Finger Taps Movement Acceleration Measurement System for Quantitative Diagnosis of Parkinson's disease

Ryuhei Okuno, Masaru Yokoe, Kenzo Akazawa, Kazuo Abe and Saburo Sakoda

Abstract— **The purpose of this study was to develop a finger taps acceleration measurement system for the quantitative diagnosis of Parkinson's disease. The system was composed of two 3-axis piezoelectric element accelerometers, a pair of touch sensors made of thin stainless steel sheets, an analog-digital (AD) converter and a personal computer (PC). Fingerstalls, with these sensors, were attached to subject's index finger and thumb. The acceleration and output of the touch sensors were recorded using the PC during the finger taps movements. Intervals between the single finger taps movements were calculated from the measured output of the touch sensors. Velocities during the single finger taps movements were calculated by integrating the measured acceleration. The amplitudes were calculated by integrating the velocities. The standard deviation of the single finger taps intervals, average of maximum single finger taps velocities and average of maximum single finger taps amplitudes were calculated from them. They were used as features for the quantitative diagnosis of Parkinson's disease.**

The developed system was used to conduct finger taps tests employing 27 normal subjects and 16 Parkinson's diseases subjects. The subjects were asked to execute continuous finger taps movement for 60 s. It was shown that the acceleration and output of the touch sensors could be measured and the features could be extracted.

I. Introduction

Parkinson's disease is a neurodegenerative disease which middle age and elderly people get. The major symptoms were tremor, rigidity, akinesia, and gait disturbance. The major treatment is pharmacotherapy with L-dopa and so on. Quantitative evaluation of the symptoms is important for dosage of the drugs. Unified Parkinson Disease Rating Scale (UPDRS) was currently a standard and widely used scale for Parkinson's disease research [1]. It was made up of the 1) mentation, behavior and mood, 2) activities of daily living (ADL), 3) motor abilities and 4) dyskinesia sections. However, guidelines described in the several UPDRS tests were vague. The scores were somewhat variable from examiner to examiner, may not be as reproducible as one would like, therefore it was necessary to develop a quantitatively evaluating system.

Finger taps test was one of the tests to assess ability of upper limb. The subject continuously repeated opening and closing of his index finger and thumb. In Parkinson's disease, the basal ganglia degenerated. The rhythm, amplitude and velocity of the finger taps movements varied with the patient's ability and symptoms. The finger taps test was suitable for assess these symptoms. It was included in UPDRS. Some previous studies were reported quantitative evaluation of the finger taps movement. In the studies, keyboard of PC and mouse were used and only rhythm of the finger taps was evaluated [2]-[7]. The studies used a 3D position measurement system [8] or high speed cameras [9, 10] were reported and the amplitude and velocity during the finger taps movement were analysis. However, these systems were at a high price, so they could not be used in usual hospitals.

The purpose of this study was to develop the finger taps measurement system with accelerometers which can be used easily at a clinic and a bedside. In this paper, the finger taps measurement system with the two 3-axis accelerometers and touch sensors was developed. Features were extracted from the measured accelerate for assess the finger taps of Parkinson's disease patients.

II. METHODS

A. Finger Taps Measurement System

Fig.1 shows the developed finger taps measurement system. This system was composed of 3-axis accelerometers, touch sensors, AD converter and personal computer.

The size of the accelerometers was 20.5 mm x 12.5mm x 5.0 mm. The weight was 4.0 g, so it did not interfere with the natural finger taps movements. The frequency band was from 0.5 to 2000 Hz. The accelerometer was put on the distal interphalangeal joint of the index finger and interphalangeal joint of the thumb using fingerstalls (Fig.1 (b)).

The touch sensors made of the thin stainless steel sheet were attached on the fingerstalls. The size of them was as same as the ventral surface of digit of the index finger and thumb. When the index fingers and the thumb contacted, the sensors were contacted.

Outputs of the accelerometer and touch sensors were measured using the AD converter.

Manuscript received April 3, 2006. This work was financially supported in part by the Program for Promotion of Fundamental Studies in Health Sciences of the National Institute of Biomedical Innovation (NIBIO).

R. Okuno is with Graduate School of Information Science and Technology, Osaka University, Suita, Osaka 565-0871, Japan (corresponding author to provide phone: +81-6-6879-7829; fax: +81-6-6879-7832; e-mail: okuno@ist.osaka-u.ac.jp).

K. Akazawa is with Department of Biomedical Engineering, Osaka Institute of Technology, Osaka 535-8585 Japan. (e-mail: akazawa@bme.oit.ac.jp).

M. Yokoe, K. Abe and S. Sakoda are with Graduate School of Medicine, Osaka University, Suita, Osaka 565-0871, Japan.

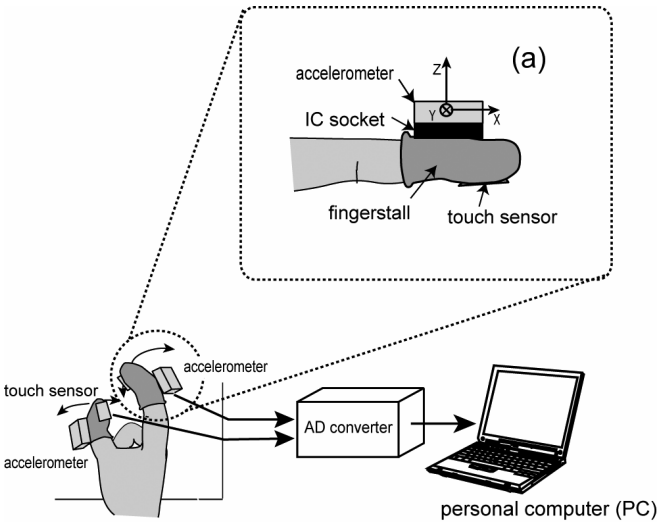

Fig.1 Finger taps movement measurement system.

B. Protocol of Measurement Experiments

The measurement experiments were executed. Subjects were sixteen Parkinson's disease patients and twenty seven normal subjects who gave informed consent and the investigation was approved by the local Ethics Committee. Average of the age of the patients was 65.7 years old. The range of the age was from 44 to 84 years old. Average of the age of the normal subjects was 62.1 years old. The range of the age was from 45 to 82 years old. The experiments were executed as follows;

1. The fingerstalls were worn on the subject's index finger and thumb, respectively. The hand fixed on the desk (see Fig.2). The plane that the index finger flexed or extended was parallel to the desk.
2. The subject practiced the finger taps movement for about ten seconds.
3. The subject was asked to execute the finger taps movements as quickly and widely as possible for sixty seconds.
4. The outputs of the sensors were recorded using PC.

This experiments were executed both right and left hands, respectively. Additionally, the neurologist evaluated score of UPDRS finger taps.

C. Features Extraction

The features for which the level of Parkinson's disease was evaluated were calculated from the outputs of the measured accelerometer and touch sensors. First we got some information out of a neurologist who evaluates UPDRS score of Parkinson's disease. Therefore we found out that the medical doctor evaluated with irregularity of the rhythm, distance between the index finger and thumb, velocity of the finger taps movement. In this study, we used standard deviation of the intervals of a single finger taps movement during sixty seconds as the irregularity of the rhythm, average of the maximum amplitude, which was distance between the tips of the index finger and thumb, during the single finger taps movement as the of the finger taps, and average of the velocity of the single finger taps movement as the velocity of the finger taps movement.

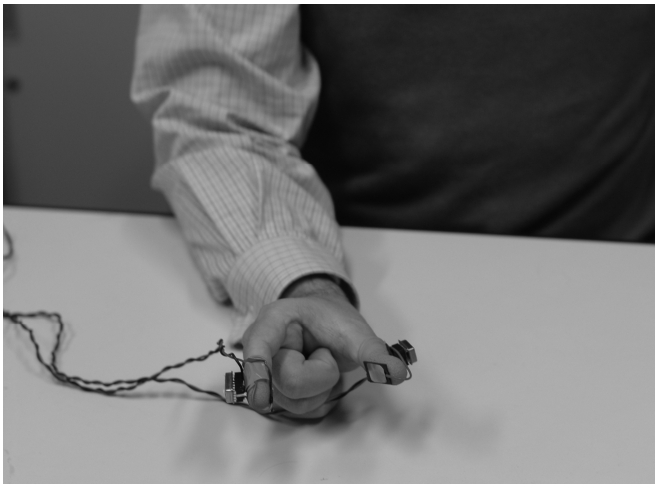

Fig.2 Finger taps measure experiment.

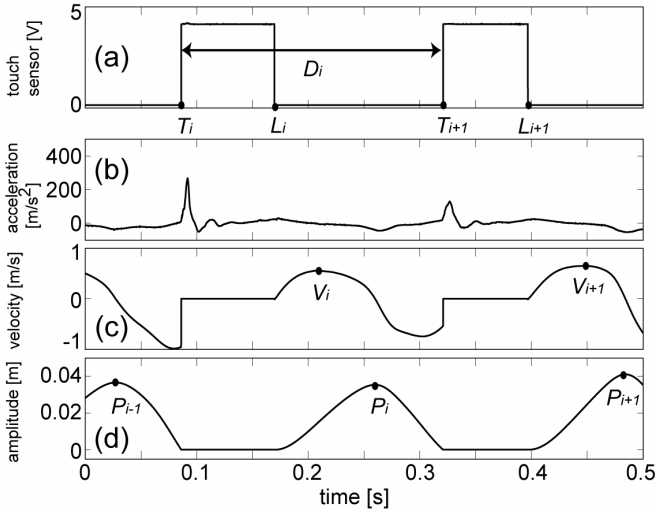

Fig.3 Measured acceleration and calculated velocity and amplitude during finger taps movement. (a) Output of touch sensor, (b) Measured acceleration, (c) Calculated velocity and (d) Calculated amplitude

Fig.3 shows the typical measured acceleration and outputs of the touch sensor. Fig.3(a) shows the outputs of the touch sensor. T_i was the time when the fingers contacted and L_i was the time when the fingers separated, where i was the number of the finger taps. The intervals between the single finger taps movements D_i was calculated from $D_i = T_{i+1} - T_i$. Then the standard deviation of D_i during 60 seconds was calculated.

Fig.3(b) shows the measure acceleration. Velocities during the single finger taps movement was calculated by integrating the measured acceleration. Fig.3(c) was the calculated velocities. V_i was The maximum velocities during the single finger taps movement. Then the average of V_i during sixty seconds was calculated.

The amplitudes were calculated by integrating the velocities. Fig.3(d) was the calculated amplitude. P_i was the maximum amplitude. The average of maximum single finger taps amplitudes was calculated.

III. RESULTS OF THE EXPERIMENTS

Fig. 4 shows a typical result of the measured acceleration and output of the touch sensor during finger taps movements. Fig. 4(a) shows the measured signals for 60 seconds. In this figure, upper panel was the acceleration of Z-axis of the index finger. Middle panel was the acceleration of Z-axis of the thumb and lower was the output of touch sensor. Fig.4(b) shows the signals expanded from 32 sec to 34 sec.

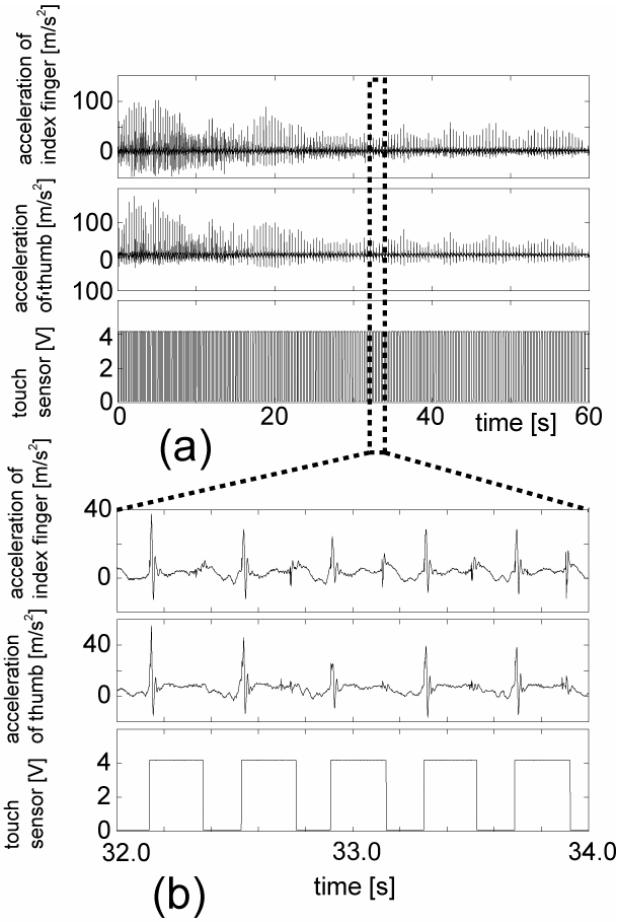

Fig.4 Measured acceleration and output of a touch sensor during finger taps movements. (UPDRS finger taps score: 1).

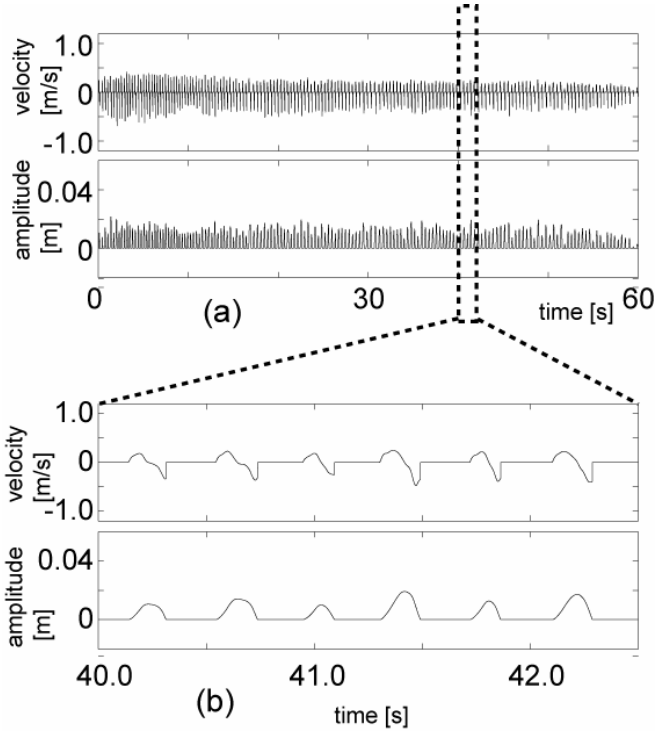

Fig.5 Velocity and amplitude calculated during finger-tapping movement with measured acceleration.

Fig.5 shows the amplitude and velocity calculated from the measured acceleration. Fig.5(a) shows the results for 60 s and Fig.5(b) shows the results from 40 s to 42 s.

Fig.6 shows calculated features according to the score of UPDRS finger taps test. Fig.6(a) shows the standard deviation of finger-tapping intervals. The standard deviation of finger-tapping increased with increasing the score of UPDRS finger taps test. It was shown that high score of the test had irregularity of the rhythm. Fig.6(b) shows the average of maximum amplitude of the finger taps. This average decreased with increasing the UPDRS score. Fig.6(c) shows the average of maximum velocity. The average of the patients was smaller than the normal subjects. These results were shown akinesia or bradykinesia was occurred during the finger taps movement.

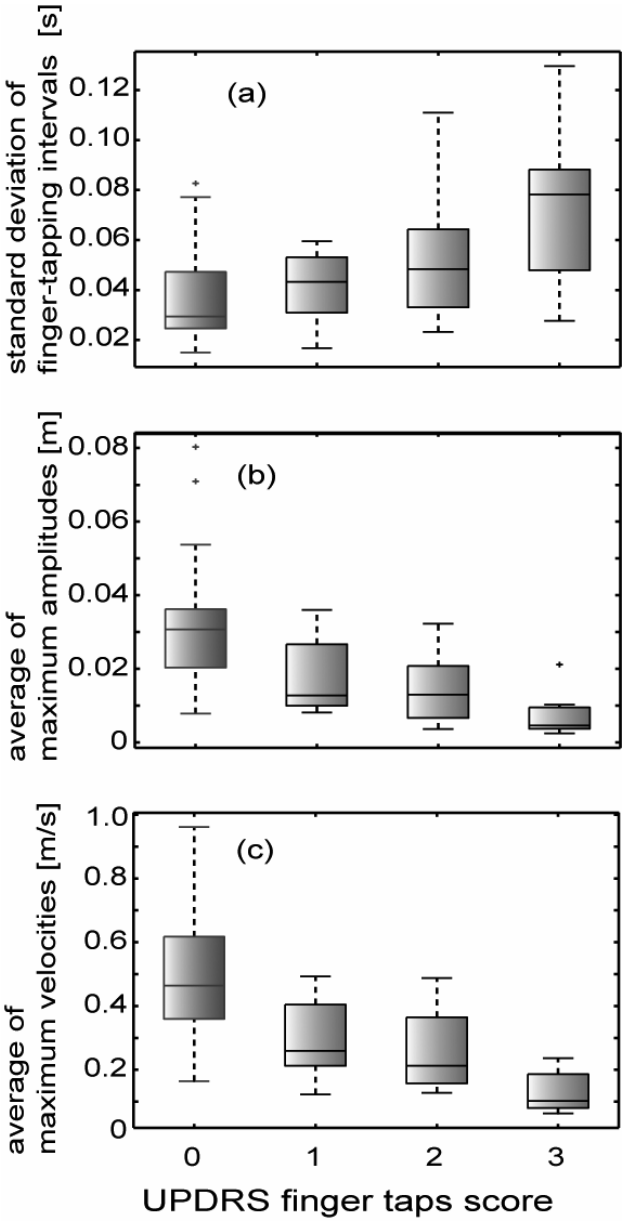

Fig.6 Calculated features and UPDRS finger taps scores. (a) standard deviation of finger-tapping intervals, (b) average of maximum amplitudes and (c) average of maximum velocities

IV. Conclusion

In this study, a finger taps acceleration measurement system for the quantitative diagnosis of Parkinson's disease was developed.

1. This system was composed of 3-axis piezoelectric element accelerometers, touch sensors made of thin stainless steel sheets AD converter and a PC. These sensors were attached to the index finger and thumb with the fingerstall.
2. The standard deviation of the single finger-tapping intervals, average of maximum single finger-tapping velocities, average of maximum single finger-tapping amplitudes were calculated as the features for diagnosis of Parkinson's disease from the measured acceleration.
3. The system developed was used to conduct finger-tapping tests employing 27 normal subjects and 16 Parkinson's diseases subjects. The subjects executed continuous finger-tapping movement for 60 s. It was shown that the acceleration and output of the touch sensor could be measured and the features could be extracted.

References

[1] S. Fahn, R. L. Elton and Members of The UPDRS Development Committee, "Unified Parkinson's disease rating scale". in Resent Developments in Parkinson's disease, vol. 2, S. Fahn, C. D. Marsden, M. Goldstein, D. B. Calne, Ed. Florham Park, New Jersey: Macmillan Healthcare Information, 1987, pp.153-63.

[2] I. Shimoyama, K. Hinokuma, T. Ninchoji, K. Uemura, "Microcomputer analysis of finger tapping as a measure of cerebellar dysfunction," *Neurol. Med. Chir.*, vol. 23, pp.437-40, 1983.

[3] H. Nagasaki, H. Itoh, H. Maruyama, K. Hashizume, "Characteristic difficulty in rhythmic movement with aging and its relation to Parkinson's disease," *Exp. Aging Res.*, vol.14, pp.171-176, 1988.

[4] J. S. Freeman, F. W. Cody, W. Schady, "The influence of external timing cues upon the rhythm of voluntary movements in Parkinson's disease," *Neurol. Neurosurg. Psychiatry.*, vol.56, pp.1078-1084, 1993.

[5] G. Giovannoni, J. van Schalkwyk, V. U. Fritz, A. J. Lees, "Bradykinesia akinesia inco-ordination test (BRAIN TEST): an objective computerised assessment of upper limb motor function," *J. Neurol. Neurosurg. Psychiatry.*, vol.67, pp.624-629, 1999.

[6] H. M. Bronte-Stewart, L. Ding, C. Alexander, Y. Zhou, G. P. Moore, "Quantitative digitography (QDG): a sensitive measure of digital motor control in idiopathic Parkinson's disease," *Mov. Disord.*, vol.15, pp.36-47, 2000.

[7] I. Shimoyama, T. Ninchoji, K. Uemura, "The finger-tapping test. A quantitative analysis," *Arch. Neurol.*, vol.47, pp.681-684, 1990.

[8] M. Frischer, "Voluntary vs autonomous control of repetitive finger tapping in a patient with Parkinson's disease," *Neuropsychologia.*, vol.27, pp.1261-1266, 1989.

[9] J. Konczak, H. Ackermann, I. Hertrich, S. Spieker, J. Dichgans, "Control of repetitive lip and finger movements in Parkinson's disease: influence of external timing signals and simultaneous execution on motor performance," *Mov Disord.*, vol.12, pp.665-676, 1997.

[10] R. Agostino, A. Curra, M. Giovannelli, N. Modugno, M. Manfredi, A. Berardelli, "Impairment of individual finger movements in Parkinson's disease," *Mov Disord.*, vol.18, pp.560-565, 2003.