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TREMORX: AN ASSISTIVE DEVICE TO IMPROVE TREMOR PATIENT WRITING CAPABILITY

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Abstract

Patients with hand tremor often face difficulties in performing daily tasks using their hands, especially writing. Hence, this paper presents an inventive assistive device named as TREMORX that can assist patients in overcoming this situation by improving their handwriting legibility. TREMORX is designed to suit the patient's handgrip and focuses more on the patient's comfort. The aim is to analyze the performance of the device based on acceleration data by implementing the power spectral density (PSD), which is focused on reduction of coherence amplitude, and displaying the signal in the time and frequency domains. The measured acceleration data are further analyzed with Matlab simulation and show a significant response. The TREMORX is designed in three different lengths of diameter and the stiffness of each one is measured. The effectiveness of the device is identified using the force sensitive resistor (FSR) to measure the force and flex sensor, as to determine the deflection. The results indicate that the patients experienced improvements in handwriting quality when using TREMORX.

Keywords: Hand tremor, assistive device, miniature accelerometer, matlab simulation

1.0 INTRODUCTION

Tremor is an involuntary or rhythmic uncontrollable oscillation of body parts. The severe illness most commonly occurs at the hand and head. Tremor may happen to anyone [8] and most PD patients are not aware at the early stage of their tremor until the tremor becomes worse. The involuntary movement of a healthy person (physiological tremor) should be small and clearly visible when a person encounters anxiety, is furious, too cold or frightened. However, for a neurologically diseased person, such as a person diagnosed with Parkinson's disease, there is a significant uncontrollable hand tremor movement [5]. Tremor may be caused by smoking habits, taking caffeine, alcohol, using certain drugs and people with a family history of movement disorder [2-3].

Tremor patients may suffer difficulty in doing daily tasks such as holding or eating, and in severe conditions, it may cause depression [1]. The disease also affects the patient's capability in writing. The hand oscillation when writing can influence the patient's handwriting quality. Tremor relatively occurs at a fixed frequency and amplitude [4],[10] and the frequency is within the range of 4 to 12 Hz [6]. This kind of tremor disease cannot be cured, but with certain medicine and surgical procedures, the severity of tremor may be reduced. The medicinal therapy involving drugs may have side effects on the patients, and in some cases may cause symptoms such as tardive dyskinesia, akathisia and clones [7].

Biomechanical loading is another method to reduce the tremor without surgical intervention or ingestion of drugs. Currently there are few researches that are trying to develop a writing device that may help tremor patients to improve their handwriting quality. PenAgain ErgoSof Pens [12] developed by Pacific Writing Insturment, Inc attempts to focus on alleviating stress and reducing the risk of repetitive strain injury while writing and the user's index finger sits in the Y-shape to give direct pressure to the pen's tip. This idea is to eliminate the need of gripping force and at the same time push the tip into the paper. Five-point grip pen (FPGP) [13] invented a touch pen that can operate directly to the computer screen by adding brace on it and introduce FPGP grip techniques. From the observation, the user is required to hold the device with unnatural gestures, such as local elbow and local wrist support during three screen tasks; writing, pointing-and-clicking and drawing. This situation may cause conflict in user behaviours and unnatural grip patterns.

The approach presented in this study is the invention of an assistive device named as TREMORX. The device can function with a regular pen, and comes with a mechanism that can absorb or reduce the hand tremor by transferring it to the device. Hence, the device is able to improve the quality of patient's handwriting by minimizing or eliminating the trembling. To validate the efficacy of TREMORX, a tremor patient, who is clinically diagnosed to be suffering from hand tremor, is selected to be a respondent for this research.

2.0 METHODOLOGY

2.1 Device Designing

The key points in designing the device are that it should be lightweight, comfortable for the hand to grip, flexible, and most importantly, able to improve the quality of a tremor patient's handwriting. Initially, to realise the ideas, the device was designed virtually with Solidworks software. The Solidworks software is used to create the two-dimensional drawing, and generate a three-dimensional view, which is vital for this research.

Figure 1 shows the final design of the TREMORX assistive device. Generally, the device acts as a sleeve to the common pen, where the writing pen is inserted inside the TREMORX. There are four crucial components for this inventive device, writing pen slot, slot A, slot B, and finger grip point. There are two circular holes at both ends of the TREMORX that are 4.5mm in diameter. These holes function to fit the writing pen, and a rubber mat is patched inside the opening of the hole to hold the pen from slipping when writing. Slot A comes with a flexible opening so that pens of different diameters can be used. Meanwhile, both sides of the TREMORX have a finger grip point area. The areas are for the placement of the user's the thumb and index or middle finger. It is very important to note this because this area is designed to absorb the tremor that can affect the quality of patient's handwriting. Slot B functions to separate the finger grip point area and main body of TREMORX, and provide flexibility in movement of the finger grip point area when the user is gripping it. The thickness of the device wall is 2.4mm and the total length is 105mm. In this research, there are three different diameter sizes of TREMORX used, 22mm, 24mm and 26mm measured from the center of the device. The use of different sizes will be further discussed in the results section to investigate whether the size has an effect on the performance of the TREMORX.

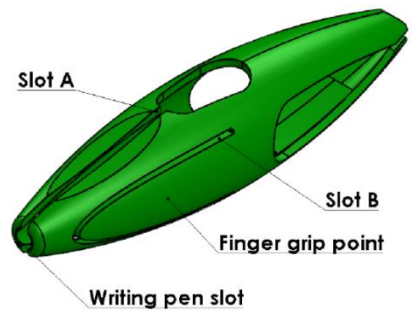
After that, the virtual design was made real by printing the design with a 3D printing machine, Replicator 2X from Makerbot Industries. The fused deposition modeling (FDM) of this machine technology melts the Acrylonitrile butadiene styrene (ABS) material in the form of wire filament through the moveable nozzle, and the programmable code will move the nozzle layer by layer until the TREMORX is fully printed. The time to complete the printing is about 4 hours and it depends on the printing quality resolution. High quality printing means the object is printed with smooth surface finishing and usually consumes more time.

2.2 Data Measurement

2.2.1 Acceleration of Tremor

A miniature accelerometer sensor (MMA7361LCR1) with dimension of 5mm (W) x 11mm (L) x 1.75mm (T) was used. The accelerometer is patched directly to the normal pen that placed inside the TREMORX to measure the acceleration after tremor absorption and the other accelerometer is patched similarly to another normal pen without TREMORX to represent the actual tremor acceleration of the patient's hand. The signals detected by the accelerometer are then sent to the computer through NI-DAQ card (PCI-6259) to store the data and further analysis is conducted using the Matlab software. Before the acceleration signals can be further analysed, the noise interferences during the measurement need to be filtered. The second-order Butterworth filter is proposed with band-pass type selection between the frequency ranges of 0.175-15Hz. This frequency range is selected properly to conserve the frequency of interest of the tremor, which is in the range of 3-12Hz [9], and at the same time eliminates the unwanted noise.

(a) TREMORX with handgrip presented



(b) Components detail

Figure 1 Overview of TREMORX

2.2.2 Stiffness Measurement

As mentioned, slot B provides the gap to allow flexibility of the finger grip point that can absorb the tremor. The effectiveness of the device is measured based on the stiffness at that area. Hence, the FSR (SN-FRC-0.5) [11] has been used to measure the finger gripping force. Meanwhile, to satisfy Hooke's law, another parameter value needs to be determined. The deflection parameter is measured based on the deflection angle of the Flex sensor (SN-FLX-FC) [11] attached at the flexible point area as shown in Figure 3.

The specification of this sensor, when straight (inflexed), resistance is ~9k Ohm, 90 degree bend resistance is ~14k ohm, and 180 degree bend resistance is 22k ohm. Both sensors' output is connected to the miniature microcontroller board before being sent to the computer for recording purposes. The output signal from both sensors is analog and hence the conversion to respective measurement units needs to be done by the microcontroller by performing C programming code.

At this stage, the sensors precision is required and hence, the calibration needs to be conducted based on reference datasheets from the manufacturer. Figure 2 depicts the deflection point and from the Flex sensor deflection (degree), the deflection value, *x* can be calculated where, *y* denotes the end-to-end length of the finger grip point area.

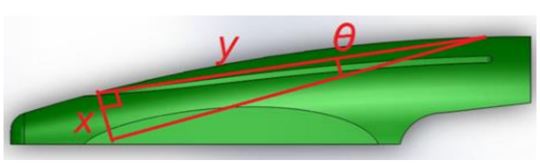


Figure 2 Finger grip point deflection

$$tan\ \theta = \frac{x}{y} \quad (1)$$

The Hooke's law equation is given by,

$$F = kx \quad (2)$$

Where *F* denotes finger grip force and *k* is stiffness of the flexibility point area. Substitute (1) into (2) and rearrange,

$$k = \frac{F}{y.tan\theta} \quad (1)$$

Figure 3 TREMORX with FSR (SN-FRC-0.5) and Flex sensor (SN-FLX-FC**)**

2.2.3 Device Validation

Figure 4 depicts the TREMORX tested by a respondent in his 60's who has been clinically diagnosed with hand tremor. The respondent was asked to track several words on the paper using TREMORX and a regular pen. During the measurement, the patient is not taking any medication and is in seated position. The aim is to investigate whether TREMORX helps to improve patient handwriting quality, as compared to using a regular pen.

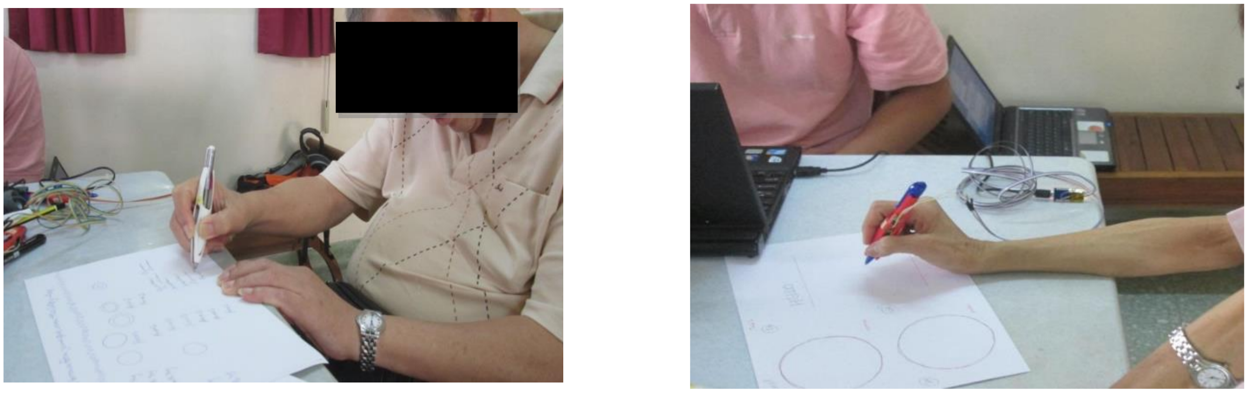


Figure 4 TREMORX tested by the tremor patient

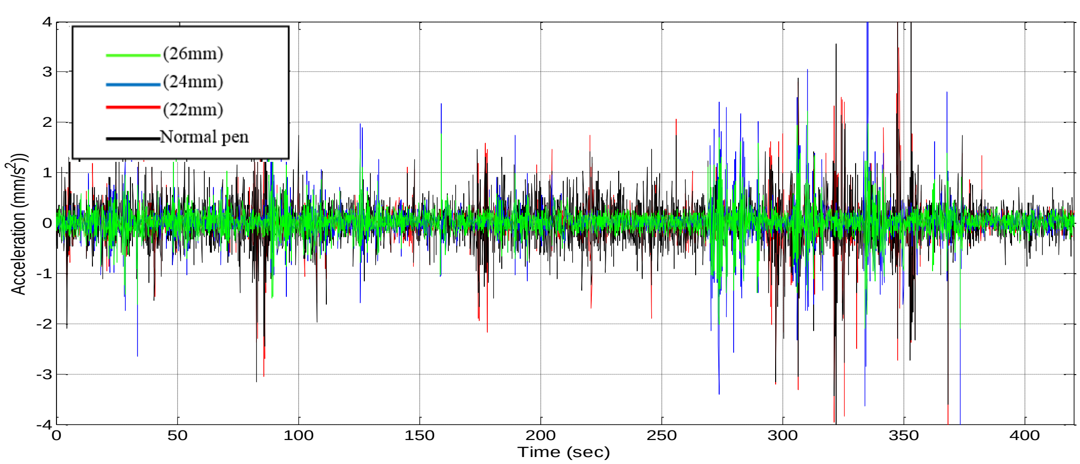
3.0 RESULTS AND DISCUSSION

3.1 Power Spectral Density

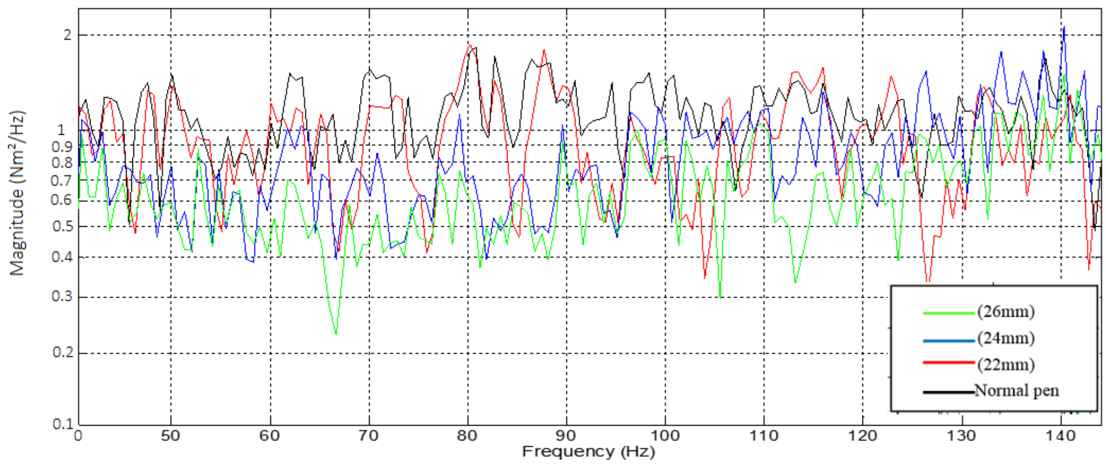
The results are obtained from performing analysis using m-file code, which is part of the MATLAB software environment. The power spectral density (PSD) is used to evaluate the performance of TREMORX based on reduction of coherence amplitude, and also to display the signal in the time and frequency domains. The results are divided into two stages, investigation of the performance of TREMORX with various diameter sizes, and tracked words done by a patient using TREMORX and a regular pen.

Figure 5 presents the comparison of acceleration data with three different diameter sizes of TREMORX, 22mm, 24mm and 26mm. The result is plotted in a 450 second time series while the patient performed the writing task. As shown in Figure 5(a), the acceleration response is plotted in time domain. TREMORX with diameter 26mm shows most significant response due to narrow acceleration response compare with others diameter. This is because the 26mm diameter provided more deflection degree angle, θ, hence the high amplitude of hand tremor can be attenuate. Based on the result, it is not easy to estimate the tremor attenuation because of the uneven signal response. This matter can be solved by plotting the acceleration response in the frequency domain as shown in Figure 5(b). Based on the figure, the result indicates that the TREMORX with diameter of 26mm provides better attenuation of tremor as compared to the TREMORX with 24mm and 22mm diameter. This shows that the different size of TREMORX device does have an effect on its performance.

Besides that, based on the investigation, the internal space inside the flexible writing grip point is vital in achieving a significant result. The bigger space inside the writing grip point area will provide enough deflection of vibration displacement while writing, and hence, the hand tremor can be widely absorbed by the TREMORX. However, the diameter of TREMORX has it limitation where it cannot design too wide because it may affect the finger comfort while grip the device.



(a)



(b)

Figure 5 Analysis of acceleration response and PSD response by using TREMORX with different diameters: (a) Time domain and (b) Frequency domain.

Table 1 depicts the results of TREMORX based on the analysis done from Figure 4. From the table, the TREMORX with 26mm diameter is able to produce 15.94% improvement, followed by 24mm with 12.66% and 22mm with 4.43%. From the percentage of improvement value, the respondent suffered non-critical hand tremor due to minimal of hand tremor magnitude plotted.

Table 1 Result of TREMORX based on average magnitude of PSD

	Average Magnitude		Improvement
Diameter TREMORX (mm)	**Actual vibration (normal pen) (Nm²/Hz)**	**Vibration improved (TREMORX) (Nm²/Hz)**	**Percentage (%)**
-	0.79	-	-
22	-	0.755	4.43
24,	-	0.69	12.66
26	-	0.06	15.94

3.2 Stiffness of TREMORX

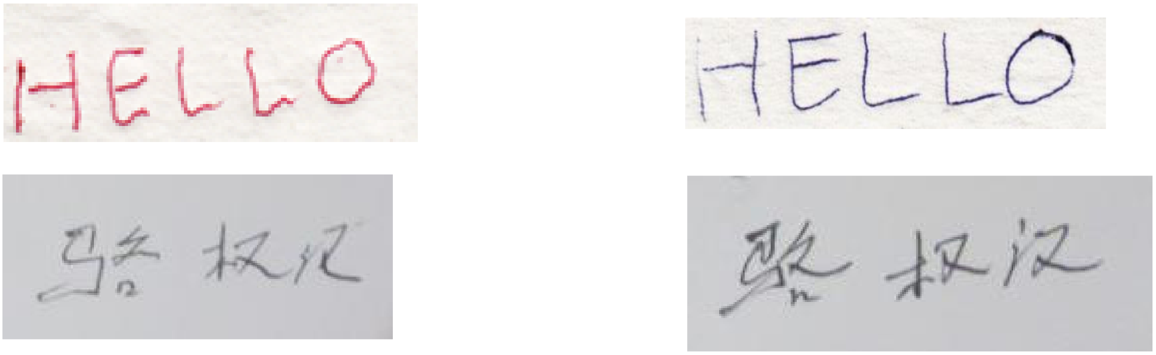
While performing the writing task, a patient was asked to press the finger on top of effective area of FSR. The reading of FSR and Flex sensor is recorded on the computer. Table 2 shows the results by calculating the average of sensor data. Based on the FSR value, the force measured by the representative patient hand grip is consistent for every single size of TREMORX, and it can be concluded that the diameter does not affect the gripping force of the user. Meanwhile, the deflection values increase as the diameter increased. This shows that the device with same shell thickness provides more flexibility when the diameter area is increased. Based on the stiffness calculations, the TREMORX with 26mm size is more flexible and significantly able to attenuate the tremor handwriting.

Table 2 Stiffness with different sizes of TREMORX

Diameter TREMORX (mm)	Finger grip force (N)	Deflection (mm)	Stiffness (N/mm)
22	6	5.22	4.43
24,	6	5.32	12.66
26	6	5.45	15.94

3.3 Handwriting Quality

Figure 6 shows the handwriting quality of the respondent diagnosed with hand tremor when using the TREMORX with 26mm diameter. Figure 6(a) and Figure 6(b) is a side-by-side comparison that clearly shows the respondent's improved handwriting quality. Evaluation is based on visual observation of the smoothness of the written word "HELLO" in blue color while using TREMORX assistive device, as compared to the quality of the word in red when the respondent used a regular pen. The respondent finds difficulty when using a regular pen to write the word due to the hand trembling and writing consumed more time compared to using TREMORX. Meanwhile, a significant improvement was observed when the respondent used the proposed assistive device while writing



(a) (b)

Figure 6 The quality of handwriting performed by a respondent using (a) with regular pen (b) TREMORX

4.0 CONCLUSION

The preliminary result for the proposed inventive assistive device to help tremor patients shows significant results. The consideration of the device size in terms of the diameter is very important in achieving optimum performance. The wide diameter of the TREMORX shows a good performance, but there are limitations for it. The size cannot be too wide because it may affect the patient's comfort and reduce the finger strength when a patient wants to write for a long period of time. For data measurement, a miniature sensor is well selected due to its size and can be patched inside the small scale area of TREMORX.

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References

[1] As'arry, A., Zain, M. Z. M., Mailah, M., Hussein, M., Yusop, Z.M. 2011. Active Tremor Control in 4-DOFs Biody-namic Hand Model. *International Journal of Mathematical Models and Methods in Applied Sciences.* 5(6): 1068-1076.

[2] Bain, P. G. 2007. Tremor, *Journal of Parkinsonism & Related Disorder*. 13(3): 369-374.

[3] Ellingsen, D. G., Bast-Pettersen, R., Efskind, J., Gjolstad, M., Olsen, R., Thomassen, Y., and Molander, P. 2006. Hand Tremor Related to Smoking Habits and the Consumption of Caffeine in Male Industrial Workers. *Journal of Neurotoxicology*. 27(4): 525-533.

[4] Engin, M. 2007. A Recording And Analysis System For Human Tremor. *Measurement.* 40(3): 288-293.

[5] Hussein, M., As'arry, A., Zain, M. Z. Md., Mailah, M., and Abdullah, M. Y. 2009. Experimental Study of Human Hand-arm Model Response. *6th International Symposium on, Sharjah.* 23-26 March 2009. 1-6.

[6] Papapetropoulos, S., Gallo, B. V., Guevera, A., Singer, C., Mitsi, G., Lyssikatos, C., Jagid, J. R. 2009. Objective Tremor Refistration During Dbs Surgery For Essential Tremor. *Clinical Neurology and Neurosurgery*. 111(4): 376-379.

[7] Pelckmans, K. 2012, Lecture Notes for a course on System Identification. *The system Identification Procedure*. 17-18.

[8] Pellegrini, B., Faes, L., Nollo, G., and Schena, F. 2004. Quantifying the Contribution of Arm Postural Tremor to the Outcome of Goal-directed Pointing Task by Displacement Measures. *Journal of Neuroscience Methods*. 139(2): 185-193.

[9] David, P., Charles, M. D., Gregory, J., Esper, B. S., Thomas, L., Davis, M. D., Robert, J., Maciunas, M. D, Rob-ertson, M. D. 1999. Classification of Tremor and update Treatment. *American Family Physician*. 59(6): 1565-1572.

[10] Zhang, J., Chu, F., and Nizamuddin, M., 2005. DSP Controller Based Signal Processing of Physiological Hand Tremor. *Proceeding of the American Control Conference* 2005. 8-10 June 2005, 1569-1574.

[11] Cytron Technologies - Your Online Store for robotic parts, embedded system, electronic components and hobby kit. (n.d.). from http://www.cytron.com.my/ Retrieved 19 August 2014.

[12] PenAgain. (n.d.). from http://www.penagain.com/ Retrieved 22 March 2014.

[13] Wu, F., and Luo, S. 2006. Design And Evaluation Approach For Increasing Stability And Performance Of Touch Pens In Screen Handwriting Tasks. *Applied Ergonomics, Kidlington*. 37(3): 319-27.