and surface EMG signals are used with different wavelet bands for the idea of discrimination of Parkinson tremor from essential tremor. The data used are from the University of Kiel, Germany. The data are 41 training subjects: 21 with Essential-tremor (ET) and 19 with Parkinson-disease (PD). Another 40 subjects of test data have 20 PD and 20 ET subjects, are used to test the technique. In this study three different data segments, each with its best fit wavelet band for each signal are selected. Then, a two-stages voting between the results is obtained. The discrimination efficiency on test data resulted 100% sensitivity, 85% specificity and 92.5% accuracy.**

***Index Terms*—Wavelet-band, Data-Segment, Voting, Parkinson Tremor, Essential Tremor, EMG, Accelerometer Signals, Discrimination**

I. Introduction

There are two very spread disorders that cause involuntary movements: Parkinson tremor (PD), which is considered the second most common form of all pathological tremors [1] and Essential tremor (ET), which is the top ranked neurological problem [2], [3].

Parkinson Disease (PD) is a neuro-degenerative disease caused by the loss of dopamine receptors which control and adjust the movement of the body [4]. The tremor may be the most well-known sign of Parkinson's disease [4].

Essential Tremor (ET) is a neurological movement disorder that causes shaking of hands, head, voice and sometimes the legs and trunk [5], [6].

Although PD and ET are considered distinct disorders, there is an overlap in some clinical features [7], [8]. Therefore, an accurate diagnosis of both of the diseases is difficult and it perhaps takes years to receive a diagnosis [9]. Another diagnostic test is neuro-imaging techniques, but these techniques are not routinely available [9]. Signal spectral analysis of tremor recorded by accelerometer and surface EMG is a common approach since it is easier for the patients, much lower-priced and takes shorter time than the usual clinical tests.

The wavelet-based soft-decision technique for discriminating ET from PD using both accelerometer and two surface EMG signals achieved 85% accuracy on this data [10]. However, the efficiency can be improved with this method. That technique was combined with the statistical signal characterization method on both accelerometer and EMG signals in frequency-domain and in Hilbert-domain to discriminate the same data in [11]. Although, after a voting between the results of all the methods, the accuracy also resulted in 88.75% on the overall data, this technique needed at least three different methodologies to achieve this efficiency.

In this study, different segments of the data are selected and the wavelet-based soft-decision method is applied to extract different wavelet bands. Each segment with its best fit wavelet band for each signal is obtained. Then, a two sequence of voting between the results is performed.

TABLE I. Results Based on Different Segments With Different Bands on Acc Signal (Test Data)

Accelerometer (ACC) Signal			
Based On		**Correct subjects**	**Total /20**
Segment 5 with Band 5	PD	1,2,4,6,7,8,9,10,11,12, 15,16,17,20	14
	ET	3,5,6,7,8,9,10,12,13,15, 16,17,20	13
Segment 6 with Band 11	PD	1,3,4,5,6,7,8,11,14,15,16, 17,18,19,20	15
	ET	5,6,8,9,11,13,14,16, 17,18	10
Segment 10 with Band 8	PD	1,3,5,6,7,8,9,10,11,12, 14,15,16,18,19	15
	ET	4,5,6,7,8,9,10,11, 14,18	10
Voting	PD	1,3,4,5,6,7,8,9,10,11,12, 14,15,16,17,18,19,20	18
	ET	1,4,6,7,8,10,11,14, 15,16,17,18	12

The organization of this paper is as the following:

Manuscript received July 17, 2013; revised September 9, 2013.

doi: 10.12720/jomb.3.2.128-132

In section 2, the data subjects are described. Section 3 explains the main idea of the wavelet-based soft-decision method including the new technique of using it, the segmentation of the data as well as the stages of voting used. Section 4 contains the results of the implementation and discussion of the results. Section 5 contains the conclusion and comments for future work.

II. Data Subjects

Subjects for this study were collected and recorded from the Hospital of Kiel University in Germany. The subjects are 39 patients with Parkinson Disease and 41 patients with Essential Tremor movement disorder. All the patients are suffering from a moderate to a severe tremor that cannot be differentiated easily using clinical tests alone.

The data are divided into two groups: The one used for training (trial data) and the one used for the testing (test data). The trial data consist of 19 PD subjects and 21 ET subjects. The test data consist of 20 PD subjects and 20 ET subjects. PD and ET data were recorded using both accelerometer (ACC signal) and two surface EMG signals EMG1 and EMG2 recording the extensor and flexor carpi-ulnaris muscles, respectively.

III. Implementation Technique

A. Wavelet-based Soft-decision (WSD) Method

The WSD [10], [11] is used to extract the wavelet bands (the low-pass and high-pass filtering) which are computed for all branches up to a certain stage m to obtain 2^m sub-bands. Then the probability of the signal to be concentrated in the low-frequency band is the ratio of the power of the low-pass signal to the total power of the signal. The probability of the high-frequency band is (1- the probability of the low-frequency band). Then the power entropy is computed using the following equation: Entropy = Probability * $\log_2$ (1 / Probability).

TABLE II. Results Based on Different Segments with Different Bands on EMG1 Signal (Test Data)

EMG1 Signal			
Based On		**Correct subjects**	**Total /20**
Segment 2 with Band 13	PD	1,2,3,4,5,6,8,9,10,11,12,13, 14,15,17,18,19,20	18
	ET	1,2,3,5,9,13,14,16,17, 19,20	11
Segment 5 with Band 6	PD	2,3,4,8,10,11,12,13, 14,15,16,17,20	13
	ET	1,2,5,6,7,8,9,10,11,13,14,15, 16,17,19,20	16
Segment 11 with Band 6	PD	1,2,3,4,5,6,7,9,11,12,14, 16,17,18,20	15
	ET	1,2,6,7,8,9,10,11,13,14,15, 16,17,18,19,20	16
Voting	PD	1,2,3,4,5,6,8,9,10,11,12,13, 14,15,16,17,18,20	18
	ET	1,2,5,6,7,8,9,10,11,13,14, 15,16,17,19,20	16

WSD method is used to find the power entropy of the first 20 bands (between 0 to 31.25 Hz) for each subject because most of the researchers found that the peak in the EMG tremor spectrum is at a frequency of 5 to 6 Hz. It may differ between both tremors. Researchers notice also that at the double of those frequencies (first harmonic), there is also a peak in the spectrum and so on, so it is better to investigate the tremor spectrum up to 18-20 Hz [11].

B. Wavelet Bands with Different Segments of the Data

The training subjects (19 PD and 21 ET subjects) are used. For each subject (PD or ET), there are three different data from ACC, EMG1 and EMG2 signals.

Each data (for each subject) of the three signals is sliced into 11 segments. Each segment is a 1000 sample length. Each segment was used on every wavelet band of the 20 bands. For each segment, a decision is taken whether the subject is PD or ET. A final decision is taken on the subject to be PD if the subject is classified as PD for 2 or more segments from the same signal, and the same procedure is used to classify ET subject.

The idea of this study is to use three different segments, each with its best fit band for the ACC signal. Afterwards, a voting between the three results is obtained to be the final result of the ACC signal. Then, the same procedure is repeated for EMG1 and EMG2 signals. Finally, another last voting is applied between the final results of the three signals; and this will be the concluding result.

C. Discrimination Performance

Sensitivity, specificity and accuracy are used to evaluate the classification [12]. Such that:

$$Sensitivity = \frac{(Number\ of\ true\ positive\ assessment)}{(Number\ of\ all\ positive\ assessment)}$$

$$Specificity = \frac{Number\ of\ true\ negative\ assessment}{Number\ of\ all\ negative\ assessment}$$

$$Accuracy = \frac{Number\ of\ correct\ assessments}{Number\ of\ all\ assessments}$$

TABLE III. Results Based on Different Segments with Different Bands on EMG2 Signal (Test Data)

EMG2 Signal			
Based On		**Correct subjects**	**Total /20**
Segment 5 with Band 9	PD	2,4,5,6,9,12,13,14, 16,18,19	11
	ET	1,2,3,5,6,8,9,11,13,14,15 ,16,17,18,19,20	16
Segment 8 with Band 7	PD	1,2,3,4,5,7,8,9,10,11,13, 14,15,16,17,19	16
	ET	1,3,5,6,8,9,10,11,13,14 ,15,16,17,18,19,20	16
Segment 11 with Band 8	PD	2,3,4,5,6,7,8,9,11,15, 16,17,18,19,20	15
	ET	2,3,4,5,6,8,9,11,13,14, 16,18,19,20	14
Voting	PD	2,3,4,5,6,7,8,9,11,13,14, 15,16,17,18,19	16
	ET	1,2,3,5,6,8,9,11,13,14,15, 16,17,18,19,20	16

IV. Results and Discussion

A. Results from Accelerometer Signal (ACC)

For each training subject, the power entropy of the 20 bands from the ACC signal is computed. Also, the subject data is segmented into 11 segments. Using each segment to obtain the power entropy of the 20 bands, the decision is taken whether the subject is PD or ET from the trial data. Then, the data under test is also segmented and classified as PD or ET by comparing it to the result from the training.

Table I shows the result of discriminating the test data using the voting between:

1. The results of using segment 5 with frequency band 5 (See Appendix A, Fig. A.1).
2. The results of using segment 6 with frequency band 11 (See Appendix A, Fig. A.2).
3. The results of using segment 10 with frequency band 8 (See Appendix A, Fig. A.3).

The selection of the segments and the associated band is not random. Actually, a blind search is used to have as best classification results as possible. After the voting, 18 PD out of 20 are correctly identified and 12 ET out of 20 are correctly recognized. The evaluation results for this stage are: Sensitivity = 90%, Specificity = 60% and accuracy = 75%.

B. Results from EMG1 Signal

The previous procedure used with ACC signal is repeated with EMG1 signal. Table II shows the result of discriminating the test data using the voting between:

1. The results of using segment 2 with frequency band (See Appendix B, Fig. B.1).
2. The results of using segment 5 with frequency band 6 (See Appendix B, Fig. B.2).
3. The results of using segment 11 with frequency band 6 (See Appendix B, Fig. B.3).

After the voting, 18 PD out of 20 are correctly identified and 16 ET out of 20 are correctly identified.

TABLE IV. RESULTS OF THE FINAL VOTING ON THE DIFFERENT SIGNALS FROM THE TEST DATA

Final Voting			
Signal		**Correct subjects**	**Total 20**
ACC	PD	1,3,4,5,6,7,8,9,10,11,12,14, 15,16,17,18,19,20	18
	ET	1,4,6,7,8,10,11,14,15, 16,17,18	12
EMG1	PD	1,2,3,4,5,6,8,9,10,11,12,13, 14,15,16,17,18,20	18
	ET	1,2,5,6,7,8,9,10,11,13,14, 15,16,17,19,20	16
EMG2	PD	2,3,4,5,6,7,8,9,11,13,14, 15,16,17,18,19	16
	ET	1,2,3,5,6,8,9,11,13,14,15, 16,17,18,19,20	16
Final Voting	PD	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15,16,17,18,19,20	20
	ET	1,2,5,6,7,8,9,10,11,13,14, 15,16,17,18,19,20	17

The evaluation results for this stage are: Sensitivity = 90%, Specificity = 80% and accuracy = 85%.

C. Results from EMG2 Signal

The same procedure used with ACC and EMG1 signals is repeated with EMG2 signal. Table III shows the result of discriminating the test data using the voting between:

1. The results of using segment 5 with frequency band 9 (See Appendix C, Fig. C.1).
2. The results of using segment 8 with frequency band 7 (See Appendix C, Fig. C.2).
3. The results of using segment 11 with frequency band 8 (See Appendix C, Fig. C.3).

After the voting, 16 PD out of 20 are correctly identified and 16 ET out of 20 are correctly classified. The evaluation results for this stage are: Sensitivity = 80%, Specificity = 80% and accuracy = 80%.

D. Final Voting for Final Result

A last voting is applied on the results from the three signals. Table IV shows the results of the last voting on the test data. The sensitivity is raised to 100%, the specificity is increased to 85% and the accuracy is improved to 92.5% on the test data.

E. Comparison Between the Use of Segments of Data vs. the Use on the Entire Data at Once

Sometimes the use of the data as a whole might be misleading. In order to extract the wanted classification information, the data is used fully. However, the discrimination results were not that promising. Therefore, in this paper, the use of some divisions of the data (segments) resulted in higher evaluation results.

Fig. 1 shows a comparison of the use of WSD on the same data [10], [11] and the work of this paper.

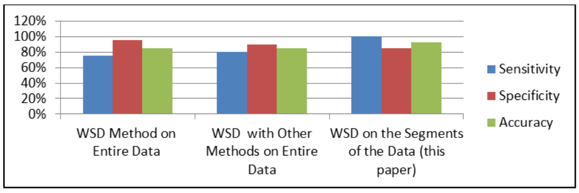

Figure 1. Comparison results of the use of WSD method on entire data at once and on segments (Test Data).

The use of WSD method alone [10] and in association with other methods [11] on the entire data are compared with the use of WSD method on the segments of data in this paper. The comparison is on the term of evaluation results (Sensitivity, Specificity and Accuracy).

It is noticeable that with the work on segments, the accuracy is improved from 85% to 92.5%. Although, the specificity is decreased to 85%, the sensitivity increased to be 100% (As seen in Fig. 1).

V. CONCLUSION AND DISCUSSION

A new technique for the classification of Parkinson tremor from essential tremor is obtained. Segments of data from three different signals, each on different wavelet bands; based on two stages of voting is investigated in this paper. Method of wavelet-based soft decision is used to extract the different wavelet-decomposed bands from accelerometer and EMG signals.

The data is segmented into 11 segments. It is noticeable that the data segment 5 was giving better discriminating information. This segment has the range (4001-5000) samples of the subject data. In addition, wavelet bands number 6 and 8 were selected twice more than other bands, which helped for better classification between the two tremors.

The use of the segments of the data with different bands increased the discrimination efficiency compared to the use the whole data (not segmented). The discrimination results of the test data after the voting using this technique are 100% sensitivity, 85% specificity and 92.5% accuracy.

Therefore, the use of segments extracted better classification information than the use of the data as a whole.

For future work, a larger-sized data is suggested as well as the use of neural network instead of the voting might bring better results.

APPENDIX A ACC SIGNAL RESULTS

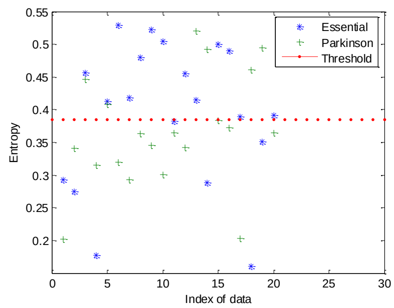

Figure A.1. Results of ACC signal using segment 5 with band 5 (Test Data).

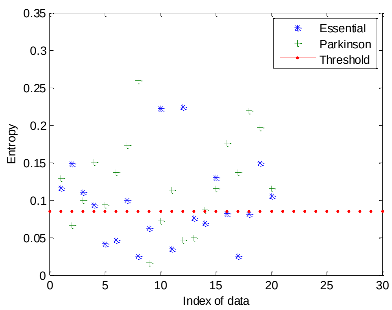

Figure A.2. Results of ACC signal using segment 6 with band 11 (Test Data).

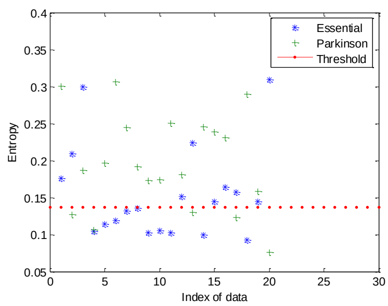

Figure A.3. Results of ACC signal using segment 10 with band 8 (Test Data).

APPENDIX B EMG1 SIGNAL RESULTS

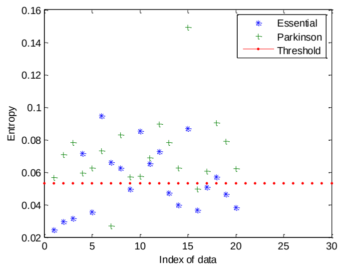

Figure B.1. Results of EMG1 signal using segment 2 with band 13 (Test Data).

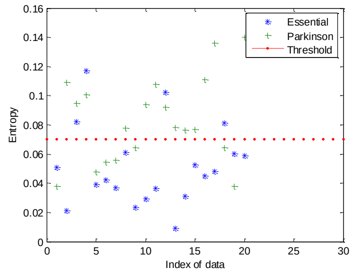

Figure B.2. Results of EMG1 signal using segment 5 with band 6 (Test Data).

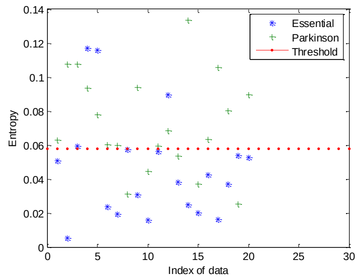

Figure B.3. Results of EMG1 signal using segment 11 with band 6 (Test Data).

APPENDIX C EMG2 SIGNAL RESULTS

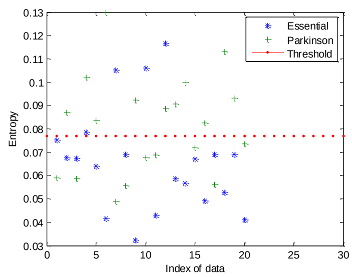

Figure C.1. Results of EMG2 signal using segment 5 with band 9 (Test Data).

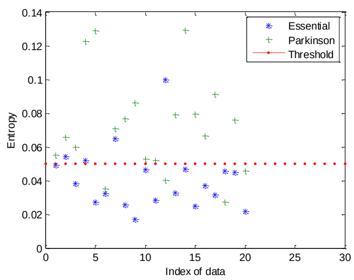

Figure C.2. Results of EMG2 signal using segment 8 with band 7 (Test Data).

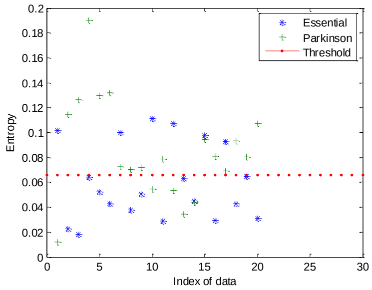

Figure C.3. Results of EMG2 signal using segment 11 with band 8 (Test Data).

ACKNOWLEDGMENT

I am grateful to Dr. Abdulnasir Hossen for supervising me in my M.Sc. thesis and for introducing me to this research. Thanks are due to the research group at both Kiel-University and the Hospital of Kiel-University in Germany (Prof. Deuschl, Prof. Heute, Dr. Muthuraman, Dr. Raethjen, and Dr. Hossen) for allowing me to use the data collected by them through the scholarship for my Master study.

REFERENCES

[1] J. Timmer, M. Lauk, *et al.*, "Cross spectral analysis of tremor time series," *International Journal of Bifurcation and Chaos*, vol. 10, pp. 2595-2610, 1999.

[2] P. Crawford, EE. Zimmerman, "Differentiation and diagnosis of tremor," *American Family Physician*, vol. 83, no. 6, pp. 697-702, 2011.

[3] P. Mansur, *et al.*, "A review on techniques for tremor recording and quantification," *Critical Reviews™ in Biomedical Engineering*, vol. 35, no. 5, pp. 343–362, 2007.

[4] Mayo Clinic, Mayo Foundation for Medical Education and Research, Parkinson's Disease [Online]. Available : http://www.mayoclinic.com/health/parkinsons-disease/DS00295

[5] International Essential Tremor Foundation. Essential Tremor Fact Sheet. (2010). [Online]. Available : www.essentialtremor.org/

[6] Neurology Now Magazine, "Essential Facts about Essential Tremor: This "quiet" disease, which affects 10 million Americans, is anything but benign," vol. 7, no. 1, 2011.

[7] J. Shahed and J. Jankovic, "Exploring the relationship between essential tremor and Parkinson's disease," *Parkinsonism and Related Disorders*, vol. 13, no. 2, pp. 67–*76*, 2007.

[8] P. E. Bermejo, C. Ruiz-Huete, and C. Terrón, "Relationship between essential tremor, Parkinson's disease and dementia with Lewy bodies," *Rev Neurol*, vol. 45, no. 11, pp. 1-15, pp. 689-694, 2007.

[9] Parkinson's Disease Foundation, Inc., Understanding Parkinson's. (2012). [Online]. Available : http://www.pdf.org/en/understanding_pd

[10] A. Hossen, M. Muthuraman, J. Raethjen, G. Deuschl, and U. Heute, "Discrimination of Parkinsonian tremor from essential tremor by implementation of a wavelet-based soft decision technique on EMG and accelerometer signals," *Biomedical Signal Processing and Control*, vol. 5, pp. 181-188, 2010.

[11] Z. Al-Hakim, "Discrimination of parkinson tremor from essential tremor using different emg signal processing techniques," M.Sc. Thesis, Dept. Elect. Comp. Eng. Sultan Qaboos University, Oman, 2012.

[12] Y. Otsuka, T. Ishizaki, Y. Miyashita, and Y Mutoh., "Combined analyses procedure of failure modes and risk phenomena using the concept of normal state conditions," *Open Journal of Safety Science and Technology*, vol. 2, no. 3, pp. 84-88, 2012.

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