A System for Analysis of Tremor in Patients with Parkinson's Disease Based on Motion Capture Technique

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Abstract. Resting tremor is one of the primary motor symptoms of Parkinsons Disease. In this paper we analyze the occurrence of tremor in Parkinsons disease by using a system for measurements of kinematic data of upper limbs. The experimental group includes seven PD patients during standing. Analysis is based on kinematic measurements done by using multimodal motion capture (MOCAP) system for registration of 3D positions of body markers, ground reaction forces and electromyography signals. All patients taking part in examination have undergone deep brain stimulation surgical treatment. Examination involved comparisons of tremor parameters across four conditions, where stimulator was turned ON/OFF and medication was ON/OFF. Obtained results confirm statistically significant differences of certain tremor parameters between different experimental conditions.

Keywords: motion capture, tremor, parkinson disease

1 Introduction

Tremor is an involuntary oscillatory - type motion of parts of human body resulting from uncontrolled contraction and relaxation of certain muscles. Tremor

is known to be associated to a number of diseases, especially to diseases associated with neurological disorders [1]. A disease whose symptoms are very closely related to tremor is Parkinson's Disease (PD). Therefore analyses of tremor are very often pursed in studies devoted to diagnosis, treatment plans, estimation of different treatment results of PD, e.g. [3][4]. Depending on the type of motion, features and cause of origin tremors are classified into several further categories[2]. Resting tremor (RT) is the type of tremor observed when patient is not performing any motion activity. It is most often localized in patient's forearms and hands. Among several types of tremor, resting tremor is the one most often observed in PD patients and belongs to basic indexes for diagnosis and evaluation of patients responses to treatments. This paper is devoted to the design of a system for experimental analysis of resting tremor in patients with Parkinson disease. Experimental setup was based on multimodal MOCAP measurement system. All measurements have been made in Human Motion Laboratory located in Polish Japanese Institute of Information Technology in Bytom, Poland. In our kinematic movement recording set-up 10-camera, 3D motion capture system (Vicon) have been used. Examination involved a group of Parkinson Disease (PD) patients who have undergone the therapy based in implanting Deep Brain Stimulator (DBS) for improving his motoric skills. The patients taking part in the research was treated in Neurology Clinic Medical University of Silesia, with DBS stimulators implanted in Department of Neurosurgery, Medical University of Silesia [5][7][8]. Examination scenario of PD patient involved tremor measurements for four experimental conditions (called sessions) defined by medication and DBS stimulation (S1 - MedOFF StimOFF, S2 - MedOFF StimON, S3 - MedON StimOFF, S4 - MedON StimON, where StimON/OFF means that stimulator was turned on/off before experiment, while med ON/OFF means that patient was under the influence of drugs or not).

2 Methods

A basic standard for recording MOCAP data, used in the performed experiments was NIH MOCAP file format c3d [9][10]. C3d file is a binary file containing spatial positions of all body markers and all additional signals collected during a MOCAP session. As a part of experimental setup a software was developed for transforming contents of c3d file to text format. Then text files were used to create Matlab data files including all experimental results. All further data processing operations were carried out in Matlab environment. Kinematic data were collected from markers located on left and right wrists during normal standing, with eyes open. Time window with a width of 15 [s] was used in the analyzes.

Analyses of tremor signal included several steps are described below:

2.1 Constant component and trend removal

As can be easily seen in Fig. 1, apart from tremor signal, X, Y and Z coordinates of the recorded signals LFIN and RFIN include constant and trend components.

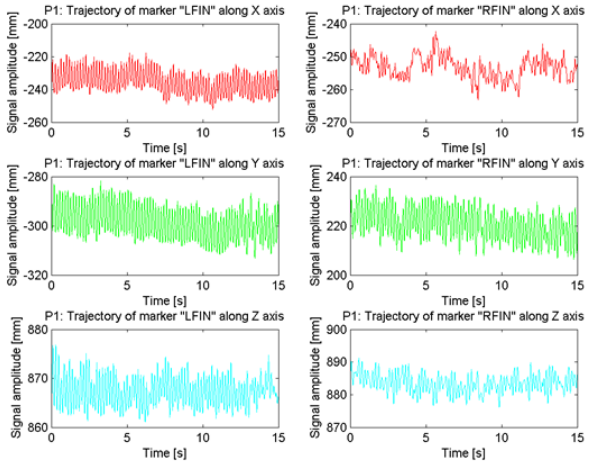

Fig. 1. X, Y and Z trajectories of c3d markers LFIN and RFIN recorded for a PD patient. Recorded signals include constant and trend components.

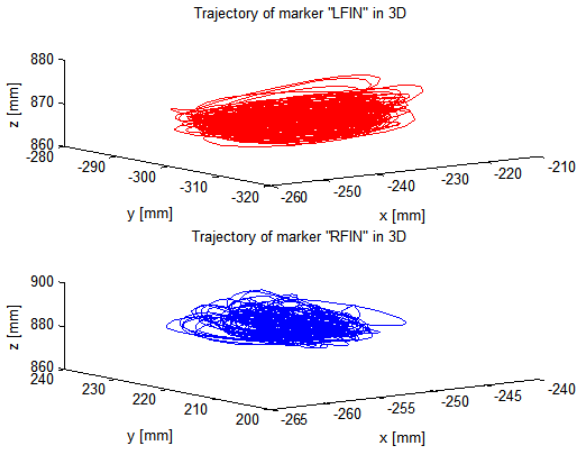

Fig. 2. Trajectories of c3d markers LFIN and RFIN recorded for a PD patient in 3 dimensions.

In order to remove constant and trend components from the X ,Y and Z coordinates of the signals from LFIN and RFIN markers, the algorithm implemented as function 'msbackadj' from Matlab bioinformatics toolbox was used. This function uses recursive histogram algorithm in order to assess the signal background. The main idea is to retrieve the mean of the noise distribution, by using the method of a histogram [6]. The first step of the algorithm is estimate the baseline within multiple shifted windows, which width was set on 100 separation units. After that it regress the differing baseline to the window points using a spline approximation. Finally it adjusts the baseline of the peak signals provided by positions of c3d marker [11].

Results of removal of constant and trend components by the above algorithm are shown in Fig. 3.

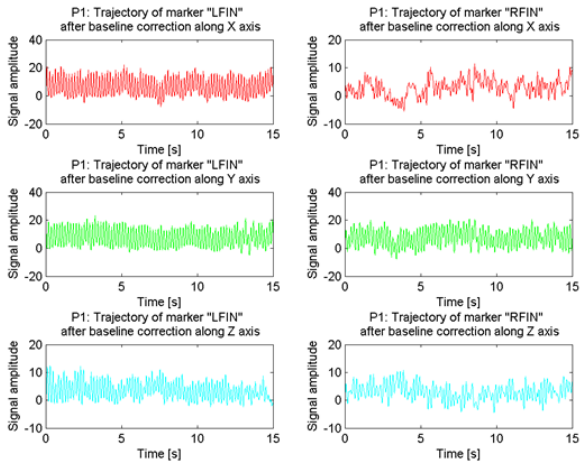

Fig. 3. Results of removal of constant and trend components of X, Y and Z coordinates of LFIN and RFIN signals.

2.2 Resultant spatial signal

The resultant 3D spatial signal across X, Y and Z axis was calculated as Euclidean distance between the actual position of the marker and its centroid (rooted sum of squares, RSS). Application of this operation led to obtaining two 3D tremor signals corresponding to LFIN and RFIN markers. Time plots of amplitudes of these signals are shown in Fig. 4.

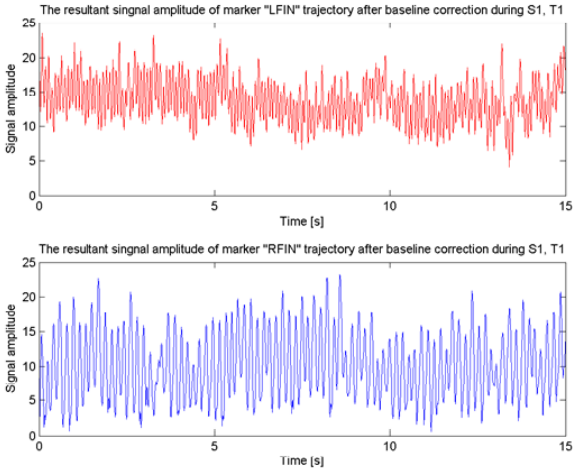

Fig. 4. Time plots of amplitudes of 3D tremor signals corresponding to LFIN and RFIN markers.

2.3 Frequency analysis

To find out how amplitude of tremor is changing across the frequency, Fast Fourier Transform (FFT) has been applied. Amplitude spectra have been calculated for the 15 [s] time course, with 100 [Hz] sampling. Based on this maximal and mean amplitude of the signal and the area under curve of spectrum in range of 3-7 [Hz] and 4-6 [Hz] were calculated. For each Patient residual values for 4 sessions were obtained. The residual value is calculated as mean across trials performed during each session for left and right separately. Examples of amplitude spectra corresponding to LFIN and RFIN tremor signals are presented in Fig. 5.

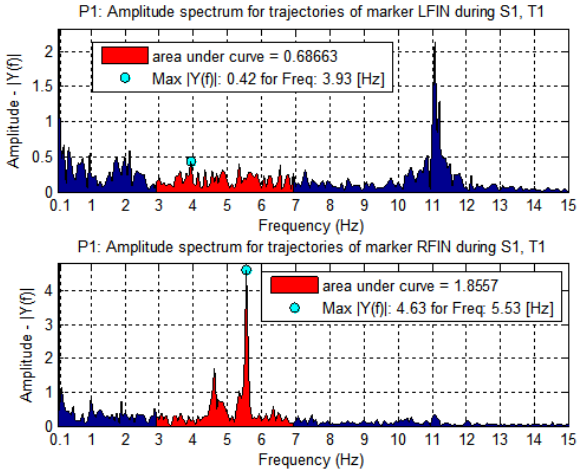

Fig. 5. Amplitude Fourier spectra of 3D tremor signals corresponding to LFIN and RFIN markers.

3 Results

All features computed on the basis of collected and processed data are summarized in Tab. 1 and Tab. 2. Tab. 1 correspond to frequency range 3-7 [Hz], while Tab. 2 corresponds to frequency range 4-6 [Hz]. Two different versions of frequency ranges follow from different definitions of frequency limits corresponding to resting tremor in PD, which can be encountered in the literature [2]. Statistical analysis of the collected data was based on the t-test performed to find out if there exist significance differences between sessions. The null hypothesis assumes that data in two compared sessions are independent random samples from normal distributions with equal means and equal but unknown variances, against the alternative that the means are not equal. The resultant value h = 1, it indicates a rejection of the null hypothesis at the 5% significance level, while h = 0, it indicates a failure to reject the null hypothesis at the 5% significance level. The results of applied statistical tests are presented in Tab. 3 and Tab. 4.

Table 1. Mean $|Y(f)|$, Mean $|Y(f)|$ and area under spectrum between 3-7 [Hz] for left and right side for 7 patients across 4 sessions

		Mean Amplitude				Max Amplitude				Area under spectrum			
Side	Patient	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Left	P1	0.24	0.02	0.18	0.11	0.64	0.07	0.52	0.14	0.86	0.08	0.61	0.51
	P2	0.03	0.01	0.22	0.08	0.04	0.01	0.28	0.11	0.11	0.03	0.90	0.35
	P3	0.05	0.01	0.05	0.09	0.12	0.01	0.08	0.12	0.20	0.02	0.23	0.38
	P4	0.78	0.55	0.55	0.65	4.25	1.76	1.77	2.34	2.18	1.52	1.61	1.78
	P5	0.03	0.01	0.02	0.39	0.07	0.02	0.05	0.45	0.15	0.04	0.10	1.64
	P6	0.30	0.04	0.11	0.03	1.69	0.06	0.16	0.11	0.81	0.15	0.47	0.14
	P7	0.04	0.02	0.03	0.01	0.16	0.05	0.05	0.02	0.27	0.09	0.15	0.04
Right	P1	0.24	0.02	0.18	0.11	0.64	0.07	0.52	0.14	0.86	0.08	0.61	0.51
	P2	0.03	0.01	0.22	0.08	0.04	0.01	0.28	0.11	0.11	0.03	0.890	0.35
	P3	0.05	0.01	0.05	0.09	0.12	0.01	0.08	0.12	0.20	0.02	0.23	0.38
	P4	0.78	0.55	0.55	0.65	4.25	1.76	1.77	2.34	2.18	1.52	1.61	1.78
	P5	0.03	0.01	0.02	0.39	0.07	0.02	0.05	0.45	0.15	0.04	0.10	1.64
	P6	0.30	0.04	0.11	0.03	1.69	0.06	0.16	0.11	0.81	0.15	0.47	0.14
	P7	0.04	0.02	0.03	0.01	0.16	0.05	0.05	0.02	0.26	0.09	0.15	0.04

Table 2. Mean $|Y(f)|$, Mean $|Y(f)|$ and area under spectrum between 3-7 [Hz] for left and right side for 7 patients across 4 sessions

		Mean Amplitude				Max Amplitude				Area under spectrum			
Side	Patient	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Left	P1	0.24	0.02	0.18	0.11	0.63	0.07	0.52	0.14	0.49	0.05	0.37	0.28
	P2	0.03	0.01	0.22	0.08	0.03	0.01	0.28	0.11	0.05	0.02	0.43	0.16
	P3	0.04	0.01	0.05	0.09	0.09	0.01	0.08	0.12	0.09	0.01	0.10	0.18
	P4	0.84	0.55	0.55	0.65	4.25	1.76	1.77	2.34	1.73	1.12	1.27	1.41
	P5	0.03	0.01	0.02	0.39	0.06	0.02	0.05	0.45	0.06	0.02	0.04	0.78
	P6	0.30	0.04	0.11	0.03	1.68	0.06	0.16	0.11	0.62	0.07	0.22	0.07
	P7	0.03	0.02	0.03	0.01	0.09	0.05	0.05	0.02	0.07	0.03	0.06	0.02
Right	P1	0.77	0.06	0.34	0.03	3.28	0.19	1.19	0.06	1.57	0.12	0.70	0.34
	P2	0.02	0.02	0.29	0.07	0.03	0.03	0.37	0.10	0.04	0.04	0.58	0.14
	P3	1.20	0.01	0.12	0.02	3.95	0.02	0.19	0.03	2.44	0.02	0.25	0.05
	P4	0.77	0.29	0.36	0.17	4.56	0.72	1.53	0.43	1.58	0.58	0.81	0.54
	P5	0.02	0.02	0.04	0.67	0.04	0.03	0.06	0.82	0.05	0.03	0.08	1.35
	P6	0.62	0.08	0.12	0.32	4.14	0.20	0.21	1.58	1.28	0.6	0.24	0.64
	P7	0.28	0.10	0.05	0.01	0.59	0.20	0.08	0.03	0.55	0.20	0.10	0.02

Table 3. Presents the results for t-test. performed to find if there exist differences between values of mean $|Y(f)|$, max $|Y(f)|$ in range 3-7 Hz, for each pair of sessions.

Mean Amplitude				Max Amplitude			
Session	Session	h	p-value	Session	Session	h	p-value
S1	S2	1	**0.018**	S1	S2	1	**0.009**
S1	S3	0	0.111	S1	S3	1	**0.026**
S1	S4	0	0.170	S1	S4	1	**0.026**
S2	S3	0	0.137	S2	S3	0	0.271
S2	S4	0	0.181	S2	S4	0	0.353
S3	S4	0	0.880	S3	S4	0	0.955

Table 4. Presents the results for t-test. performed to find if there exist differences between values of mean $|Y(f)|$, max $|Y(f)|$ in range 4-6 Hz, for each pair of sessions.

Mean Amplitude				Max Amplitude			
Session	Session	h	p-value	Session	Session	h	p-value
S1	S2	1	**0.01**8	S1	S2	1	**0.011**
S1	S3	0	0.099	S1	S3	1	**0.032**
S1	S4	0	0.146	S1	S4	1	**0.033**
S2	S3	0	0.137	S2	S3	0	0.271
S2	S4	0	0.181	S2	S4	0	0.353
S3	S4	0	0.880	S3	S4	0	0.955

4 Conclusion

The size of the group of PD patients in the experiment performed in this study was rather small, it included only 7 subjects. Nevertheless statistically significant differences between amplitudes of tremor in Session S1 (no medication no stimulation) and three remaining sessions S2, S3 and S4 were observed. In the future research we plan to re-analyze the experimental results for larger group of PD patients, including 30-40 subjects and to develop the experimental design by several new features of the tremor, amplitude asymmetry, phase difference between LFIN and RFIN.

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