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Early detection of Parkinson's diseases by using the relationship between time response and movement characteristics of human arms

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Abstract

Parkinson's and stroke diseases are brain problems of many elderly people. This study was done to investigate an early detection method for Parkinson's disease using the relationship between the brain time response and arm movement characteristics. 120 healthy people were examined and classified into four age groups (<20, 20-40, 41-60, >60 years old). The relationship between the two parameters was examined using a fabricated electronic device with an accelerometer on a hammer and a star-pattern generator a with a 9-position lighted keypad. Several simple and complex light patterns were designed to test brain function. The experimental treatments were developed using a 4×2 factorial experiment in a completely randomized design (CRD). The results showed that the time response of the >60 age group was the longest compared to other groups ($p<0.01$). Based on the experiments using a pattern-position approach, all age groups completed the simple pattern faster than the complex pattern ($p<0.01$). The accelerometer signal patterns in 20-40 years old and +60 years old were found to have polynomial and linear signal patterns, respectively. The relationship between the time response and the accelerometer signal were found to be negatively monotonic ($r_{sr} = 0.835$, $p < 0.01$). Therefore, this finding could identify healthy people without Parkinson's disease with an accuracy of 99.58 %. The results suggest that tests such as these can be developed for early detection of Parkinson's and related diseases.

Keywords: Brain defect, Accelerometer, Keypad light pattern, Detection, Relationship, Polynomial, Linear regression

1. Introduction

Nowadays, the number of elderly people has been increasing in societies; and brain diseases have been commonly found in the elderly. The symptoms of patients are such as unusually slow movement and slowing of response on the environments caused by structural brain disorder and affective impairment; hence, depressed patients who suffer with communications' issues and the life events. The early physically symptoms of brain disorder patients are such as motor impairment and psychomotor retardation. Since 1998, the research on the response time by using the LED signal changing was studied [1] and found the facts that the young people provided the fastest response during the experiment, while the elderly people gave the slowest response.

The study of a changing movement speed of the target by using computer games for a testing device by Ali-Akbae Samadani and Zahra Moussavi (2009), the device could be configured a changing movement speed of the target at least two patterns such as simple and complex patterns. The results showed that the subject can learn the simple pattern better than the complex pattern; moreover, this work also applied statistical analysis to the results of experiments in order to improve the reliability of the test [2]. In addition, Akos Jobbagy (1998) studied the detection of the Parkinson's disease and stroke disease [3], which analyzed on the body motion of patients, such as using Fast Fourier Transform (FFT) to find the frequency range of motion during the test. The prior research found that Parkinson's range was higher frequency than normal people. An accelerometer has been applied to detect human's motion [4-14]. Motion movement such as the walking and running from one point to another point was detected by using vibration sensor attached at the ankles, wrists, and waist.

This research studied on the relation between the time response of the brain and the movement characteristics of the human's arms in order to identify the symptom of brain disorder such as Parkinson's disease while the previous works studied the characteristics and the frequency of shaking. The experiment was applied to four groups of age: less than 20 years old, between 20 to 40 years old, between 41 to 60 years old, and over 60 years old, the results of this work could predicted a symptom of brain malfunction of patients. The outcome of this research can be useful for medical diagnosis to predict the early detection of brain diseases by using the relationship between the time response and a human's arms movement characteristics.

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2. Materials and methods

2.1 Hardware structure and software

The response on the environment of the patients under test was conducted by using the self-made keypad-light signal generator as shown in Figure 1. The time response and the arms' movement characteristic were measured. The position of the light signals and the keypad were designed with 9 positions using LED (Light Emitting Diode), and Light-Dependent Resistor (LDR) or photocell embedded inside to keypads. The radius of Pad 1-8 away from the central (Pad 0) is 20.5 cm in which is the estimated distance of the human's arms.

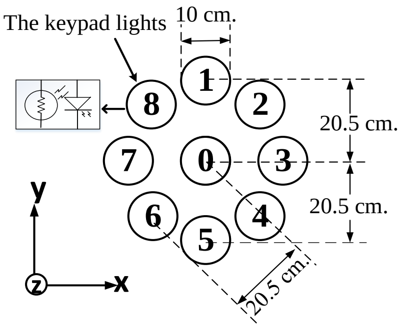


Figure 1 Keypad light signal generator

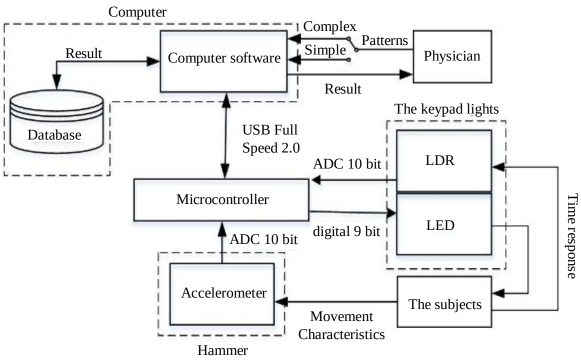


Figure 2 Block diagram of circuit connection

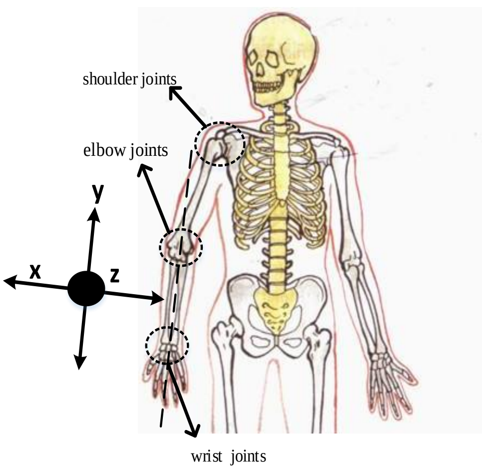


Figure 3 Relationship between the axis of the 3-D accelerometer and the arms when subjects hold a hummer
Image source: http://xn--y4caa.vcharkarn.com/lesson/1412

For the design and creation of a testing device, the hardware and software consists of a microcontroller, LDR, LED, an accelerometer, and database, as shown in Figure 2. The computer software controlled all functions, which can be selected testing patterns from computer software; there are four patterns as follows: I: Looping pattern, II: Switch pattern, III: Random pattern, and IV: Custom pattern. The time responses were measured when the subjects pressed the keypad lights from a center point to outer point and the movement characteristics of arms by using the accelerometer. Data of the time responses and the movement characteristics of arms were presented as a graph on a monitor and then recorded to the database. The interfaces between computer software and a microcontroller were communicated by using USB 2.0 Port, and they collect an acceleration signal every 10 ms. The MMA7341L was used as accelerometer which can record ±5,000 values of an output voltage signal at each axis with sensitivity of 440 mV/g from ±3 g mode and 117.5mV/g from ±11 g mode.

Figure 3 describes the relationship between the axis of the accelerometer and the subjects' arms when they hold a hummer. This shows that subjects use force from the three joints in the motion. The subjects hit x (left-right) z (elevation-Pressing) axis at an angle perpendicular to the lower arm and parallel the y (forward-backward), and the enforcing axial movement x (left-right), the subjects must use to force from the elbow joints to axis y from the shoulder and force them to the joints, elbow, and wrist for z axis the motion.

The keypad-light signal generator has the sequence patterns as following:

1) Pattern I: Looping pattern
0=>1=>0=>2=>0=>3=>0=>4=>0=>5=>0=>6=>0=>7=>0=>8
2) Pattern II: Switch pattern
0=>1=>0=>3=>0=>5=>0=>7=>0=>2=>0=>4=>0=>6=>0=>8
3) Pattern III: Random pattern
Subjects are unknown keypad lights, which display at any points, but the points display unique points.
4) Pattern IV: Custom pattern
The devices set display patterns of keypad lights by users.

Notably, symbol "=>" indicates changing of the keypad lights from 1) to 2). The keypad lights are changed when the subjects use a hammer to turn off keypad lights, which display on a device by using accelerometer inside the hammer.

2.2 Accelerometer

The output obtained from the accelerometer is:

$$\vec{a} = \vec{g}_{\theta} + \vec{g}_{m}, \tag{1}$$

where $\vec{a}$ is an output of an accelerometer, $\vec{g}_{\theta}$ is a gravity or an angle of the 3-D accelerometer, which compares to the earth's surface between ±1g or ±90 degree, $\vec{g}_{\theta}$ = 0 is the 3-D accelerometer when one of them is parallel to the earth's surface. And $\vec{g}_{\theta}$= 1 g is the 3-D accelerometer when one of them is perpendicular to the earth's surface. A calculation of the angle has been calculated as follows: [13]

$$\theta = \arcsin\left(\overrightarrow{g_{\theta}}\right), \tag{2}$$

where θ is the angle between the 3-D accelerometer and the earth's surface, and $\vec{g}_m$ is an acceleration, which occurs when the accelerometer is moving; which one g is 9.81 *m/s²*. It can be calculated an analog output of the accelerometer to the acceleration, which is calculated as follows: [13]

$$\vec{a}(n) = \frac{\vec{v}(n) - v_{\text{offset}}}{\frac{\Delta\vec{v}}{\Delta\vec{g}}}, \tag{3}$$

where $\vec{a}\,(n)$ is the acceleration value of each axis, $\vec{v}\,(n)$ is the analog output voltage of the accelerometer axes. v_{offset} is an analog output voltage of a stationary accelerometer and $\vec{g}_\theta = 0$g=, and $\frac{\Delta\vec{v}}{\Delta\vec{g}}$ is a sensitivity of the accelerometer.

2.3 The experiments

The conducted experiments were carried out by the subjects hammered the keypad light. The hammer was embedded with an accelerometer to measure the time response and to detect the arm movement characteristics of the subjects of 120 normal people. The pattern of light keypad was categorized into two groups: the simple and the complex patterns. The simple patterns composed of Pattern I and Pattern II while the complex patterns are Pattern III and Pattern IV. The results statistically analyzed with a confidence level of 95% for a standard of the response time of the test in each age group.

3. Data analysis

3.1 The analysis of time responses

Time responses (T_r) was determined by using equation (4)

$$T_r = t_s + t_m, \tag{4}$$

where t_s is a time of eyes responding to the keypad lights at outer points, t_m is a time of the arms moving to hit the keypad lights at outer points. We were immediately timing t_s and t_m after subjects hit the keypad lights at a center points.

3.2 The analysis of movement characteristic

Arm movement characteristics were calculated by using 3 parameters as follow:

The first parameter is an acceleration $(a)_{rms}$, which was calculated a_{rms} by using data to obtain from output of an accelerometer as follow:

$$a_{rms} = \frac{1}{T_r}\sum_{n=1}^{T_r\times\Delta t}\sqrt{\left(\vec{a}_x(n)-\mu_x\right)^2+\left(\vec{a}_y(n)-\mu_y\right)^2+\left(\vec{a}_z(n)-\mu_z\right)^2} \tag{5}$$

where $\vec{a}(\cdot)$ is an acceleration of each the axle, Δt is the timing on a sampling data, μ are estimated a value of an angle $(\vec{g}_\theta)$.The second parameter is a maximum spectrum of an acceleration (A_{fs}) in a frequency domain by using Fourier transform [3] as follows:

$$A(f)\Big|_{f=0.125}^{f=10} = \frac{1}{T_r}\sum_{n=p}^{q}\left(\left|\vec{a}(n)\,e^{-j\omega t(n)}\right|\right) \tag{6}$$

Then

$$A_{fs} = A(f)_{\text{Peak}} \tag{7}$$

The frequency on maximum spectrum of an acceleration $(F)_r$ is in a frequency domain by

$$F_r = f; \quad \text{while } A(f)_{\text{Peak}}, \tag{8}$$

where $A(f)$ is a frequency domain signal, $A(f)_{\text{peak}}$ is a maximum spectrum of the acceleration, ω is the angular frequency, which is a frequency (f) in a range of 0.125 to 10 Hz., $\vec{a}(\cdot)$ is the acceleration in the time domain, p is a time of subjects which hit to the center point, and q is a time of subjects which hit to the outer points. We converted the time domain to the frequency domain signal in the frequency range between 0.125-10Hz. instead of using band pass filters because the signal of the arm's movement characteristics is not suitable to use with filters.

3.3 Analysis of difference of the treatment

All parameters of experiment were subjected to 4×2 factorial experiments in completely randomized design (CRD) by splitting into two groups of factors, which are the age groups and a changing pattern of keypad lights by using the equations in the variance analysis (ANOVA)

All the experiments, increased the reliability of the results, the statistical analysis by using ANOVA at a confidence level of 95% and the compared difference performs of the average in each experimental group within the Duncan's New Multiple.

3.4 The relationship between accelerations and time responses

The relationship between an acceleration$(\vec{a})$, time(t), velocity $(\vec{u})$, and distance (d)as follows:

$$d = \vec{u}t + \frac{1}{2}\vec{a}t^2 \tag{9}$$

The relationship between accelerations and time responses of the subjects was desired; therefore, we determined $\vec{u} = 0m/s$ because the beginning of arms' experiment of subjects had not movement, d is the distance of the keypad lights measured from a center point to an outer point, which is equal to 20.5 cm., t is equal to time responses (T_r), and $\vec{a}$ is equal to the estimation of an acceleration $\vec{a}_e$ We can estimate the relationships between an acceleration (a_{rms}) and T_r of the experiments. The calculation of $\vec{a}_e$ as follow:

$$\vec{a}_e = \frac{2d}{T_r^2} = \frac{0.41}{T_r^2} \tag{10}$$

Research authors hypothesized between a_{rms} and a_e which should be the same trends; therefore, a_{rms} and T_r has correlated a statistically significant at level P<0.05 and it considered when it was at the equation (10), it was found a negative non-linear correlation.

We used the Spearman Rank correlation (r_{sr}) on the calculations to find the correlations between a_{rms} and T_r, there were the monotonic correlation.

However, the correlations between a_{rms} and T_r were calculated by using 3 methods to compare a_{rms} and T_r are the most of any relationship as follow: the Pearson method $(r)_s$ for a linear correlation, the Kendall method (r_k) and the Spearman method (r_{sr}) for a monotonic correlation, respectively.

4. Results and discussion

These recall results were the time responses T_r, the arm's movement characteristics signal was measured by the accelerometer of each points, and these were showed in Figure 4. Where x_1 is the entire duration of the experimentation, x_2 is the accelerated characteristics while subjects hit the keypad lights, x_3 is the time response(T_r), and x_4 is the movement characteristics signal of the arms on the time domain $\vec{a}(n)$.

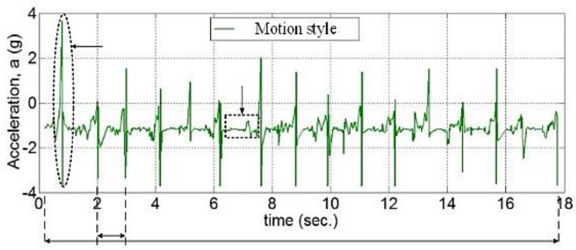


Figure 4 Recall results as the time responses (T_r) and the arm's movement characteristics signals

4.1 The time responses

Figure 5 shows the interaction of T_r between the points of the keypad lights, and the group of subjects finds the subjects group which are the 20 to 40 years old group and <20 years old group has the fastest response, and T_r increasing on the subjects of the 41 to 60 years old group and the groups of >60 years old group, respectively.

Figure 6 shows, the changing pattern of the keypad lights, which are the most effect on the <20 years old group and the less effective when it is the increasing age groups.

The means of the time response ($\overline{T}_r$) of each factor in 8 point recall data in Table 1 that is One-way analysis of variance (ANOVA) to apply. The results show $\overline{T}_r$ of each age groups different significantly to $\overline{T}_r$, P<0.01, $\overline{T}_r$ of the age < 20 years old group, age 20 to 40 years old group, age 41-60 years old group, and age more than 60 years old is equal to 0.773 0.614 0.831 and 1.124 seconds, respectively. This is shown that the range group 20 to 40 years old is found the response times faster than other age groups. This could be the result of a visually reaction with the movement of the arms faster than the other age groups. The age more than 60 years old responds more slowly than other age groups. These results are consistent with the research [1] was noted that the age range of 20 to 30 years responded to the eyes faster, and the other age as the age range 60 to 79 years responded slower than to the other age range.

One-Way ANOVA reveals $\overline{T}_r$ of the pattern test factor between Complex pattern and Simple pattern, which are significantly different, P< 0.01. The test results are consistent with the research [3] was found that the response of the changing speed of the Random pattern was different results of response changing speed Simple pattern. The $\overline{T}_r$ of the Simple pattern and Complex pattern were 0.824 and 0.843

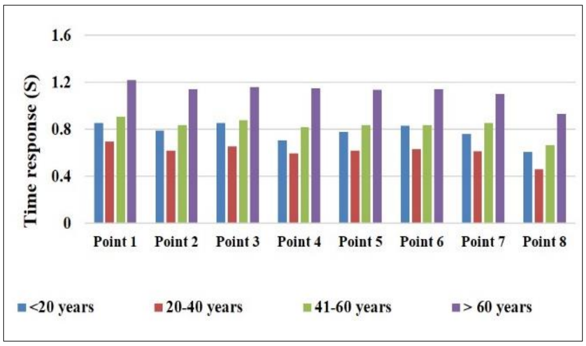


Figure 5 Interaction of the time response between the point of keypad lights and the group of subjects

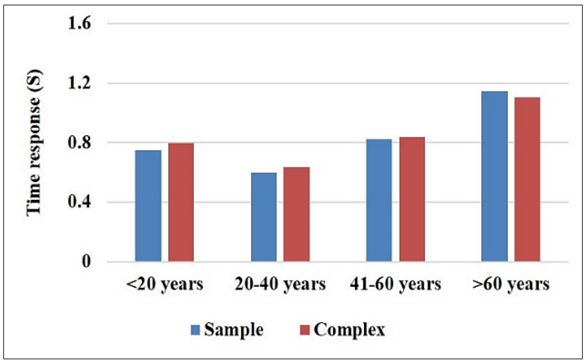


Figure 6 Recall results as the interaction of the time response between the group of subjects and the changing pattern of the keypad lights

Table 1 One-way analysis of variance (ANOVA) applied to results of T_r between the aged of group and Patterns test

Parameter	**T_r (Sec.)**
A:age of subjects(years old)	**
<20	0.773[c]
20 to - 40	0.614[d]
41 - 60	0.831[b]
>60	1.124[a]
B: Patterns test	**
Simple	0.824
Complex	0.843
A × B	*
Pooled SE	0.005

where [a b c d] are the statistically difference of the means in each experimental group with the Duncan's New Multiple method between the rows in the table,* and ** are significantly different (ANOVA) of $\overline{T}_r$, P<0.05 and P<0.01, between the rows.

seconds, respectively. In addition, Simple pattern easy to guess the keypad lights in the next position while the Complex pattern is the time response more than other patterns.

Finally, we found the result 4×2 Factorial Experiment in Completely Randomized Design between age groups and pattern test in Table 1 that show in the pattern test affects the time response of the significant difference each age statistically at the less than 0.05.

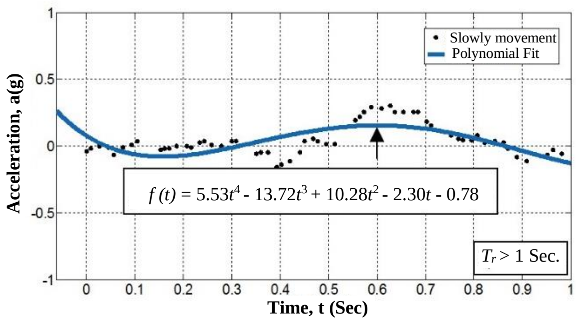
4.2 Movement characteristics of arms

The movement characteristic ($\vec{a}(\cdot)$) of arms analyzed the signals of the accelerometer are that measure the acceleration of the arms while subjects hit the keypad lights at the midpoint (points 0) to outer (points 1-8).

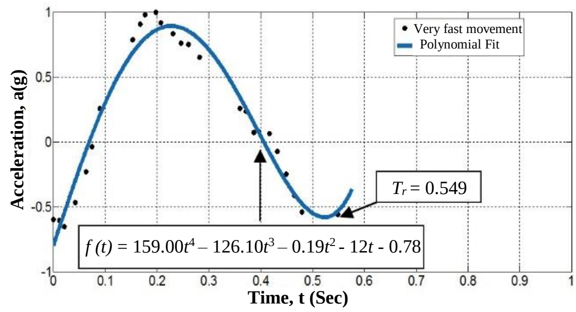
$\vec{a}(\cdot)$ is x_4 on Figure 4. We found trends line of $\vec{a}(\cdot)$, and it has Two tends lines in slowly trend movements (an acceleration linear trend line). They are very fast trend movements (an acceleration polynomial trend line) and shown in Figure 7(a)-(b).

Figure 7 (a)-(b) shows the trend line $\vec{a}(\cdot)$ of a point. The polynomial acceleration model of the fast movement is found equal to 0.9212 of R-square, and slowly movement equals to 0.3337 of R-square. Therefore, the fast movements are similar to the polynomial trend line more than the slowly movement. The slowly movements are similar to the linear trend line more than the polynomial trend line. We found the fast movement with the subjects aged between 20 to 40 years old, and the slow movement found the subjects aged more than 60 years old and aged between 41-60 years old partially.

The cause is the linear trend line, probably due to the constant movement because subjects were used less force in motion that shows Figure 7 (a). Where $\vec{a}(\cdot)$ is different, the more slope $\Delta\vec{a}/\Delta t$ is a subject by using arms to force more for controlling the motion. In addition, $\vec{a}(t)$ from the Figure 7 (a)-(b) was converted to $A(f)$ shows in Figure 8 (a)-(b).



(a) The trend line of $\vec{a}$ are slowly moving

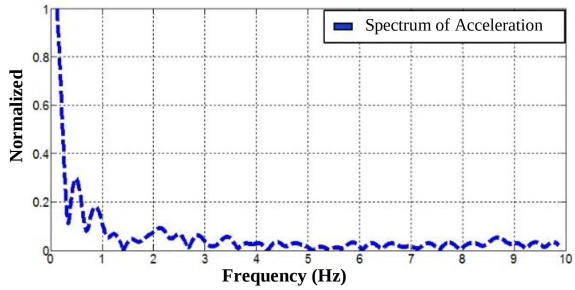


(b) The trend line of $\vec{a}$ are very fast moving

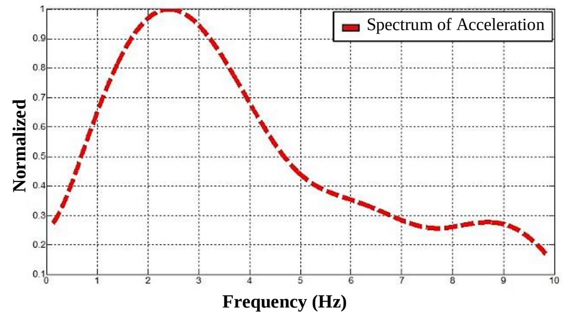
Figure 7 Trend line of movement characteristic of the arms are moving

The $f(t)$is the acceleration polynomial model with four order, SSE: 0.5854, R-square: 0.5769, Adjusted R-square: 0.5524, and RMSE: 0.09211. The characteristic of the movement slowly, and the movement very fast were SSE: 0.3114, R-square: 0.9625, Adjusted R-square: 0.9554, RMSE: 0.1218.

The observation of the arms' signal characteristics in Figure 7 and Figure 8 shows A_{fs} the slowly movement signal



(a) The frequency domain of the slow movement



(b)The frequency domain of very fast movement

Figure 8 Frequency domain of the acceleration time domain

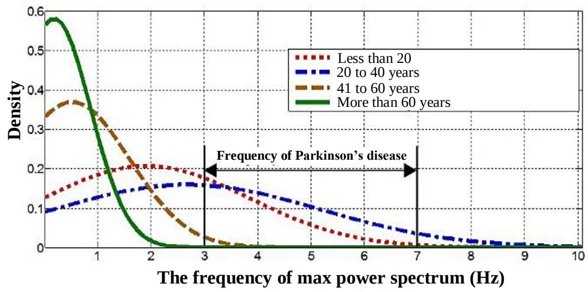


Figure 9 Recall as the distribution of F_r

found F_r is near 0 Hz, and A_{fs} is very fast movement signal that is found F_r in increasingly high.

The graph in Figure 9 shows $\bar{F}_r$ in z-axis of each aged group, which is the trend signal on <20 years group and 20 to 40 year group in the polynomial signal. The 41 to 60 years group is in the linear signal mixed to the polynomial signal, and aged over 60 years are the linear signal. This can see that the age subjects under 40 years old group is found the distribution on the frequency range of the Parkinson's disease because it is F_r of the fast moving characteristic; It is not a tremor characteristic that can be detected by using the relationship between F_r and T_r.

The results from Table 2 are found the age of the subjects that related to the frequency range with the statistical significance at the 0.01 level of all directions, but the pattern tests are not statistically different (P<0.05).The age increases in $\bar{T}_r$ downward trending. However, the results of conflict in studies [3] increases the ages the frequency of the arms' tremor. Nerveless, the study has different results due to the different experiments. The research [3] measured the frequency of the arms while the arms were stationary.

The statistically significant difference (ANOVA) at the 0.01 level means on the aged subjects as shown in Table 3 is found the relationship between A_{fs} and a_{rms}, and the values are very different in the axis x through the ages, that arrange $\bar{A}_{fs}$ from the most to the smallest value as follows: 20-40 years old group, less than 20 years old group, 41-60 years old group, and more than 60 years old group, respectively. $\bar{a}_{rms}$ is found the results the elderly group less than young group.

4.3 The relationship between time response and movement characteristic

The last sections analyzed to determine the differences of the parameters in each experiment, which is already found the subjects in each different group.

Table 2 One-way analysis of variance (ANOVA) applied to results of F_r between the aged groups and patterns test

Parameter	$\bar{F}_r$ (Hz)		
	x	y	z
A: age	**	**	**
<20	1.964[a]	0.302[b]	1.888[b]
20-40	1.919[a]	1.110[a]	2.681[a]
41-60	1.344[b]	0.148[b]	0.533[c]
>60	1.116[b]	0.179[b]	0.191[d]
B: Patterns	ns	ns	ns
Simple	1.576	0.468	1.320
Complex	1.595	0.401	1.327
A x B	ns	ns	ns
Pooled SE	0.038	0.022	0.027

where [a b c d] are the statistically difference of the means in each experimental group with the Duncan's New Multiple method between the rows in the table,* and ** are significantly different (ANOVA) of $\bar{T}_r$, P<0.05 and P<0.01, between the rows.

Table 3 One-way analysis of variance (ANOVA) applied to results of A_{fs} and a_{rms} between the aged groups and Patterns test

Parameter	$\bar{A}_{fs}$			$\bar{a}_{rms}$
	x	y	z	
A: age	**	**	**	**
<20	27.55[b]	100.35[c]	31.12[d]	15.43[b]
20-40	35.57[a]	101.72[c]	56.76[b]	32.26[a]
41-60	22.33[c]	116.16[a]	108.16[a]	15.61[b]
>60	17.81[d]	104.65[b]	40.57[c]	11.89[c]
B: Patterns	**	ns	ns	*
Simple	24.223	106.758	58.982	18.184
Complex	26.309	105.062	59.052	18.024
A x B	*	ns	ns	ns
Pool SE	0.249	0.350	0.863	0.248

where [a b c d] are the statistically difference of the means in each experimental group with the Duncan's New Multiple method between the rows in the table,* and ** are significantly different (ANOVA) of $\bar{T}_r$, P<0.05 and P<0.01, between the rows.

Table 4 Relationship between time response and movement characteristic

Between parameter	Correlations method (r)		
	linear	monotonic	
	Pearson	Kendall	Spearman
$T_r - F_r$	-0.354**	-0.365**	-0.483**
$T_r - A_{fs}$	-0.388**	-0.333**	-0.478**
$T_r - a_{rms}$	-0.353**	-0.659**	-0.835**
$F_r - A_{fs}$	0.316**	0.296**	0.390**
$F_r - a_{rms}$	0.587**	0.376**	0.523**
$A_{fs} - a_{rms}$	0.191**	0.403**	0.523**

**, Correlation is significant at the 0.01 level (1-tailed), the minus symbol is correlation in the opposite direction.

This section analyzed the relationship between the parameters of the response times and the movement characteristic by using three methods correlation; Pearson correlation coefficients the measured linear relationships, Kendall, and Spearman correlation coefficients the measured monotonic relationships as shown in Table 4. It is the significant correlation at the 0.01 level in the all parameters. We found that the time response has negatively relationship with the all movement parameters characteristic. We found that the time and the acceleration have the most negatively monotonic as shown in Figure 10, the blue dotted line represents the estimation results from normal people by using Curve fitting tool function from MATLAB. The equation is the calculated from below:

$$a_{en}\left(T_r\right) = \frac{13.05}{T_r^{0.8}} \tag{11}$$

The arms always shake in the Parkinson's disease and the trend was sum of sine as equation (12).

$$a_s\left(t\right) = w_1 \sin\left(u_1 t + v_1\right) + w_2 \sin\left(u_2 t + v_2\right) + w_3 \sin\left(u_3 t + v_3\right), \tag{12}$$

where $a_s(\cdot)$ is the tremor arms of the Parkinson's disease while it is stationary, and w, u, v are the constant variableness.

Therefore, the amplitude acceleration of the patients is equal to the equation (13)

$$a_p\left(T_r\right) \times \sum_{n=1}^{T_r \times \Delta t} \left(\sqrt{a_{sx}^2\left(n\right) + a_{sy}^2\left(n\right) + a_{sz}^2\left(n\right)} \right) \tag{13}$$

Therefore, the estimated shaking is the Parkinson's disease symptoms while the arms move by using the equation (14).

$$a_{ep}\left(T_r\right) \approx a_{rms}\left(T_r\right) + a_p\left(T_r\right) , \tag{14}$$

where $a_{ep}(\cdot)$is the estimated acceleration of the Parkinson's disease; It is in the red line in Figure 10.

The red line (a_{ep})in Figure 10, the results are obtained from one Parkinson disease and red dotted line is $\bar{T}_r$ of > 60 years old group because the patients who are shaken have a slowly respond more than normal patients. We could take the results on the upper red line and the over red dash line to the right side for the detection of Parkinson's disease by using the equation (15).

$$D(0,1) = \begin{cases} 1 ; a_{rms}\left(T_r\right) \geq a_{ep}\left(T_r\right) \text{ and } T_r > T_{r4} \\ 0 ; \text{Other wise} \end{cases}, \tag{15}$$

where $D = 0$ is the normal people's result, $D = 1$ is the patient's result, $\bar{T}_{r4}$ is $\bar{T}_r$ of > 60 years old.

We can use equations (16)-(18) to measure sensitivity, specificity, and accuracy, respectively [15].

$$\text{Sensitivity} = \frac{TN}{TN + FN}, \tag{16}$$

$$\text{Specificity} = \frac{TP}{TP + FP}, \tag{17}$$

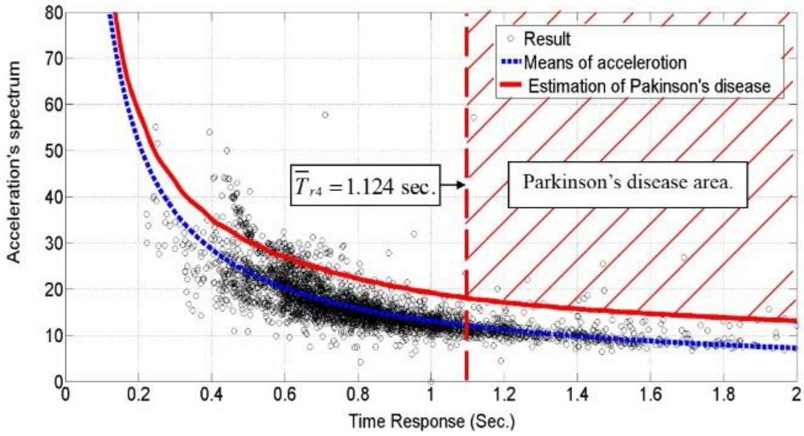


Figure 10 Relationship between T_r and a_{rms} of the trial results, A total 120 number (3840-point)

$$\text{Accuracy} = \frac{TN + TP}{TP + FP + TP + FP}, \tag{18}$$

where FN is the number of the upper red line results and the right red dotted line of the normal subjects, TN is the results, which are not under the conditions of FN. TP is the results number of the upper red line and the right red dotted line of the patients. FP is results, which are not under the conditions of FN. Figure 10, the sensitivity was 99.58%, but it cannot be measured specificity and accuracy because there are no trial results of the patients.

4.4 Analysis of arm-controlled movement

Table 2 and Figure 3 show F_r in direction of the x-axis range during 1.116 to 1.964 Hz. It means the subjects using the force in elbow joint motions on x-axis, which are the most valuable. The < 20 years old age group uses the force of elbow and wrist joints in the motion, and aged 20 to 40 years group is the frequency highest in F_r of motion in all directions due to subjects use the three-point force to the control movement. The 41 to 60 years old age group has F_r the little x and z that are used the force from the elbow, and wrist for moving, and the aged at slowest motion is >60 years old that is found F_r in the only x-axis and the force-elbow only for controlling the motion.

5. Conclusion

This article showed the relationship between the time responses and the movement characteristics of normal human's arm for early detection of brain disease, such as Parkinson's disease. The results of the statistical analysis were found that the different age groups with P<0.01 in the time response could be sorted from the most to the least as follows: the age group 20 to 40 years, less than 20 years, 40 to 60 years, and more than 60 years, respectively. The outstanding factor of the relationship was the acceleration (a_{rms}) that had the negatively monotonic correlation ($r_{sr} = -0.835$, P<0.01). This method can identify the healthy subjects without brain disease with 99.58% accuracy. The promising results can benefit the medical diagnosis for brain disease effectively.

Finally, the experimental results and the analysis in this article conclude that this work provides a useful tool for medical appliances in order to predict diseases or assist patients who have the arms' shaking problem in the evolution. This helps to reduce the diagnosis and treatment time and the effects in patients.

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