# A Study for Automatic Diagnosing System of Parkinson Disease
## *A Systematic Analysis of Parkinsonian Tremor by Accelerometer*

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Abstract: New objective diagnosing methods of Parkinson Disease is proposed with 3 D accelerometers. A mathematical model based on the peripheral feedback theory is tested by computer simulation with good coincident with the clinical data. We have found the main frequency of Parkinsonian tremor is about 4Hz in arms comparing the one of physiological tremor (8Hz). Patients in L-Dopa treatment have been measured by the system that corresponds well to a parameter $F_{gk}$ that indicates the fatigue of intrafusal muscle. Biofeedback training by sound and visual parameters are also proved with good tremor improvement in its main frequency and severity.



## 1 INTRODUCTION

The Parkinson's disease (morbidity 0.1%) is etiology unknown neurologic disease that makes adults unable to work with three main symptoms (tremor, rigidity, bradykinesia). The problem of the diagnosis depends upon the neurologists' subjective decision. We have been trying to help non-specialist using an automatic diagnosing unit with 3D accelerometers.

## 2 TREMOR MEASUREMENT

The tremor measurement was executed on four tremor patients as a preliminary experiment using an accelerometer and the data was analyzed by FFT (Fig.1). They have 2-4Kg weights in order to cause their tremor.

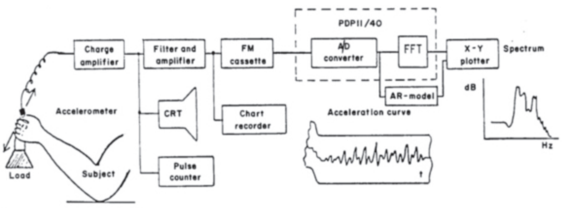


Figure 1: Tremor measuring system.

The obtained tremor graph is clearly distinguished in two groups, namely Parkinson tremor and Physiological tremor (Fig.2).

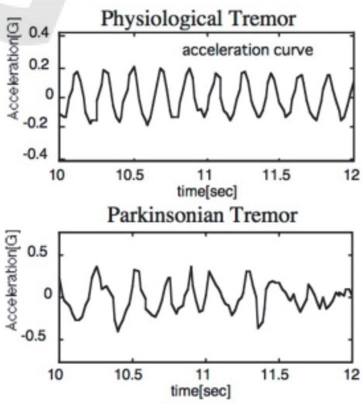


Figure 2: Parkinson tremor and Physiological tremor.

Measured tremor graph is analyzed by FFT (Fig.3) and we have found that the main frequency of Parkinson tremor is about 4Hz and the physiological tremor is about 8Hz in arms. The severity of tremor is classified in five levels from 0 (no tremor) to 4 (most severe) subjectively by a tremor specialist. The two tremor groups are plotted in one graph by the tremor severity level (Fig.4). They can also be divided in two groups clearly and Parkinson tremor has tendency of negative correlation between the severity and the main frequency.


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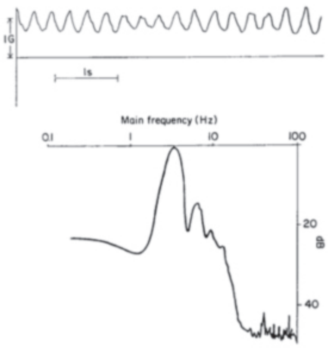


Figure 3: FFT analysis of tremor.


Figure 4: Correlation between tremor severity and main frequency.

Six Parkinson patients in L-Dopa treatment are examined using the measuring system. The tremor power in the accelerometers' output (mV) is plotted in the same graph (Fig.5).

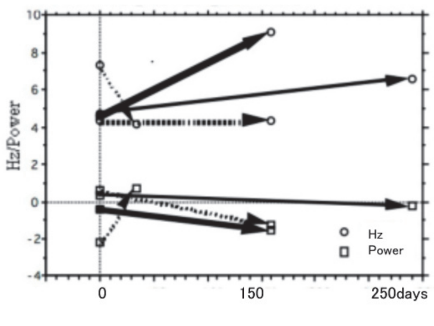


Figure 5: Tremor change by L-Dopa treatment.

Almost all patients except one show the increased main frequency and the decreased tremor power. The one patient has On-Off phenomenon that means the failure in pharmacological treatment.

# 3 MODEL & SIMULATION

There are two hypotheses on the cause of Parkinson tremor namely the central oscillation theory and the peripheral feedback theory. The former thinks that there are oscillators in bran stem that may activate skeletal muscle to elicit tremor at certain determined tremor frequencies. The latter insists that the tremor may be caused by the feedback loop between the skeletal muscle and the motor neuron in bone marrow. The obtained data from our experiment show that the main frequency can be changed by medical treatment, which means the peripheral feedback theory is more likely true.

But it is almost impossible to be certified because human brain is too complicated and very difficult to be analyzed anatomically. Computer simulation on the mathematical model is another way to prove the hypotheses.

Auto-regression analysis (AR) is executed in order to get the number of independent parameters on the Parkinson patients' tremor (Fig.6). It shows that eight independent parameters are enough to describe the tremor producing system.

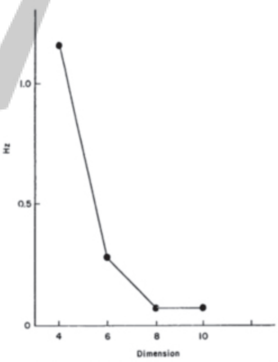


Figure 6: AR model analysis of Parkinson Tremor.

A mechanical oscillating model is constructed for the human forearm tremor (Fig.7).

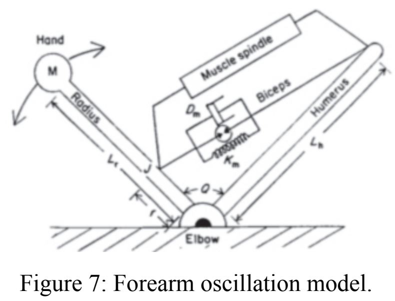


Figure 7: Forearm oscillation model.

The muscle spindle is also made using central modifiable intra spindle muscle (Fig.8).

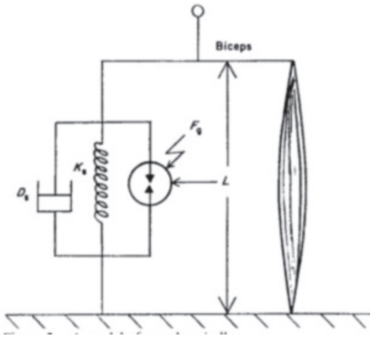


Figure 8: Intra muscle spindle model.

A mathematical formulation is described in simple equations.

The rotation of the forearm due to the torque N(t) is described by defining the inertia of the forearm J, the elastic coefficient of the biceps Km, viscosity coefficient Dm, the deviation of Q from the initial angle $Q_0$, $\theta$, so that $Q=Q_0+\theta$ giving

$$J\frac{d^2\theta}{dt^2}+D_m\frac{d\theta}{dt}+K_m\theta=N(t)$$

$$\omega^2=\frac{K_m}{J}-\frac{D_m^2}{(4J)^2}$$

$$\theta(t)=\int_0^t\frac{N(u)}{J(\omega)}\exp\left(\frac{-D_m(t-u)}{2J}\right)\sin\omega(t-u)du$$

$$+\theta_{(0)}\exp\left(\frac{-D_m t}{2J}\right)\cos\omega t$$

$$+\left(\theta'_{(0)}+\frac{\theta_{(0)}D_m}{2J}\right)\frac{1}{\omega}\exp\left(\frac{-D_m t}{2J}\right)\sin\omega t$$

Let the viscosity coefficient of the intrafusal fiber be Ds and the mass of the intrafusal fiber be negligible.

$$D_s\frac{dU_s}{dt}+K_sU_s=F_g$$

Using the elastic coefficient of the intrafusal muscle fiber Ks, a non-dimensional effectively coefficient appears including simulating effect by gamma neuron $F_{gk}$, the unit of which is the number needed to stretch the intrafusal muscle fiber by half its original length (c.a. 6mm).

$$F_g=0.003K_sF_{gk}$$

$F_{gk}$ may be thought to indicate the level of the intrafusal muscle.

Computer simulation using the mathematical model is executed by varying the $F_{gk}$ value (Fig.9).

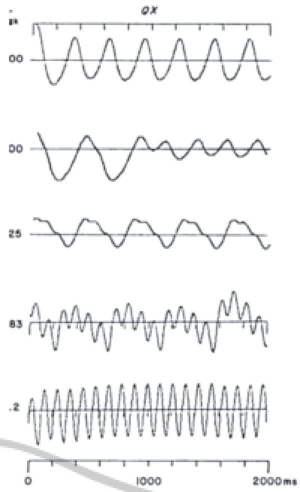


Figure 9: A Simulation result varying $F_{gk}$.

Most remarkable result of the simulation may be the sudden change of the main frequency by $F_{gk}$ (Fig.19).

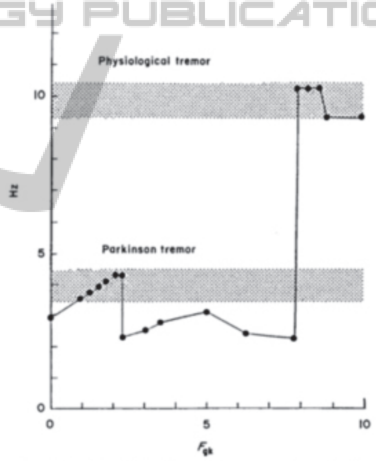


Figure 10: Parkinson tremor suddenly changes to Physiological tremor by $F_{gk}$ increasing.

The graph shows that the main frequency can take only two state namely the Parkinson tremor (4Hz) and Physiological tremor (8Hz) and it cannot take the middle value. The fact corresponds well to the clinical observation and our measured data.

Main frequency obtained from 50 Parkinson patients are plotted against their The Hoehn and Yahr scale (□) (Fig.11).

Main frequencies calculated from corresponding $F_{gk}$ value are also plotted in the graph (○). The two plots vary simultaneously and the fact may support the based hypothesis of peripheral feedback oscillation.

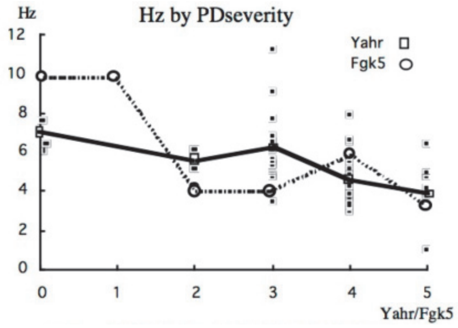


Figure 11: Yahr scale vs. Main frequency of Parkinson patients.

## 4 BIOFEEDBACK TRINING

Medical treatment of Parkinson's disease has several shortcomings such as Wearing-Off or On-Off phenomena as well as side effects of involuntary movement. Biofeedback training is new non-invasive treatment for psychological diseases. We have applied the tremor measurement method to the biofeedback training of Parkinson tremor.

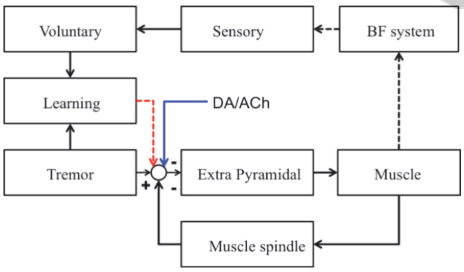


Figure 12: Biofeedback system of Parkinson tremor.

Figure 13: Tremor biofeedback with accelerometer.

Biofeedback needs biological signal sensor and feedback unit of the signal to patients. The feedback signal is tremor curve in visual biofeedback and modified pure sinusoidal tone in sound biofeedback. The visual biofeedback is executed on three healthy student (♀1♂2).

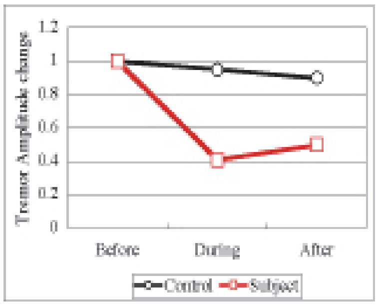


Figure 14: Visual biofeedback.

The subjects listen to the pure tone of which loudness changes according to the tremor frequency and they try to decrease the tone amplitude.
The tremor power (amplitude) decreases during and after the biofeedback training (Fig.14). The main frequency of tremor increases by the visual biofeedback (Fig.15).

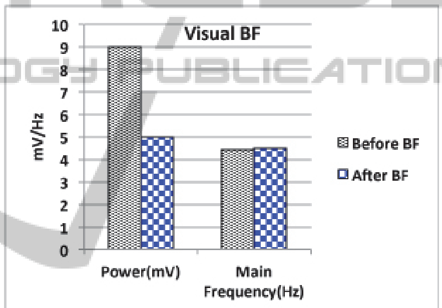


Figure 15: Tremor change by visual biofeedback.

Sound biofeedback uses pure sinusoidal tone modified by tremor power as the feedback signal instead of the tremor curve. The sound biofeedback is executed on ten Parkinson patients (♂2♀8, 74.9±5.1years old).

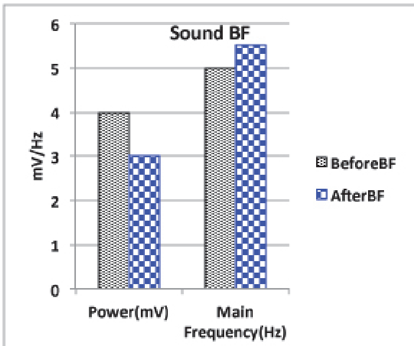


Figure 16: Tremor change by sound biofeedback.

The training effect shows the decrease of tremor power ($p<0.05$) and the increase of main frequency ($p<0.05$) (Fig.16).

Both L-Dopa medical treatment and the two biofeedback trainings show the same effect but the medical is most effective (Fig.17).

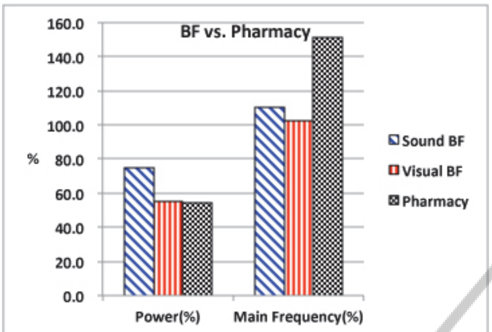


Figure17: Comparison of three methods for the tremor improvement.

## 5 CONCLUSIONS

Parkinson Disease can be measured and diagnosed objectively with 3 D accelerometers. A mathematical model based on the peripheral feedback theory is tested by computer simulation with good coincident with the clinical data. We have found the main frequency of Parkinsonian tremor is about 4Hz in arms. Using our method the tremor improvement by biofeedback training is objectively proved without any arbitral evaluation. The result that the main frequency of tremor increases and the tremor power decreases according to the treatments corresponds well to clinical fact.

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