



UNIVERSITI PUTRA MALAYSIA

**ACTIVE TREMOR CONTROL ON HUMAN HAND TREMOR TEST RIG
MODEL USING P+FUZZY LOGIC CONTROLLER**

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MODEL USING P+FUZZY LOGIC CONTROLLER**

By

HAFIZ BIN JAMALUDIN

**Thesis Submitted to the School of Graduate Studies, Universiti Putra
Malaysia, in Fulfillment of the Requirements for the Degree of Master of
Science**

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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January 2019

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Tremor is the vibration in the sinusoidal orientation that are experienced regularly by Parkinson Disease (PD) patients that disturbs their daily lives. Thus, in PD patients, every action will be hindered by the tremor. Hence, this problem needs to be addressed by making a solution to counter the tremor back to ease their daily lives or routines. One solution that may be used to counter this tremor is by making active tremor control system that uses controllers to reduce the tremor vibration. The controller of Proportional (P) and Fuzzy Logic (FL) are being proposed as the controllers to control the linear voice coil actuator (LVCA) and will later be implemented into a system of hand tremor test rig to study the controllers' performance in reducing the hand tremor vibration. To find out precisely how hand tremor test rig works in reducing tremor vibration, a LabView system modelling is created to help implement the LVCA and controllers together. The current experimental results have shown the combination of controllers consists of P controllers and two different types of Fuzzy Logic controllers (FLC) that use different set of rules have managed to produce satisfactory performance and significant improvements in reducing the hand tremor vibrations. Thus, this research study is done to prove the combination of controllers (P and FLC) can reduce the tremor vibrations better compared to the use of single controllers. Besides that, this research is also done to compare the performance of controllers in terms of its displacement, acceleration, frequency and power spectral density (PSD) values. From this research study, it can be concluded that the most optimum controller that produces the most tremor reduction is the P+FLC 1st set of rules compared to P+FLC 2nd set of rules and P controller only with a highest percentage of 88.39% of tremor reduction with the actual tremor vibrations of PD patients as the reference result. The P+FLC 2nd set of rules has the highest percentage of tremor reduction with a value of 86.81% whereas P controller only has the highest tremor reduction percentage of 67.10%. This percentage of tremor reduction is based on the PSD values in which it represents the intensity of the tremor vibration itself. This experimental study can be

used as the initial step for researchers and engineers to design and develop an anti-tremor device in the future.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KAWALAN GEGARAN AKTIF KE ATAS RIG UJIAN GEGARAN TANGAN MANUSIA MENGGUNAKAN ALAT KAWALAN P+FUZZY LOGIC

Oleh

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Gegaran atau 'tremor' ialah satu gegaran sinusoidal yang terjadi dan terhasil kepada pesakit Parkinson Disease (PD) yang telah mengganggu rutin harian mereka. Oleh sebab itu, setiap kerja yang ingin dilakukan oleh pesakit PD akan terganggu disebabkan oleh gegaran atau 'tremor' ini. Dan oleh sebab itu juga, satu jalan penyelesaian telah diusulkan untuk menyelesaikan masalah gegaran ini. Salah satu cara untuk menyelesaikan masalah ini adalah dengan membuat sistem kawalan gegaran aktif yang menggunakan beberapa jenis alat kawalan untuk mengurangkan gegaran atau 'tremor'. Alat-alat kawalan proportional dan fuzzy logic controller (FLC) dicadangkan untuk digunakan untuk mengawal gegelung suara penggerak selari (LVCA) dan kemudian akan digunakan bersama rig ujian gegaran tangan untuk menyasat prestasi alat kawalan dalam mengurangkan gegaran tangan. Untuk mengetahui dengan tepat bagaimana rig ujian gegaran tangan berfungsi dalam mengurangkan gegaran pesakit PD, sistem kawalan LabView telah dihasilkan untuk membantu LVCA dan alat kawalan berfungsi bersama-sama. Keputusan kajian eksperimen ini menunjukkan gabungan alat kawalan yang terdiri daripada alat kawalan P dan dua jenis alat-alat kawalan FLC yang menggunakan set aturan yang berbeza telah berjaya menghasilkan prestasi yang memuaskan dalam mengurangkan gegaran tangan. Oleh itu, kajian eksperimen ini dilakukan untuk membuktikan kombinasi alat kawalan (P dan FLC) dapat mengurangkan gegaran tangan lebih baik dibandingkan dengan penggunaan alat kawalan tunggal (alat kawalan P). Selain itu, kajian ini juga dilakukan untuk membandingkan prestasi alat-alat kawalan dari segi sesaran, pecutan, frekuensi dan kepadatan spektrum kuasa (PSD). Dari kajian penyelidikan ini dapat disimpulkan bahawa alat kawalan yang paling optimum yang menghasilkan pengurangan gegaran tangan yang paling efektif adalah dari set aturan pertama P + FLC berbanding dengan set aturan kedua P + FLC dan alat kawalan P dengan peratusan tertinggi 88.39% pengurangan gegaran tangan. Set aturan kedua P + FLC telah menghasilkan nilai peratusan tertinggi dengan nilai 86.81%

pengurangan gegaran tangan manakala alat kawalan P menghasilkan nilai peratusan tertinggi dengan nilai 67.10% pengurangan gegaran tangan. Nilai peratusan pengurangan gegaran tangan ini adalah berdasarkan nilai PSD yang mewakili intensiti gegaran atau 'tremor' sendiri. Kajian eksperimen atau penyelidikan ini boleh digunakan sebagai langkah pertama atau batu loncatan untuk mereka-bentuk dan membangunkan alat anti-gegaran pada masa akan datang.



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LIST OF ABBREVIATIONS

PD	Parkinson Disease
LVCA	Linear Voice Coil Actuator
P	Proportional
I	Integral
D	Derivative
PI	Proportional-Integral
PID	Proportional-Integral-Derivative
AFC	Active Force Control
AFCAIL	Active Force Control and Iterative Learning
FLC	Fuzzy Logic Controller
NT	Neuropathic Tremor
PT	Psychogenic Tremor
ET	Essential Tremor
OT	Orthostatic Tremor
DT	Dystonic Tremor
RMS	Root Mean Square
PSD	Power Spectral Density

CHAPTER 1

INTRODUCTION

1.1 Background Study

Tremor can be defined as an involuntary, rhythmic, and sinusoidal movement of one or more body parts (Abdo, van de Warrenburg, Burn, Quinn, & Bloem, 2010). Besides that, tremor can also be defined as rhythmic oscillations of a part of the body around one or more joints (Marsden, 1984).

A way to approach tremor correctly is by characterising them based on their types. Rest tremor can easily be recognized from other types based on the conditions whereby the tremor-affected body part is completely supported against gravity without any muscle movement. But, for action tremor, the tremor will happen in the presence of muscle movement. There are two kinds of action tremors which are the postural tremors and sustention tremors that occurs after the posture is fixed against the gravity. Besides that, there is another tremor that occurs when the person is in active movement, which is the kinetic tremor. In addition, there is a subgroup of kinetic tremors that exist when it is specific to any goal-directed movements happening, which are known to be as intention tremors. This tremor can be similar to other types of the same subgroup tremor that occurs when there is active muscle contraction against an object that has already been fixed in position. This tremor can be called as isometric tremor.

Even though tremors that happen in real life are usually not voluntary, the patient may experience or be diagnosed with psychogenic tremor separately or with other neurologic complaints such as Parkinson psychogenic (Findley, 1996).

Parkinson's disease (PD) can be known as multi-symptomatic syndrome. This is because almost all PD patients will experience tremor at a specific time during the disease process (G Deuschl, Krack, Lauk, & Timmer, 1996; Jankovic, 2008; Rajput, Rozdilsky, & Rajput, 1991) The sign of PD in terms of the clinical aspect can be different to each PD patient as some patients will show tremor signs at the early stage and eventually disappear whereas other PD patients will experience the tremor that can increase in its amplitude as the disease progresses by the years (Hughes, Daniel, Blankson, & Lees, 1993).

Around 50% of PD patients have resting tremor. Hence, resting tremor is considered as a common characteristic for PD (Fishman, 2008; Leventoglu & Baysal, 2008). In a more scientific explanation, the tremor of PD patients will usually occur when the limb is at rest, when the hand or arm is supported, or hanging freely without any

muscle movements in order to counteract gravity (Daneault, Carignan, Rahimi, Sadikot, & Duval, 2013; Günther Deuschl, Bain, & Brin, 1998; Jankovic, 2008). This tremor also has a characteristic whereby the tremor tends to disappear at rest on any movement initiation, but may present once again if the patient has already reached the endpoint of his or her movement (Duval, 2006; Jankovic, Schwartz, & Ondo, 1999).

It is very significant to counter this type of tremors as it can affect the daily life of a patient. In addition, this kind of disease also can be embarrassing to the PD patients while facing other people, and most of the time, PD patients will prefer to stay at home than going out (Szabo, Storkova, Hozman, & Zanchi, 2007). One of the solutions that can be proposed that may help to solve this problem is using active elements from the likes of specific actuator with its own control system. Other treatments also can be used to counter the tremor effect. However, each of the treatment methods have their own weaknesses. For example, treatment using drugs may give negative effects in the long run whereas for surgical treatment, it is a high-risk treatment as it includes operation on the cerebrum. Thus, the idea to utilise mechanical based non-obtrusive treatment may be the correct approach to diminish the tremor impacts.

For this experimental study, the linear voice coil actuator (LVCA) was used as the main element or main device to dampen the vibration of the tremor or reduce the tremor vibration amplitude. The P controller and fuzzy logic controller performance are also investigated in order to control the actuator movement. The reason why the fuzzy logic controller is picked as the controller is due to the controller being said to be capable of being a robust controller as it was able to provide a satisfactory performance when dealing with something that was not certain and inaccurate to the real world like vibration, noise and other kinds of system parameters (Doctor, Hagra, & Callaghan, 2005). Thus, a control system consisting of P controllers and fuzzy logic controllers was built to act as the main controllers to dampen the tremor vibration or reduce the tremor.

1.2 Problem Statements

All works nowadays will not be successfully completed if there is any problem to any of the human body parts especially hands. Thus, it will be such an inconvenience to do any kind of daily works because of that. One of the problems that is related is the tremor problems like those present in Parkinson's disease (PD) patients. If the hands are affected from tremor effects like in PD patients, it can make the daily task cumbersome and difficult to do or complete. Some of the daily tasks that can be difficult to complete because of tremors are such as eating using utensils, holding phone when trying to call someone or using industrial tools.

Furthermore, tremors can also make it difficult for PD patients to interact with other people in their lives. This is because in some situations, the tremor is so severe that it can cause total disability to the affected PD patient and it embarrasses the PD patients. Thus, PD patients will not try to interact with other people because of that.

Hence, an idea can be conceived from this problem in order to counter the tremor effects by using mechanical based non-invasive treatments. There are also surgery treatments that can be used to counter the tremor effects like Thalamotomy, Pallidotomy, Deep Brain Stimulation (DBS) and Subthalamotomy. However, surgery treatments are high risk to PD patients as the surgery involves the brain. Thus, a control system using certain kinds of actuators like LVCA can be used as the mechanical based non-invasive treatment to lessen or reduce the tremor effects on PD patients.

Most of the technology nowadays to counter the tremor effects uses the passive tremor control principle, which means that they use the manual tuning controller. This type of controller can be effectively good, but it can be troublesome and may give discomfort to the PD patients as it cannot adapt quickly to sudden changes since it has less intelligence to determine the exact solution when different tremor behaviour happens. Thus, with the use of intelligent controller such as fuzzy logic controller (FLC), it can help to provide the desired solutions to these sudden changes in tremor behaviour in which it can be said to increase the intelligence for the anti-tremor control system devices.

1.3 Objectives

The objectives of this study are:

- a) To develop hand tremor test rig to emulate the behaviour of hand tremors.
- b) To investigate the effects of P controller and fuzzy logic controller (FLC) on the human hand tremor test rig model to reduce hand tremors.
- c) To compare the performance between Proportional (P) controller (single controller) and P+Fuzzy logic controller (hybrid controller) to reduce hand tremors.

1.4 Scope Of Project

The scope of this study is to focus on making a control system that can help to reduce the tremor vibration for PD patients. This control system will be done using LabView 2016 and the controllers that will be implemented into the control system are Proportional (P) controller and fuzzy logic controller (FLC). For this study, the

tremor vibration raw data of PD patients from previous data collection will be implemented to the control system that act as the input of the control system. Then, the tremor vibration can be analysed further after the tremor raw data passes through all the components of the control system. The outcome to reduce or diminish the tremor vibration can be determined at the end of this experimental study.

1.5 Significance Of Project

This study's significance is the ability to make a control system using the P controller and fuzzy logic controller together. Both controllers will act as the controller to reduce tremor vibrations. This study also will be using new tremor test rigs and the control system will be connected to the new tremor test rig. Thus, the results from the set-up can be further analysed using the new tremor test rig and new types of controller combinations. Furthermore, this experimental study is being done to show whether this current control system with both controllers in it can be good to be implemented to future anti-tremor devices' control system. Besides that, this study is also being done to analyse the behaviour of the tremor vibration of PD patients when implementing P controllers and fuzzy logic controllers. This research study will be mainly focused on PD patients. Moreover, this study can be a reference and benchmark study and for other researchers to study more about tremor vibrations and ways to overcome it. Thus, this study with new types of controller combinations can be viewed as the alternative solution to surgery or drug treatments to overcome or reduce tremor vibrations of PD patients.

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LIST OF PUBLICATIONS

As'arry, A., Jamaluddin, H., Z. Rahman, T. A., Rezali, K. A., & Zain, Z. (2016). Suppression of Parkinson's hand-like tremor using fuzzy-PID controller. In *2016 IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS)* (pp. 1–5), IEEE.

H. Jamaludin, K. S. Eng, A. As'arry, K. A. M. Rezali, R. K. Raja Ahmad, M. Z. Md Zain. Design, Fabrication And Analysis Of Tremor Test Rig To Emulate Human Hand Tremor. *JMechE*.

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