33rd Annual International Conference of the IEEE EMBS
Boston, Massachusetts USA, August 30 - September 3, 2011

Distance Estimation from Acceleration for Quantitative Evaluation of Parkinson Tremor

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Abstract— **The purpose of this paper is to assess Parkinson tremor estimating actual distance amplitude. We propose a practical, useful and simple method for evaluating Parkinson tremor with distance value.**

We measured resting tremor of 7 Parkinson Disease (PD) patients with triaxial accelerometer. Resting tremor of participants was diagnosed by Unified Parkinson's Disease Rating Scale (UPDRS) by neurologist. First, we segmented acceleration signal during 7 seconds from recorded data. To estimate a displacement of tremor, we performed double integration from the acceleration. Prior to double integration, moving average method was used to reduce an error of integral constant. After estimation of displacement, we calculated tremor distance during 1s from segmented signal using Euclidean distance. We evaluated the distance values compared with UPDRS. Averaged moving distance during 1second corresponding to UPDRS 1 was 11.52mm, that of UPDRS 2 was 33.58mm and tremor distance of UPDRS 3 was 382.22 mm. Estimated moving distance during 1s was proportional to clinical rating scale – UPDRS.

I. INTRODUCTION

Tremor is broadly defined as any involuntary, approximately rhythmic, and roughly sinusoidal movement. Instruments for clinical diagnosis of tremor have been EMG, accelerometer and gyroscope[1]. Among these devices, accelerometer is available, reliable and inexpensive transducer[1]. Therefore, many studies have used accelerometer to detect and quantify tremor including Parkinson tremor. Vaillancourt examined the time and frequency structure of Parkinson tremor in which there is no clinical signs[2]. Elble studied postural tremor in neurologically healthy people with accelerometer and EMG to determine the prevalence of tremor-related motor-unit entrainment in young and elderly adults [3]. Bilodeau assessed differences in physiological tremor amplitude between the dominant and non-dominant side with accelerometer and EMG [4]. Lees et al. developed a portable device capable of objectively measuring dyskinesia with triaxial accelerometer, measured acceleration, and compared acceleration in the 1~3Hz frequency band with established clinical dyskinesia rating scales [5]. Hoff also developed continuous ambulatory multichannel accelerometry (CAMCA) to detect and assess tremor in patients with PD calculating duration, intensity of resting tremor, and body position [6]. These studies mostly have shown the results of the spectral analysis and have been not interested in tremor's actual amplitude in displacement unit except several studies.

According to Duval [7], the number of oscillations increases from displacement to velocity to acceleration and this may be affect the result of frequency analysis of acceleration and displacement. In addition, some studies reported that part of the high-frequency components of tremor is relevant to central oscillator activity [8-10]. Other authors suggested that tremor should be evaluated in displacement unit when examined with respect to robotic surgery since actual amplitude of tremor is not acceleration but displacement. [11]. Therefore, we tried to evaluate Parkison tremor in displacement unit. We measured rest tremor of PD patients and speculated displacement and distance of tremor. And then, Unified Parkinson's Disease Rating Scale (UPDRS) was compared to estimated total distance.

II. METHOD

Seven PD patients (5 females; 67±3.4, 2 males; 62±2.8) participated for recording tremor. All subjects were recruited in Parkinson center of Seoul national University hospital and agreed the informed and written consent for this study. A neurologist diagnosed their hand tremor and both hands were separately tested. Total 13 cases were evaluated by Unified Parkinson's Disease Rating Scale (UPDRS). UPDRS ranges from 0 to 4, and the larger scale is, the severe hand tremor is.

Tremor-dominated finger was measured with triaxial accelerometer (MMA 7260Q, Freescale Semiconductor). Subjects were seated comfortably on a chair and their both hands were placed on their thigh in resting position for evaluating resting tremor of the hand. The accelerometer was positioned on the nail of the tremor-dominated finger maintaining in a horizontal direction. Data was recorded during 30s.

Prior to measurement, accelerometer was simply calibrated. We placed the device on a flat surface so that X axe is at 0g, Y axe is at 0g, and Z axe is at +1g. The values were recorded and stored. When we analyze recorded data, stored calibration values always subtracted. After this, we processed recorded tremor data at 64Hz sampling frequency with Matlab (Mathwork, Miami, USA). To estimate moving distance from acceleration, we had to perform double integration and

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978-1-4244-4122-8/11/$26.00 ©2011 IEEE

calculate Euclidean distance using triaxial position value. Prior to 1st and 2nd integration, we used moving average to remove bias. After this, velocity was calculated by 1st integration and displacement values of triaxial were reckoned by 2nd integration. And then, we computed Euclidean distance from displacement to estimate moving distance of tremor.

III. Results

Fig 1 illustrated the comparison between measured acceleration and estimated displacement at 3 dimension of 3 patients corresponding to UPDRS 1,2 and 3. Fist, this figure shows tremor displacement is proportional to UPDRS (Fig 1 (a),(c),(e)). Amplitude of displacement in UPDRS 3 is very large and strong in y axe but, there is little movement in other directions (Fig 1 (a). Displacement of UPDRS 2 is relatively small compared with that of UPDRS 3 (Fig 1 (c)). Direction is dominant at X unlike UPDRS 3. Fig 1 (e) represents that UPDRS 1 has the smallest displacement and its movement is not relevant to directivity. Acceleration is also proportional to UPDRS (Fig 1 (b),(d),(f)). However, in the case of directivity, 3D displacement plot far more clearly illustrate than acceleration plot. This is because displacement is actual amplitude of movement and acceleration represents a change of velocity.

Table 1 indicates averaged distance during 1s of each individual. This distance value was calculated from tremor measured during 7s. In the case of UPDRS 1, mean distance of most subjects didn't exceed 15mm except 1 subject and mean distance was about 11.52mm. Distance of UPDRS 2 was 33.58mm. 3 patients had movement between 15.8mm and about 23mm but only a patient trembled with mean 76.01 mm during 1s, which affected group's mean distance. Patients of UPDRS 3 had tremor with 383.22mm. All their distance exceeded 100mm. Particularly a patient moved 602.29mm and Fig 1(a) was 3D trajectory of this case.

In fig 2, estimated distance of each second is depicted. Tremor corresponding to UPDRS 3 moved from about 360mm to about 600mm during 7s (fig 2(a)). Tremor of patient with UPDRS 2 have minimum distance 18mm and maximum distance 26mm. All distance of UPDRS 1 is less than 10mm. Fig 2 explains that distance amplitude increased and more varied with the severity of tremor.

IV. Discussion and Conclusion

The purpose of this study was to evaluate Parkinson tremor with moving distance. We measured tremor using triaxial accelerometer, estimated displacement of 3 directions by means of double integration and calculated total moving distance. And then, we compared total distance values with UPDRS of hand tremor. We approached this method with intuition that the severer hand tremor is, the more tremble the hand and moving distance is likely to increase.

Results showed that mean distances during 1s were 11.52mm, 33.58mm and 383.22mm corresponding to UPDRS 1, 2 and 3. Fig 3 indicates that moving distance of hand tremor in PD exponentially increases with UPDRS. This is similar to Elble's results [12]. Elble explained tremor amplitude was logarithmically related to tremor rating scales.

In table 1, distance of no.1 patients is larger than that of no.7. This means that quantitative evaluation is need in tremor diagnosis. Current method like UPDRS might be subjective because UPDRS is by visual inspection. In addition, no.6 patient's distance is very large compared. This affected group mean of UPDRS 2, Mean except no.6's distance value is 19.43mm.

Table 1. Mean distance during 1s of each individual

No. of patent	UPDRS	Total distance (mm)
1	1	17.59
2	1	8.68
3	1	13.76
4	1	8.5
5	1	9.08
Mean of UPDRS 1		**11.52(±4.03)**
6	2	76.01
7	2	15.8
8	2	19.044
9	2	23.46
Mean of UPDRS 2		**33.58(±28.46)**
10	3	157.14
11	3	425.71
12	3	345.74
13	3	604.29
Mean of UPDRS 3		**383.22(±185.47)**

However, we need to validate this study with more subjects and compensate distance estimation for more accuracy. Result tended to somewhat overestimate moving distance of tremor, particularly, UPDRS 3.

Nevertheless, proposed method is so natural, intuitive and simple to implement that it is efficient to use this method as smart phone's application. Recently, evaluation of hand tremor using smart phone was performed with accelerometer equipped to phone [13]. An assessment with smart phone might be very useful to clinicians and patients in that tremor information could be provided to them when patients do not visit hospital because of its portability.

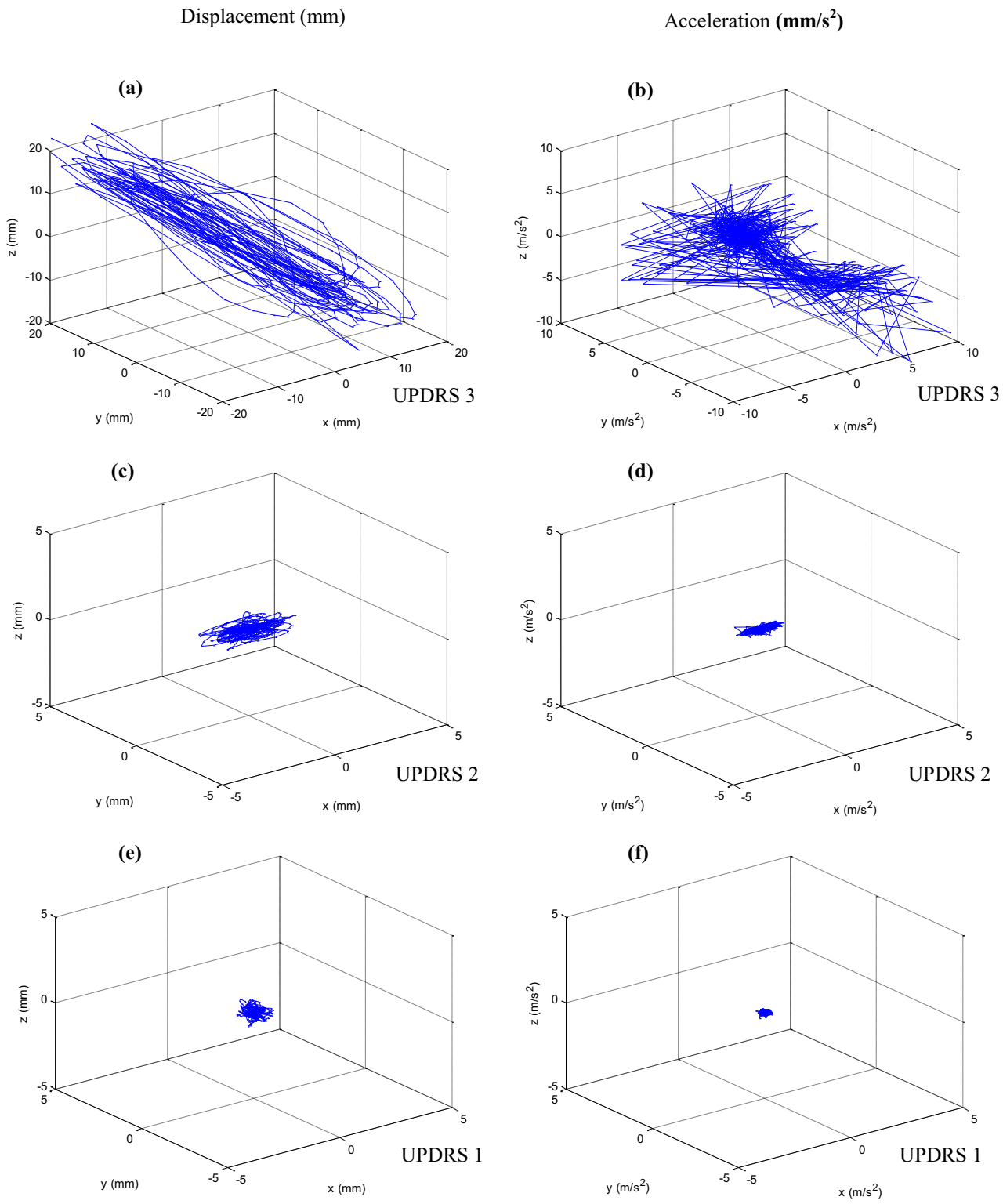

Fig.1 3D displacement and acceleration of Parkinson tremor corresponding to UPDRS 1,2 and 3

Left illustrates displacement, and right displays acceleration of 3 subjects. Displacement more clearly represents the severity of tremor in amplitude unit and directivity than acceleration.

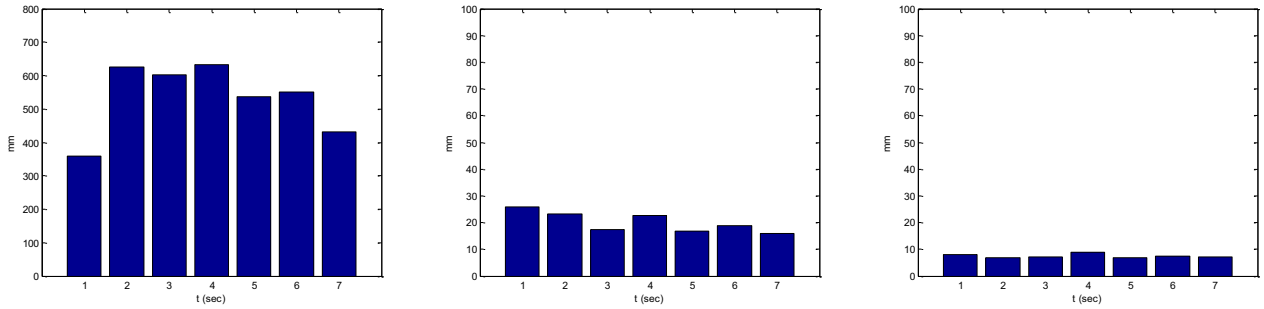

Fig.2 Estimated distance of each second.
Amplitude distance is proportional to clinical rating scale, UPDRS. Change of amplitude is large as UPDRS increases

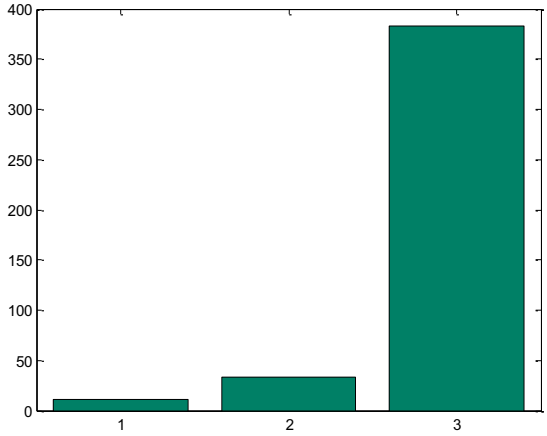

Fig.3 Mean distance of 3 group, UPDRS 1,2, and 3.
Averaged distance during 1second exponentially increases with UPDRS.

ACKNOWLEDGMENT

This work was supported by a grant of the Korea Healthcare technology R&D Project, Ministry for Health, Welfare and Family Affairs, Republic of Korea (A101808) and Samsung Electronics.

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