UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Engineering

AN IMPLEMENTATION OF FUZZY CONTROLLER FOR MICRO-GRIPPER

SAEED ABDULHALIM ABDULWAHID MOHAMMED ALDHUBHANI

Bachelor of Electrical Engineering with Honor

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APPROVAL

I hereby declare that I have read through this report entitled "AN IMPLEMENTATION OF FUZZY CONTROLLER FOR MICRO-GRIPPER (MEMS) " and found that it has compiled the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering.

Signature : …………...……………..

Name :Ir. Fauzal Naim bin Zohedi

Date :…………………..……..

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SAEED ABDULHALIM ABDULWAHID MOHAMMED ALDHUBHANI
B011410316

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DECLARATION

I declare that this report entitles “AN IMPLEMENTATION OF FUZZY CONTROLLER FOR MICRO-GRIPPER (MEMS) .” is the result of my research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : …………...……………..

Name : Saeed Abdulhalim Abdulwahid Mohammed Aldhubhani

Date :…………………..……..

DEDICATION

I dedicate this work to my beloved country, Yemen, the country that I was born and raised within its borders. I also dedicate this project to my beloved family; my dear father, En. Abdulhalim Abdulwahid, who has been supporting me; my beloved mother Tchr. Eman Saeed for encouraging and motivating me throughout the years of my life to reach this level; to my dear sisters. Also, I would like to dedicate my project to all my friends who helped and supported me.

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ABSTRACT

Micro-gripper is one of MEMS application that used to grip a micro object in medical field in case that it cannot be done by human hand. In this project, the design of micro-gripper actuator is explored which has several designs such as electro-thermal, shape memory alloy, piezo-electric, pneumatic, electrostatic, and electromagnetic actuations. Based on the comparation, electrostatic micro-gripper was chosen in this project to be studied since it is widely applied for microactuation and provides a largely displacement without hysteresis with a simple structure. However, electrostatic micro-gripper suffers from vibration and shaking during the pick and placed movement. Therefore, it is very crucial to implement a controller for the system to achieve the best response that provides a smooth closing and opening movement of the gripper fingers. Fuzzy Logic Controllers is an intelligent technique that proves to be the one of the most reliable controller that suits well for system due to the simple control based on user input without any prior knowledge to the mathematical model. To be more specific, three types of fuzzy logic rules are being selected which is 9,25,49 rules and applied in two different designs for the linguistic variables that has different universe of discourse range. The implementation of this project is conducted by using simulation of micro-gripper through MATLAB Simulink. The performance was analyzed and studied in terms of transient response based in overshoot (OS%), settling time (Ts), rise time (Tr), and steady state error (ess). The result shows the improvement in the transient response. The rules have been designed and compared with the original mems micro gripper system. From the comparative study second design of 3x3 rules shows the better performance result can be gained from fuzzy logic controller. It has modified the transient problem and directly eliminate the vibration and shaking in the mems micro gripper system. So, it will benefit the medical field and its application.

ABSTRAK

Gripper mikro adalah salah satu aplikasi MEMS yang digunakan untuk menggenggam objek mikro dalam bidang perubatan sekiranya ia tidak dapat dilakukan oleh tangan manusia. Dalam projek ini, reka bentuk penggerak mikro gripper dieksplorasi yang mempunyai beberapa reka bentuk seperti elektro-haba, aloi memori bentuk, piezo-elektrik, pneumatik, elektrostatik, dan elektromagnetik. Berdasarkan perbandingan, elektrostatik mikro-gripper dipilih dalam projek ini untuk dikaji kerana ia digunakan secara meluas untuk microactuation dan menyediakan sebahagian besar ansalan tanpa histeresis dengan struktur mudah. Walau bagaimanapun, elektrostatik mikro gripper mengalami getaran dan gegaran ketika memilih dan bergerak. Oleh itu, sangat penting untuk melaksanakan pengawal bagi sistem untuk mencapai tindak balas terbaik yang menyediakan pergerakan penutupan dan pembukaan jari-jari gripper yang lancar. Pengawal Logik Fuzzy adalah teknik cerdas yang terbukti menjadi salah satu pengawal yang paling boleh dipercayai yang sesuai dengan sistem kerana kawalan mudah berdasarkan input pengguna tanpa pengetahuan sebelumnya terhadap model matematik. Untuk menjadi lebih spesifik, tiga jenis peraturan logik fuzzy dipilih iaitu 9,25,49 peraturan dan diterapkan dalam dua reka bentuk yang berbeza untuk pembolehubah linguistik yang mempunyai julat cakerawala yang berbeza. Pelaksanaan projek ini dijalankan dengan menggunakan simulasi mikro gripper melalui MATLAB Simulink. Prestasi dianalisis dan dikaji dari segi tindak balas sementara berdasarkan overshoot (OS%), masa penyelesaian (Ts), kenaikan waktu (Tr), dan ralat keadaan mantap (ess). Hasilnya menunjukkan peningkatan dalam tindak balas sementara. Peraturan-peraturan telah direka dan dibandingkan dengan sistem gripper mikro mems asal. Dari reka bentuk perbandingan perbandingan 3x3, menunjukkan prestasi prestasi yang lebih baik dapat diperolehi daripada pengawal logika fuzzy. Ia telah mengubah suai masalah sementara dan secara langsung menghapuskan getaran dan gegaran di dalam sistem gripper mikro mems. Jadi, ia akan memberi manfaat kepada bidang perubatan dan aplikasinya.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

MEMS has been implemented in medical fields for ages. It is call Biomems, stand for biological microelectromechanical systems. The capabilities for Biomems is promising and it has been widely applied in diverse science and engineering domains. Which the number of its applications keeps increasing noticeably. MEMS micro-gripper is one of the application in medical field that plays an important role in the human body since it is used to develop and organize an artificial organ and organ tissue to help to alleviate some of the problems surrounding organ failure. This is called tissue engineering. Nowadays it is a very important process for any region to guarantee the safety of people. Several types of MEMS micro-gripper are currently being tested by researchers. Researchers are working on perfecting its components and its controls to achieve high proficiency, more accuracy and stability. On the other hand the micro-gripper also offers low-coast and compact size.

1.2 Problem statement

Microelectromechanical system is a system that can be used for several medical purposes. One of its application is micro-gripper where it is a type of device that developed based on microelectromechanical system in order to ease the surgery that involved in micro medical operation that deals with organ tissues [1]. Different types of controllers involve to control the displacement of pick and place applications. However, some micro-grippers suffer from lack of robust control for vibration and shaking during the pick and placed movement required an accurate controller that provide a smooth closing and opening movement of the gripper fingers [2]. Hence, the fuzzy controller is one of the controller that can be implemented to control the gripper's fingers movement with avoiding vibration and shaking of gripper itself.

1.3 Objective

Upon completion of this project, the following proposed goals should be achieved:

1. To investigate the modelling equation of the micro-gripper system and the types of controllers that involved in controlling the micro-gripper.
2. To implement the fuzzy logic controller into the micro-gripper.
3. To evaluate the performance base on of fuzzy logic controller in term of time response, maximum overshoot and steady state error.

1.4 Scope and limitation of the project

The project will be applied for Bio-MEMS (micro-gripper). It will be implemented based on the simulation rather than hardware. In this project the fuzzy logic controller is the controller that will be used in this project to control the gripper movement. The target is to analyze and validate the stability and accuracy of the parameters. The MATLAB-Simulink is the simulation that will be conducted in this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the deep knowledge of this project will be briefly explained. This section provides a review of the pervious pertinent works. The published information related to this research will be discussed to gain some of the useful knowledge as well as theoretical and methodological contributions to make this research successful.

2.2 Microelectromechanical System (MEMS)

Micro-Electro-Mechanical System is an invisible device to human eye that integrates of micro fabricated mechanical and electrical structures components. So, it is considered as a complete system due to the electrical elements process data while the mechanical elements implement that data. In another word, the electrical elements act as the brain of the system while the mechanical system act as the arms and eyes. MEMS also known as Micro System Technology (MST) in Europe .In Asia it is known as Micromachines while the MEMS is the technology in the United States [3]. MEMS is a tiny device that has a range in size of less than 1mm to 1 micron that has been fabricated along with integrated circuit (IC) in one chip by using batch fabrication [4] . During the past decades, MEMS had developed in a different number of manufacturing techniques such as wafer bonding, high aspect ratio micromachining technology and bulk micromachining. Currently, surface silicon micromachining beings the most popular manufacturing techniques for MEMS. This is due to the silicon has a unique characteristics (high elastic , repeatable motion , reliability and low cost) [1]. MEMS can be classified into two categories microsensors and microactuators that can be used in different application to convert from one energy to another which lead to be used in some different applications.

The advantages of MEMS are the suitable size due to the small size, mass, and volume, better performance. Economically advantages of MEMS are large reduction in power consumption, low cost, small thermal constant with high thermal expansion tolerance, and possibilities for batch fabrication in massive quantities [5].

Microelectromechanical System has been widely applied in various fields .Which lead its applications to be increasing noticeably in different domains such as automotive , military and industrial domains as well as it has been applied in irrelevant fields such as microelectronics and biology [1].

2.3 BioMEMS

Biomedical microelectromechanical systems (BioMEMS) is a MEMS implementation on the biology and medical field. Micro-Electro-Mechanical System (MEMS) is currently noticed as an area of high potential impact. MEMS application is very broad. In medical industry, Biomems is expanding rapidly with explicated income of $850 million in 2003 to over $1 billion in 2006 in rate of 11.4% [6]. Currently Biomems market is approximately $2.1 Billion.

In future BioMEMS potential are endless such as in tissue engineering field which has a widely used to develop and organize an artificial organ and tissue. Charles stark Draper laboratory said that Biomems help to alleviate some of the problems surrounding organ failure.

2.3.1 Fabrication

In order to study the BioMEMS in literature review. It is important to have knowledge about the Micro-fabrication processes as the main materials of the Biomems. Basically, over the last decades, the MEMS devices were imported from (IC) integrated circuit fabricating to MEMS devices that have undergone another transition for Biomems. This is due to the raising awareness of microfluidic physics and the surface science of silicon, glass, polymers, and ceramics.

Nowadays, the fabrication becomes more complicated. Polymers materials are expected to have a prestigious future for manufacturing of microfluidic systems. In industrial companies they are interesting in using plastics in MEMS fabrication because this materials are cheap and easier to work with it [6]. In some Biomems processing , they search about different polymers such as spin castable polymer , EPON SU-8, Polypyrrole (PPy) and Polydimethylsiloxane (PDMS) [6].

2.3.2 Areas of Applications

BioMEMS have been applied in various areas, following is some areas that already being utilized in market as well as in researches studies:

i. Detection
ii. Analysis
iii. Diagnosis
iv. Therapeutics
v. Drug delivery
vi. Cell culture Detection

Figure 2.1 shows the illustration of Biomems areas of applications.

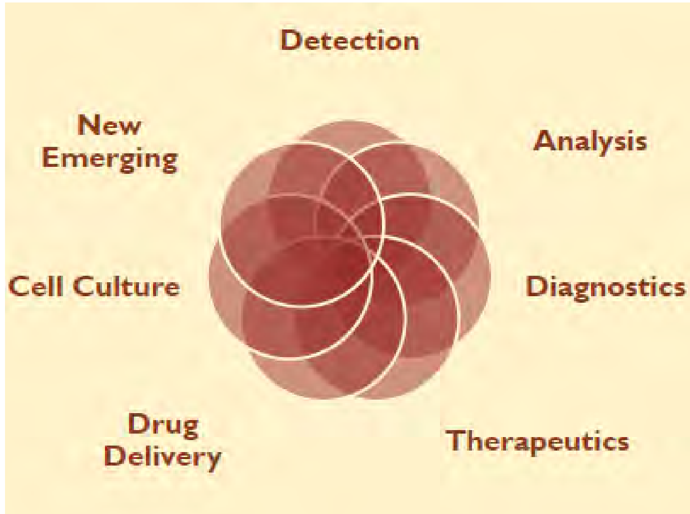

Figure 2.1: Areas of Biomems Applications

2.3.3 BioMEMS Applications in Term of Surgery

The treatment of illness in human body by instrumental or manual called surgery. Over the past years exactly in 1867 (first-generation technique) the surgery involved the sewing and cutting of tissue by using the basic tools and medical equipment. Huge number of incision was made in the patient by the surgeon to make save the patient which is known by "open surgery". In this technique, the surgeon was able to see the real view of the surgical site. Plus, he was enabled freely to manipulate the tissue or organ directly by his hand or using fundamental tools. This technique has been applied to a wide range of surgery during the near past years. Consequently, this method has many side effects since this technique costs a long time hospitalize and the patient is suffering [7].

September 1985, was the beginning of the second generation technique lead by Muhe as first laparoscopic gall bladder removal [8].This technique of surgical it is called "minimally invasive surgery" (MIS) and it was known as telescopic, micro, and minimal access surgery. MIS is considered as an advanced technique since the operations needs a small incision as holes or port and trocars (tube with valve using in medical operation to save the body from oxidation). This method required an endoscope to give the surgeon a view of its internal parts[9]. It takes short hospitalize stay and speedy recovery. It is 35% safer and more effective compared to the first-generation technique which is open surgery.

Figure 2.2: Intuitive Surgical da Vinci Robotic System

Figure 2.3: Minimally Invasive Surgery Stereo Display

2.4 Micro –Gripper

Micro-griper is a micro device that uses to handle small objects such as tissue or cells under a microscope in order to act in cases that surgeon cannot achieve it by human hand.

In 1980s, micro-gripper had been introduced by the researcher community [10]. Since that time, the micro-griper comes with several designs. The main microactuators and microsensors type that used in microgripper such as electro-thermal, Shape Memory Alloy , piezo-electric [1], pneumatic, and electromagnetic actuations [11].

Through the aforementioned different types of actuators the electrostatic actuators is widely applied for microactuation [12]. Since it provide a largely displacement without hysteresis with a simple structure [11]. Movement configuration specifically has two types:

i. Transverse comb drive: which can achieve a large movement [11].
ii. .Lateral Comb drive: which generates a stability and high accuracy [1].

2.4.1 Electrostatic Actuator

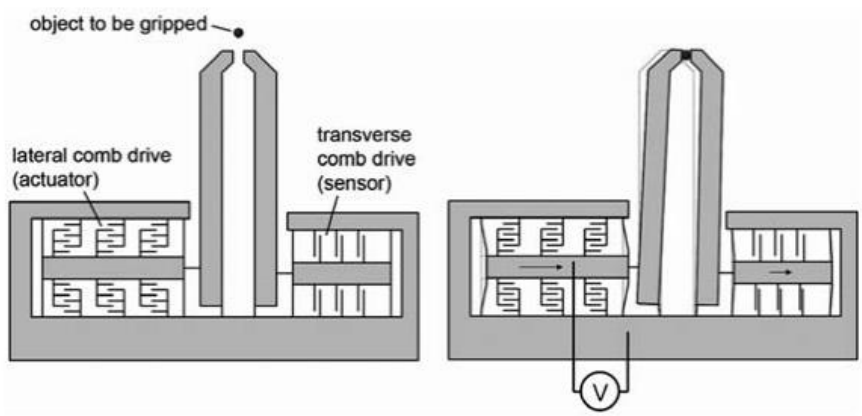

Figure 2.4: Electrostatic Micro-Gripper with Integrated Force Sensor

Electrostatic actuator can be considered as electrically isolated. Since it provides a large displacement, no hysteresis with negligible current in the gripper's arm. Figure 2.4 shown the solid model of the electrostatic micro-gripper. The main components of electrostatics actuator are the combo drives. The electrostatic actuator micro-gripper has two electrodes fingers which one is movable and the other one is fixed to be connected with parallel-plate capacitor. In order to move the comb, the actuator should be forced by apply voltage to the fixed and movable plates as shown in Figure 2.5 [11].

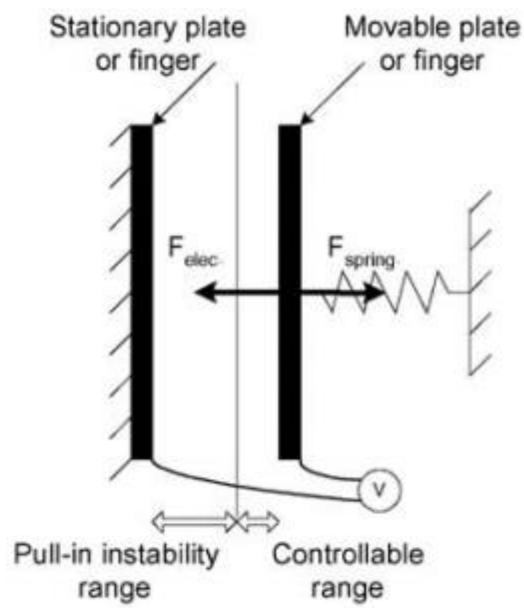

Figure 2.5: The Parallel-Plate Arms

2.4.2 Modeling of Electrostatic Micro-gripper

As shown in Figure 2.6 one lower electrode is fixed and the upper electrode is movable. The movement of the electrode is tied by spring. The forced of electrostatic electrode is zero when the applied voltage is zero. It is known as the initial status. G is the air gap between the two electrodes. As the voltage applied and increasing the applied voltage from zero, the electrode moves toward the electrode until the gape be zero and the spring force equals the electrostatic force.

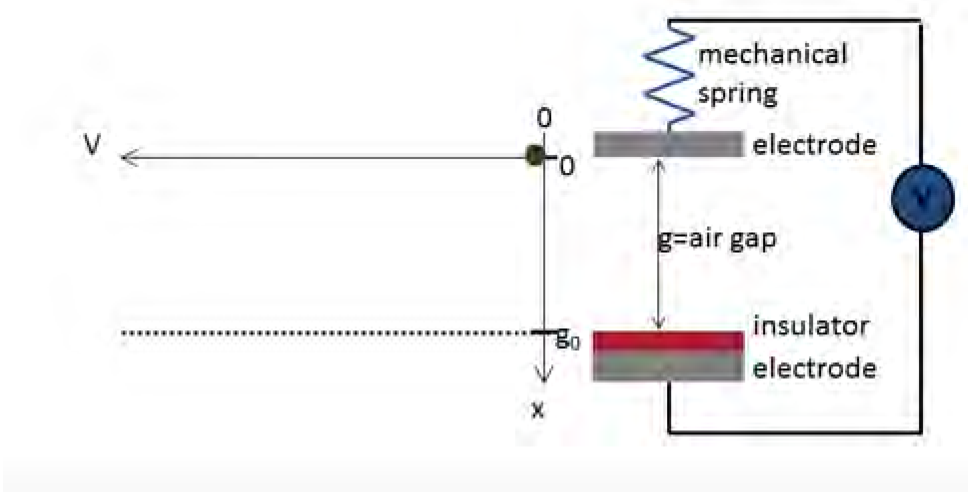

Figure 2.6: Model of Parallel Plate Actuator

The transfer function of the system is stated below based on previous studies [20]:

$$G(s) = \frac{0.17213}{0.1s^3+0.99s^2+0.48s+0.85}$$

2.5 Artificial Intelligence

Artificial intelligent is a science that has been introduced to simulate human intelligence, recognize the decisions and act as human reasoning process [13]. It is an important field that has widely used in various areas and systems in order to develop and improve the behavior of systems. There are many artificial intelligence techniques to be applied in the real-word to solve problems and get more desired result [14] such as:

i. Neural Networks.
ii. Fuzzy Logic.
iii. Chaos Theory.
iv. DNA Computing.
v. Quantum Computing.
vi. Expert System.

2.6 Fuzzy Logic Controller

In 1960s, Dr. Lotdi Zedah was introduced the Fuzzy Logic. In English Fuzzy means blurred [15]. Fuzzy logic controller (FLC) considers as one of the intelligent techniques that have been applied and studied in various engineering, researchers and studies. It becomes the most successful controller to be applied in applications systems as a controller [16]. The Fuzzy logic is acting as human being's felling and thinking. Fuzzy logic controller can be received one or more number of parameters or conditions that can be measure in the system to be analyzed or controlled Figure 2.7 shows the block diagram of the fuzzy controller.

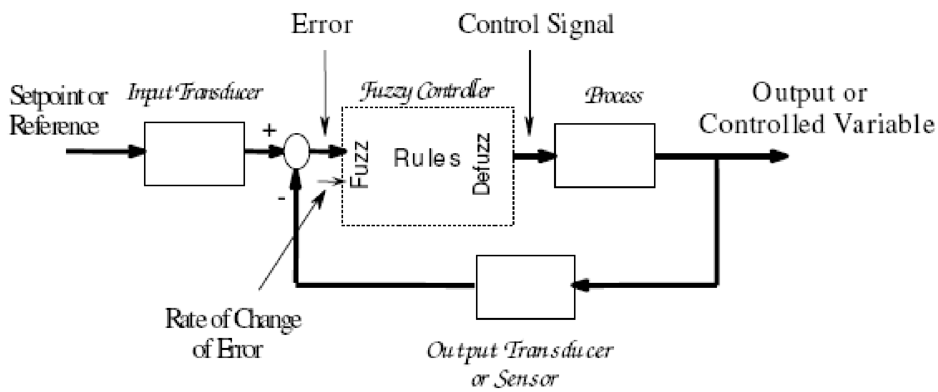

Figure 2.7: Fuzzy Logic Control System

2.6.1 Classical vs Fuzzy Sets

The possible range of values for the inputs of (FLC) is called universe of discourse. Figure 8 Illustrates the X universe of discourse with classical set as A