行政院國家科學委員會專題研究計畫 成果報告

掃描探針　器有參數變化及磁滯效應時之智慧型設計研究
研究成果報告(精簡版)

計 畫 類 別 ：個別型
計 畫 編 號 ：NSC 99-2221-E-216-020-
執 行 期 間 ：99 年 08 月 01 日至 100 年 07 月 31 日
執 行 單 位 ：中華大學通訊工程學系

計畫主持人：林君明

計畫參與人員：碩士班研究生-兼任助理人員：邱胤華
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報 告 附 件 ：出席國際會議研究心得報告及發表論文

公 開 資 訊 ：本計畫可公開查詢

中　華　民　國　100 年 11 月 18 日

中文摘要： 目前以音圈(Voice Coil)或是電磁裝置(Electromagnetic Device)，作為力致動器(Force Actuator)的趨勢，有快速增加的現象，這是因為它很便宜，且很很容易驅動使用的緣故。但是這種音圈力致動器或
電磁裝置，有很嚴重的非線性效應，例如死帶區(Dead Band)及磁滯效應(Hysteresis Effect)，並且使用久了，其中非常重要的彈簧及線圈電阻，會有彈性係數變差，及電阻變大的特性。傳統設計是在工作
點(Operating Point)的附近，將系統動態方程式進行線性化，再利用各種線性控制方法，進行控制器的
設計。但是當系統參數有變化(Parameter Variation)，或是有負載干擾(Load Disturbance)時，這些預先設計好(增益及補償器皆為固定式)的控制器，就不一定能使系統維持良好的反應，可能誤差會加大，
甚至產生不穩定的現象，所以必須要找一個更有效的方法。

本次掃描探針輪廓儀設計研究，與以往的方式有很大的不同，即是將以往在內迴路的模糊控制器，移到外迴路，取代原來外迴路的比例積分控制器(PI Compensator)。詳細的作法是以 MATLAB 套裝軟體，進行音圈力致動器，有參數變化及磁滯效應時，智慧型掃描探針輪廓儀外迴路設計，如模糊理論及模擬分析，另一方面，則是整合可調接觸力垂直探針輪廓儀硬體系統，並進行界面電路的設計分析。結果發現在外迴路，用模糊控制器可以降低系統參數有變化(Parameter Variation)，或是有磁滯效應時的影響。

中文關鍵詞： 掃描探針顯微術，模糊控制，音圈式力致動器死帶區，磁滯效應

英文摘要： This research is to upgrade the previous work of a contact force-controlled scanning probe microscopy system design, which had main parts as: XYZ-stage, force actuator (voice coil) and driving circuit, Linear Variable Differential Transformer (LVDT), Linear Velocity Transducer (LVT), load cell, diamond probe (1μm accuracy), data acquisition board, and operating system programming. The PID controller and LVT were applied to improve the inner-loop damping and the transient response of the system that would be degraded by the dead-band as well as the hysteresis effects of the force actuator, the contact-force of the probe was detected by a load cell and feedback to move the force actuator to make the desired contact-force between the probe and the sample under test. Thus the force actuator dead-band as well as the hysteresis effects can be minimized. The drawbacks of the previous method were that if one made a long time test, then the temperatures of the voice coil as well as the load cell would be increased. Thus not only the parameters of the system, such as coil resistance and the spring constant would be varied, but the load cell noise would be raised, which will reduce the accuracy performance of the system. In this research the fuzzy controller is moved to the outer loop instead of the original one in the inner loop. The results show that the fuzzy controller is more robust to parameters variation and hysteresis effects of the force actuator.

英文關鍵詞： SPM, Fuzzy Control, Voice Coil Force Actuator, Dead-band, Hysteresis Effect

附件一

行政院國家科學委員會補助專題研究計畫■成果報告□期中進度報告

掃描探針輪廓儀音圈力致動器有參數變化及磁滯效應時之智慧型設計研究

計畫類別：■個別型計畫　　□整合型計畫

計畫編號：NSC 99－2221－E－216－020－

執行期間： 2010 年 08 月 01 日至 2011 年 07 月 31 日

執行機構及系所：中華大學通訊工程學系

計畫主持人：林君明

共同主持人：

計畫參與人員：張琪琨、卓昆泰、邱胤華、蔣淞宇。

成果報告類型(依經費核定清單規定繳交)：■精簡報告　□完整報告

本計畫除繳交成果報告外，另須繳交以下出國心得報告：

□赴國外出差或研習心得報告

□赴大陸地區出差或研習心得報告

■出席國際學術會議心得報告

□國際合作研究計畫國外研究報告

處理方式：除列管計畫及下列情形者外，得立即公開查詢

□涉及專利或其他智慧財產權，□一年■二年後可公開查詢

中　華　民　國　100 年　10 月　18　日

研究計畫中英文摘要

（一）計畫中文摘要。

目前以音圈(Voice Coil)或是電磁裝置(Electromagnetic Device)，作為力致動器(Force Actuator)的趨勢，有快速增加的現象，這是因為它很便宜，且很很容易驅動使用的緣故。但是這種音圈力致動器或電磁裝置，有很嚴重的非線性效應，例如死帶區(Dead Band)及磁滯效應(Hysteresis Effect)，並且使用久了，其中非常重要的彈簧及線圈電阻，會有彈性係數變差，及電阻變大的特性。傳統設計是在工作點(Operating Point)的附近，將系統動態方程式進行線性化，再利用各種線性控制方法，進行控制器的設計。但是當系統參數有變化(Parameter Variation)，或是有負載干擾(Load Disturbance)時，這些預先設計好(增益及補償器皆為固定式)的控制器，就不一定能使系統維持良好的反應，可能誤差會加大，甚至產生不穩定的現象，所以必須要找一個更有效的方法。

本次掃描探針輪廓儀設計研究，與以往的方式有很大的不同，即是將以往在內迴路的模糊控制器，移到外迴路，取代原來外迴路的比例積分控制器(PI Compensator)。詳細的作法是以MATLAB套裝軟體，進行音圈力致動器，有參數變化及磁滯效應時，智慧型掃描探針輪廓儀外迴路設計，如模糊理論及模擬分析，另一方面，則是整合可調接觸力垂直探針輪廓儀硬體系統，並進行界面電路的設計分析。結果發現在外迴路,用模糊控制器可以降低系統參數有變化(Parameter Variation)，或是有磁滯效應時的影響。

關鍵詞:掃描探針顯微術，模糊控制，音圈式力致動器死帶區，磁滯效應

研究計畫中英文摘要

（二）計畫英文摘要。

This research is to upgrade the previous work of a contact force-controlled scanning probe microscopy system design, which had main parts as: XYZ-stage, force actuator (voice coil) and driving circuit, Linear Variable Differential Transformer (LVDT), Linear Velocity Transducer (LVT), load cell, diamond probe (1μm accuracy), data acquisition board, and operating system programming. The PID controller and LVT were applied to improve the inner-loop damping and the transient response of the system that would be degraded by the dead-band as well as the hysteresis effects of the force actuator, the contact-force of the probe was detected by a load cell and feedback to move the force actuator to make the desired contact-force between the probe and the sample under test. Thus the force actuator dead-band as well as the hysteresis effects can be minimized. The drawbacks of the previous method were that if one made a long time test, then the temperatures of the voice coil as well as the load cell would be increased. Thus not only the parameters of the system, such as coil resistance and the spring constant would be varied, but the load cell noise would be raised, which will reduce the accuracy performance of the system. In this research the fuzzy controller is moved to the outer loop instead of the original one in the inner loop. The results show that the fuzzy controller is more robust to parameters variation and hysteresis effects of the force actuator.

Keywords: SPM, Fuzzy Control, Voice Coil Force Actuator, Dead-band, Hysteresis Effect

前言

由於我國目前正大力推動兩兆雙星產業，所以投入大量資金，購買設備與訓練高科技人才。21 世紀高科技產品之開發趨勢，更是朝向超微小材料結構方向發展。此時亟需正確量測與描述奈米材料物理性質之儀器，如半導體、光電、及硬碟製造技術，不斷推陳出新，有一個共同的特徵：就是對加工物表面的平坦，或輪廓的要求越來越高。例如半導體晶圓在進行金屬化連線製程之前，需要先做平坦化處理(CMP)，以確保金屬連線後的可靠度。而硬碟讀取頭也需要在平坦度極高的磁碟片上飛行，進行資料快速的存取。而光電元件表面粗糙度，也是影響影像傳輸品質的重要因素。所以近來工業界對於各類表面輪廓儀的需求，是非常的殷切。值得我國儘速投入人力及設備進行研發。其中掃描探針顯微術(Scanning Probe Microscopy,SPM)，便是一個極具潛力的技術[1-10]。由於 SPM 已在實驗室中展現出搬移單原子，並製造原子尺寸材料結構的能力，也可在真空、空氣、水溶液等環境下操作，使得掃描探針顯微術，成為奈米科技的發展基礎，並受到全球科技界的重視。但是國內在發展高科技產業的同時，其中最重要的 SPM 等相關檢測設備，須向其他先進國家購買，不但設備價格高昂，維修不易，如果碰到競爭對手干預，則將會遭到設備出口管制問題。所以本研究是建立自製檢測設備的能力與基礎，而以發展接觸式掃描探針顯微系統為出發點。

研究目的

目前以音圈(Voice Coil)或是電磁裝置(Electromagnetic Device)，作為力致動器(Force Actuator)的趨勢，有快速增加的現象，這是因為它很便宜，且很很容易驅動使用的緣故。但是這種音圈力致動器或電磁裝置，有很嚴重的非線性效應，例如死帶區(Dead Band)及磁滯效應(Hysteresis Effect)，並且使用久了，其中非常重要的彈簧及線圈電阻，會有彈性係數變差，及電阻變大的特性。傳統設計是在工作點(Operating Point)的附近，將系統動態方程式進行線性化，再利用各種線性控制方法，進行控制器的設計。但是當系統參數有變化(Parameter Variation)，或是有負載干擾(Load Disturbance)時，這些預先設計好(增益及補償器皆為固定式)的控制器，就不一定能使系統維持良好的反應，可能誤差會加大，甚至產生不穩定的現象，所以必須要找一個更有效的方法。

由於可控制接觸力之掃描探針顯微系統[11-15]，複雜性比前述之SPM 檢測設備低，環境容忍能力也較高。而檢測的精度可以利用機構的設計，數值處理的手法，以及電路方面的提升，而具有開發的潛力。以往運用傳統PID控制技術，已經完成一套接觸式掃描探針顯微系統[16-17]，如圖 1。

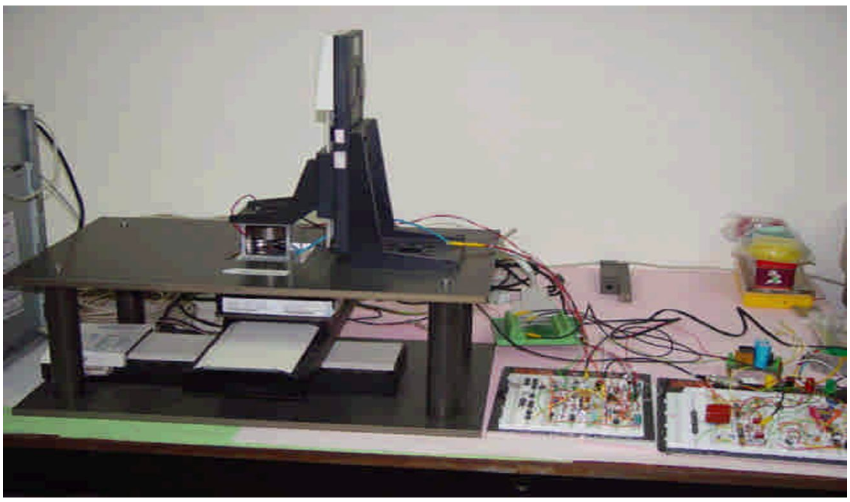
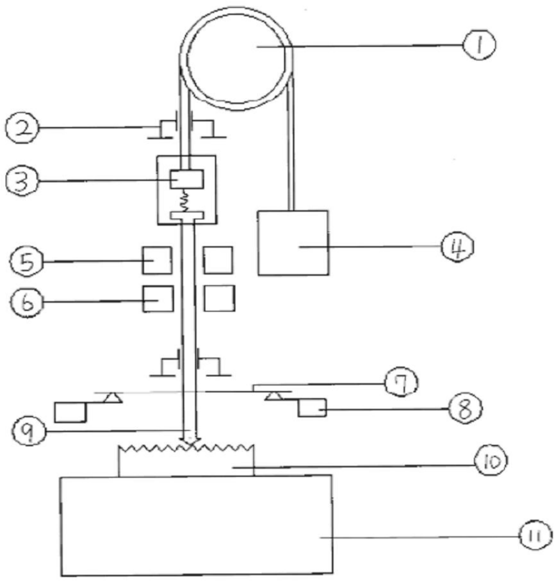


圖 1　可控制接觸力之掃描探針顯微系統

本計畫先前運用傳統PID控制技術之系統[16-17]，主要元件包括：XYZ 移動平台、音圈力致動器(Voice Coil Force Actuator)、線性可調式差分變壓器(LVDT， Linear Variable Differential Transformer，)、荷重計(Load Cell，精密度 10 毫克)、垂直鑽石探針頭(半徑 10μm)、驅動電路、訊號擷取卡，及自行研發的系統操作程式(Operating System Programming)。基本操作原理是：先設定探針與待測物的接觸力(如 40 毫克)，而後運用XYZ 平台，進行平面掃描，配合荷重計，線性可變差分變壓器，類比/數位訊號擷取卡，並利用PID 控制器補償，將荷重計的訊號做回授與處理，再將誤差訊號，傳到力致動器，做施力誤差補償。系統硬體架構連結及MATLAB 模擬方塊，如圖 2 及 3。最後是將擷取到的數位資料，利用軟體程式，以畫面呈現在電腦螢幕上。但是系統的性能，會受到力致動器輸入死帶區，及遲滯效應(Dead Band and Hysteresis Effect)的影響，如圖 4。



1、滑輪。2、固定機構。3、音圈式力致動器。4、配重塊。5、線性可調式差分變壓位移量測器（LVDT）。6、速度感測器（LVT）。7、薄葉型簧片（Leaf Spring）。8、精密電子天枰。9、探針。10、待測物。11、X.Y.Z 平台。

圖 2 先前運用傳統PID控制技術之可控制接觸力之掃描探針顯微系統架構圖

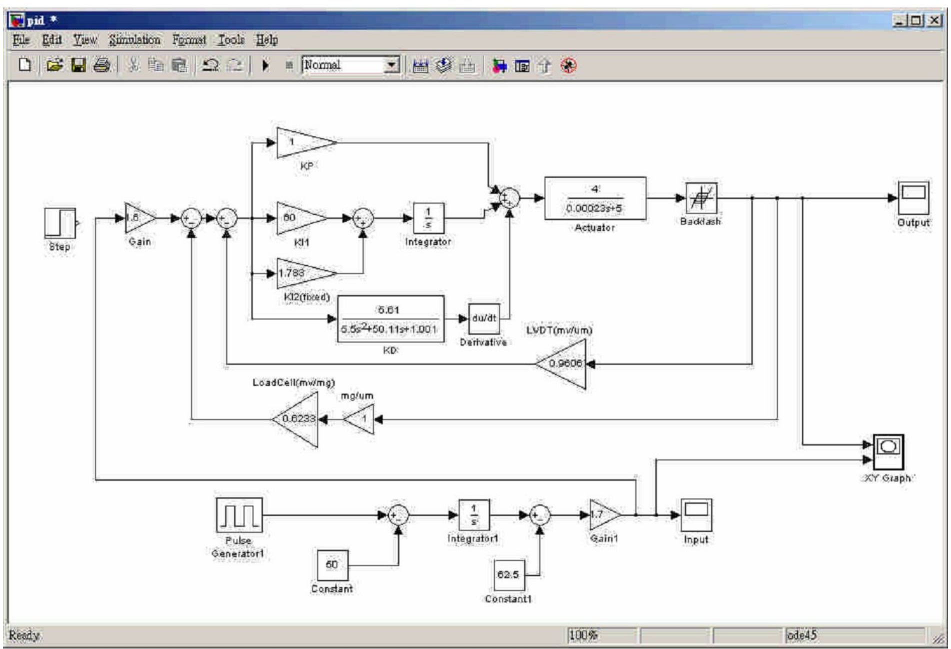


圖 3 先前運用傳統PID控制技術研發之MATLAB 系統模擬方塊圖

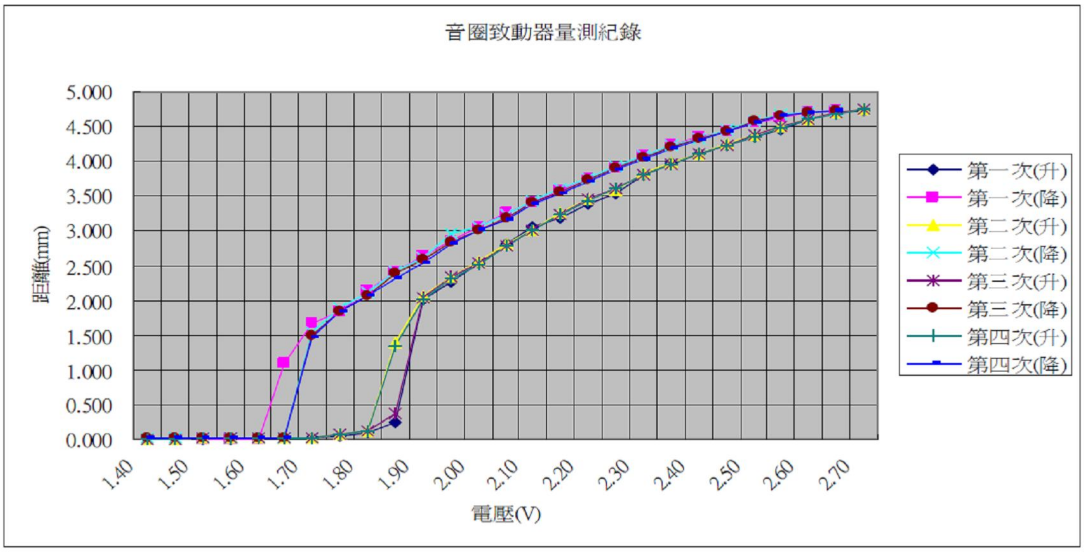


圖 4 力致動器輸入死帶區及遲滯效應曲線量測圖

後來因微分控制器，會造成雜訊放大效應，而沒有採用。設計模擬結果，如圖 5-6 所示，其中(a)為力致動器輸入三角波， (b)微系統輸出三角波， (c)為輸出及輸入曲線(XY PLOT)的對照圖，可知當積分器的增益逐漸增加(I=10)，超過某一數值(I=20)時，此種補償方式，對於力致動器磁滯效應的改善，趨於一極限。而另一方面，當積分器的增益太高時，系統反應變差，量測結果，比較容易震盪而不穩定，為一項缺點。

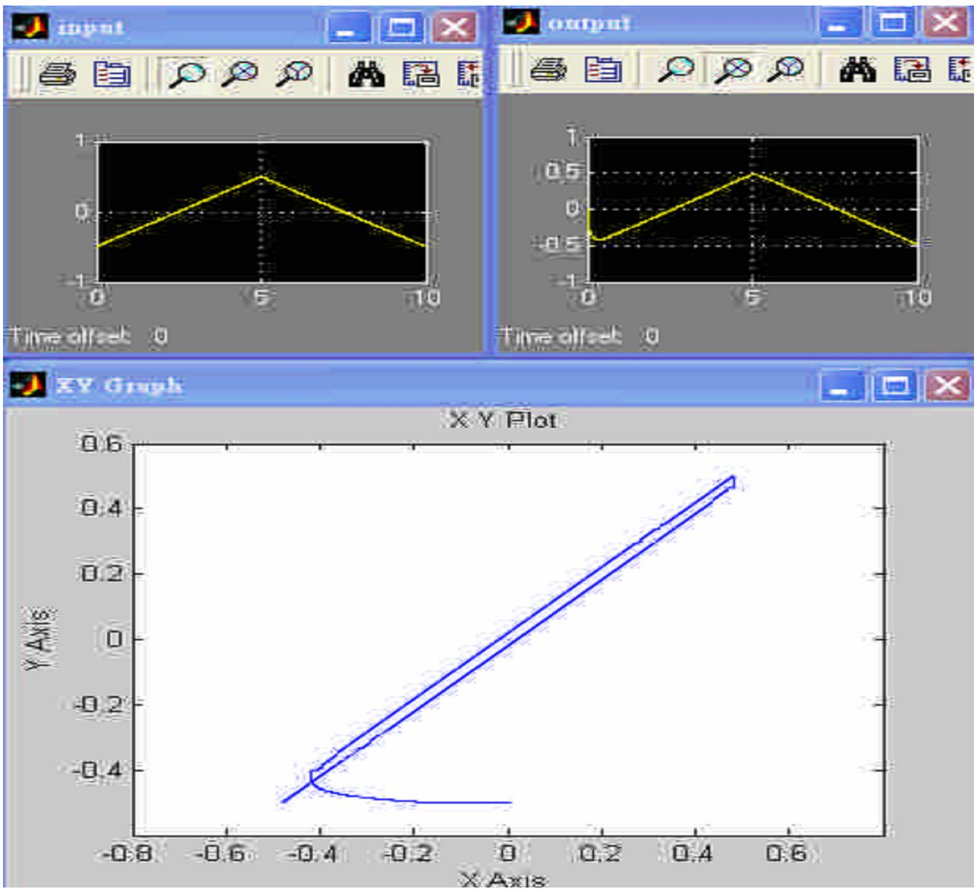


圖 5 P = 0.5，I = 10 之力致動器(a)輸入三角波,(b)輸出三角波,及(c) 輸出及輸入之曲線圖(XY PLOT)

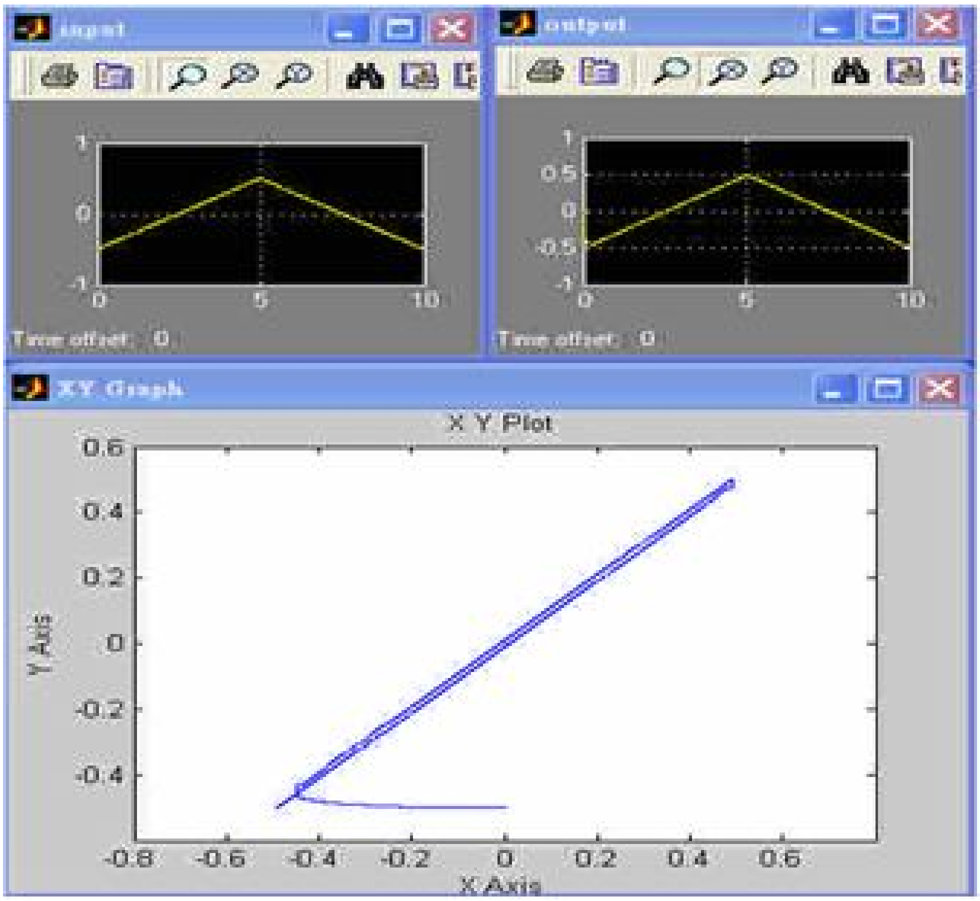


圖 6 P = 0.5，I = 20 之力致動器(a)輸入三角波,(b)輸出三角波,及(c) 輸出及輸入之曲線圖(XY PLOT)

文獻探討

一般非線性系統設計法[24，27]可分為：滑動模式控制(Sliding Mode Control, SMC) [19-21]，模糊控制[19，22]，H∞控制[21，23]，及回授線性化控制[24]，其中以滑動模式，及模糊控制為最常見。滑動模式控制，是利用不連續的控制輸入，使系統狀態能確保於切換平面(Switching Plane)附近，並沿著切換平面滑動至原點，使受控體(Plant)不受系統參數變化，及外在負載干擾的影響。但是這種方法需要先設定參數變化，及負載干擾之最大不確定量。但是這麼一來，系統往往會有明顯的抖動切跳現象(Chattering Effect) 。這是因為滑動模式中的輸入信號，會因符號函數(Sign Function)的切換，而巨量改變的緣故。反之若選擇過小的不確定量為邊界，則會產生穩態誤差。

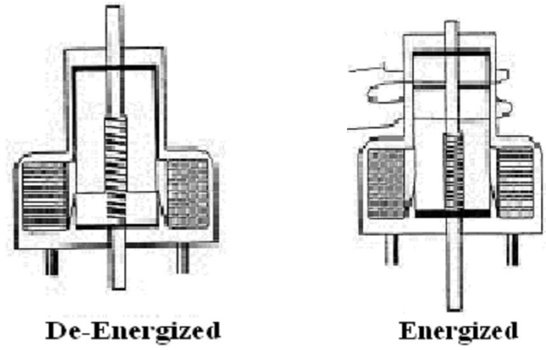
另一方面，模糊邏輯理論自 Lotfi Zadeh 於 1965 創始以來，已被廣泛應用於各個領域，它被證明是個出色的方法，可用來處理繁雜的非線性系統。於智慧型控制領域中，另一個被大量應用的是類神經網路（Neural Network），由於其可藉由系統輸入輸出的取樣資料，當作訓練範例，從訓練範例中，學習系統之間的行為模式，而不需要許多複雜的數學式，且訓練範例，經過篩選的步驟後，利用類神經網路的收斂速度，與學習能力，能夠更快得到更佳的神經網路架構。類神經網路若以學習方法分類，有許多不同類型的神經網路。其中應用最為廣泛、普遍的是：倒傳遞神經網路（Back-Propagation Network ）。模糊控制主要是針對已知，或未知的非線性成分，依據模糊變數，及模糊控制準則，來消除非線性成分[19，22，25-27]，且系統模型不需很準確，即可達成強健控制目的。

研究方法

由上可知模糊控制較簡單，所以本研究是採用這種方法，進行強健式系統設計，如力致動器有非線性磁滯效應，及彈簧有彈性疲勞，而導致彈性係數(k)變差；及電阻(R)因電流生熱而變大的現象。本研究是以 MATLAB 套裝軟體，進行模糊控制整合及模擬分析，最後進行及軟體及硬體整合測試，相關成果已發表 [59-60]。詳細步驟說明如下：

音圈(Voice Coil)型力致動器的結構，如圖 7，其中圖 7 (a)是未通電流的情況，致動桿沒有向下伸出。而圖 7 (b)是通電流後的情況，致動桿有向下伸出。因為音圈通電流後，所產生的作用力F，與通過的電流，有下列關係：

$$F = B\ell i \tag{1}$$



(a)未通電流致動桿沒有伸出(b)通電流致動桿有伸出

圖 7 音圈(Voice Coil) 型力致動器及致動桿結構圖(a)未通電流，(b)通電流

另一方面，音圈(Voice Coil) 型力致動器，產生的作用力，與壓縮彈簧使致動桿，產生的位移x，及彈簧係數k (Spring Constant)，有下列關係：

$$F = kx \tag{2}$$

$$F = B\ell i = kx \tag{3}$$

又：外加於音圈(Voice Coil)型力致動器的相電壓(Phasor Voltage)，與通過的相電流(Phasor Current)，有下列關係：

$$\mathbb{V}(s) = \mathbb{I}(R + jwL) \tag{4}$$

其中 R 及 L 分別為音圈的電阻及電感。由式(3)及(4)可得音圈致動器的轉移函數為：

$$\frac{\mathbb{X}}{\mathbb{V}} = \frac{B\ell k}{R + jwL} = \frac{\frac{B\ell k}{L}}{S + \frac{R}{L}} \tag{5}$$

由上式可知這種音圈型力致動器外加電壓 v，與其位移 x，是成正比的關係。所以目前以音圈(Voice Coil)，作為力致動器(Force Actuator)，有快速增加的現象[18-26]，這是因為它很便宜，且很容易驅動使用的緣故。但是這種音圈力致動器或電磁裝置，有很嚴重的非線性效應，例如死帶區(Dead Band)，及磁滯效應(Hysteresis Effect)，且使用久了，其中非常重要的彈簧，會有彈性疲勞，而導致彈性係數(k)變差。而另一方面，電阻(R)因通過電流，生熱而會有變大的現象。

研究內容

本次的研究目標，是使用下列3種控制器架構，針對音圈致動器磁滯效應(Hysteresis Effect)，進行掃描探針顯微術設計(Scanning Probe Microscopy, SPM)。圖 8 為內、外迴路前向迴路中，運用PI 控制器之方塊圖(系統 1)，雙PI補償器的目的是：穩態誤差於內迴路及外迴路趨近於 0。圖 9 為不用LVT之SPM系統方塊圖(系統 2)，以降低成本。圖 10 為不用LVT之SPM系統PID模糊控制器 (系統 3)。期望能分析何者對磁滯效應的處裡方面，有更好的成果。

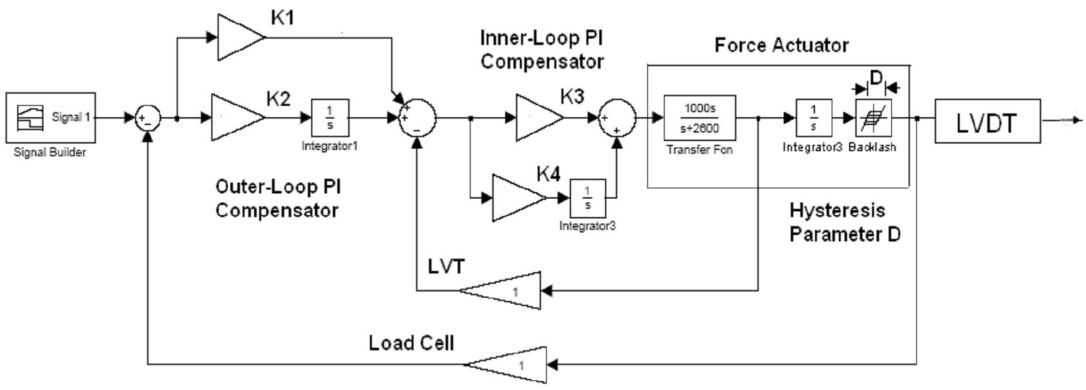


圖 8 內、外迴路前向迴路中運用PI 控制器方塊圖(系統 1)

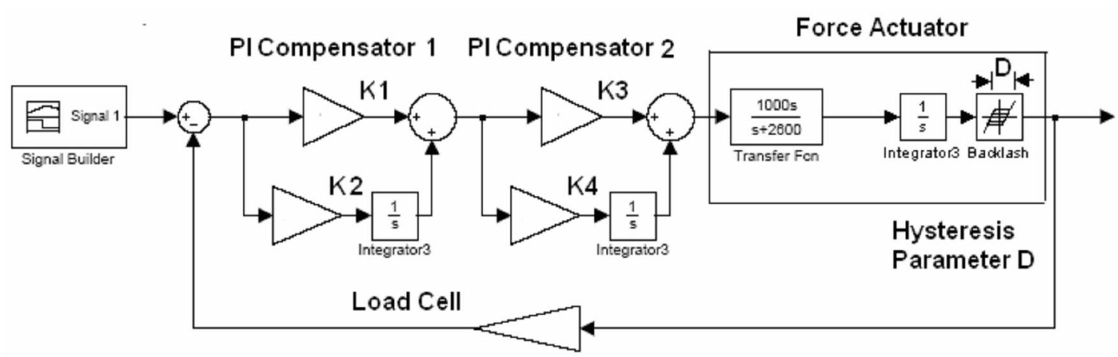


圖 9　不用LVT之SPM系統MATLAB模擬方塊圖(系統 2)

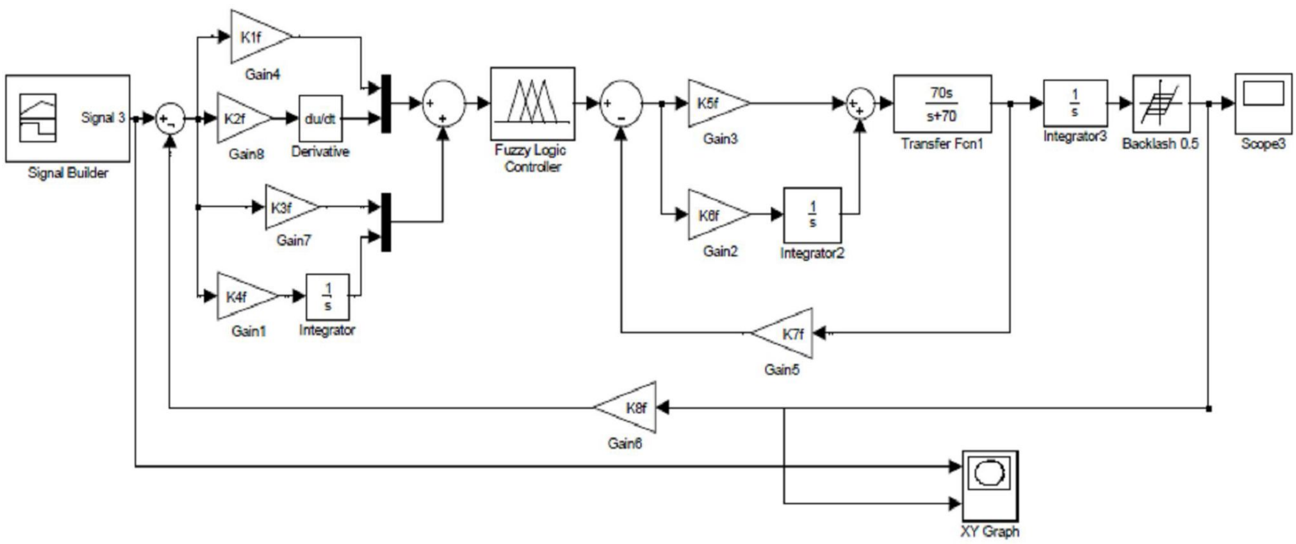


圖 10 不用LVT之SPM系統PID模糊控制器MATLAB模擬方塊圖(系統 3)

表 1 列出圖 8(系統 1，用LVT)所用的控制器設計，6 種情況時之增益餘裕，相位餘裕，及穿越頻率 ω_c (Phase Cross-over Frequency)之比較。而圖 11-14 是用方案(Case)1、2、5、和 6 之波得圖響應。若磁滯效應D=0.3，則各對應方案的鋸齒波輸出響應，結果如圖 15 到圖 19。可知無論哪一種情況，輸出磁滯效應都很明顯。。

表 1　圖 8(系統 1，用LVT) 控制器設計之增益餘裕，相位餘裕及穿越頻率 ω_c比較

Case	K1	K2	K3	K4	GM1	PM1 (Deg)	GM2	PM2 (Deg)	ω_c (rad/sec)
1	12	120	1	200	∞	73	∞	85	9840
2	10	100	0.8	180	∞	75	∞	70	7500
3	15	100	1.5	200	∞	65	∞	88	20000
4	20	150	2	150	∞	63	∞	89.5	40000
5	8	80	0.5	300	∞	85	∞	60	30000
6	18	200	1.3	220	∞	70	∞	90	30000

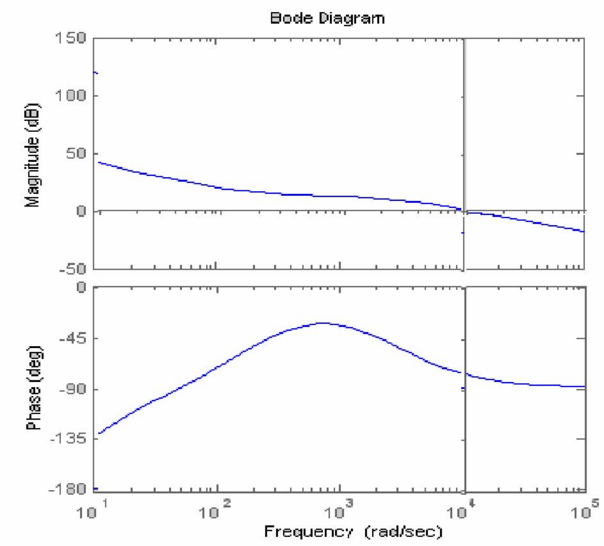


圖 11 系統 1 使用 Case 1 之波得圖

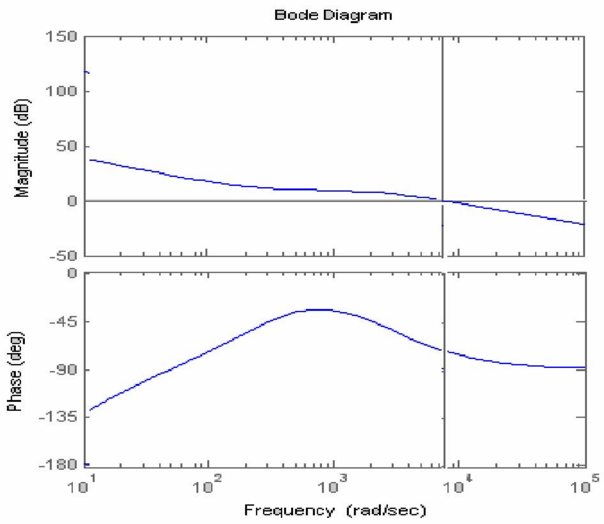


圖 12 系統 1 使用 Case 2 之波得圖

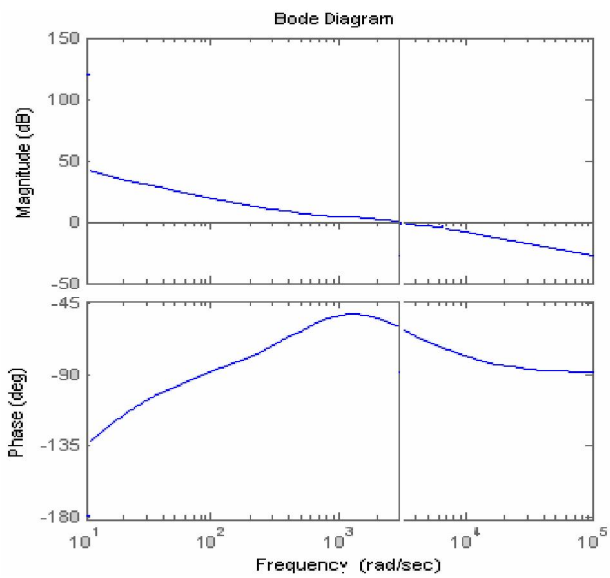


圖 13 系統 1 使用 Case 5 之波得圖

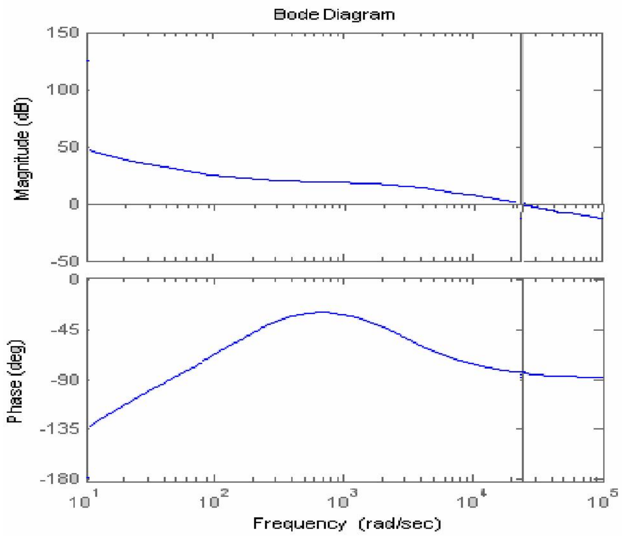


圖 14 系統 1 使用 Case 6 之波得圖

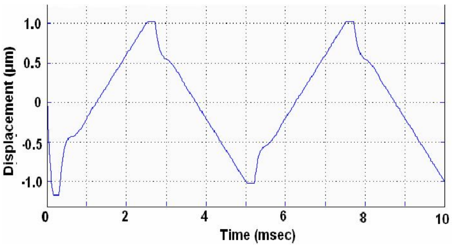


圖 15　系統 1 使用 Case 1 之輸出響應(D=0.3)

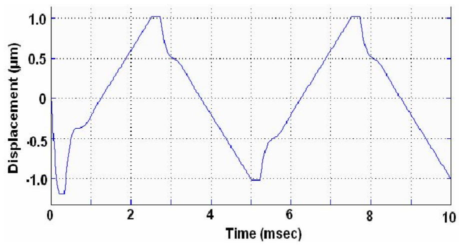


圖 16 系統 1 使用 Case 2 之輸出響應(D=0.3)

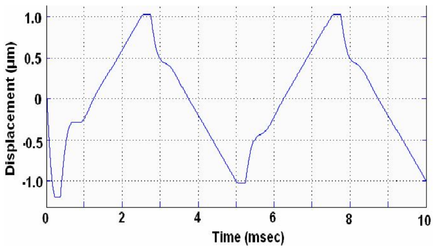


圖 17 系統 1 使用 Case 5 之輸出響應(D=0.3)

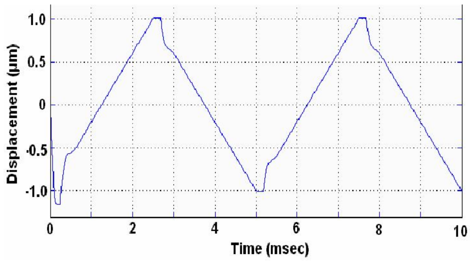


圖 18 系統 1 使用 Case 6 之輸出響應(D = 0.3)

其次運用如圖 9(系統 2，不用 LVT)，進行 SPM 系統的設計，表 2 同樣也列出了內迴路，及外迴路的增益餘裕，相位餘裕，以及對應之穿越頻率 ω_c。方案(case)1、3、4 及 8 的波德圖，如圖 19-22。輸出鋸齒波響應，如圖 23-26。可知相較於 Case 1(較大的相位餘裕)，磁滯效應明顯降低，因為系統反應速度提昇很多，使磁滯效應造成的延遲減少，如圖 23。不過，相較於 Case 3 以及 Case 4，產生的相位餘裕及 ω_c 又更大。另外，Case 8 中初始的相位餘裕，及穿越頻率 ω_c 都太小了，所以圖 26 中系統的穩定性，又再度下降，因為磁滯效應使系統最後的相位餘裕，趨近於 0。

表 2　圖 9(系統 2，不用 LVT)控制器設計之增益餘裕，相位餘裕及穿越頻率 ω_c 比較

Case	K1	K2	K3	K4	GM	PM (Deg)	ω_c (rad/sec)
1	1	0	1	200	∞	109	80
2	0.5	0	1	200	∞	100	40
3	0.25	0	1	200	∞	98	20
4	0.1	0	1	200	∞	90	8
5	1	0.2	1	200	∞	110	90
6	0.5	0.4	1	200	∞	92	30
7	0.25	0.6	1	200	∞	89	20
8	0.1	0.8	1	200	∞	50	9

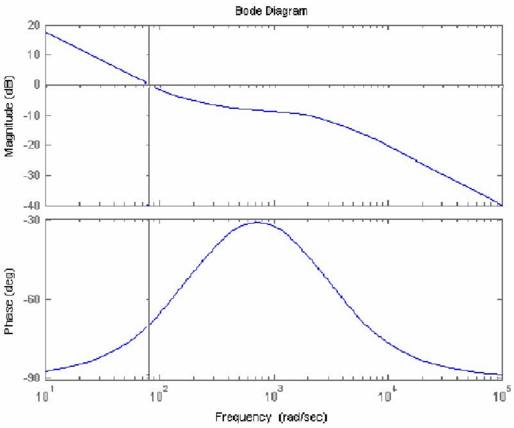


圖 19 系統 2 使用 Case 1 之波得圖

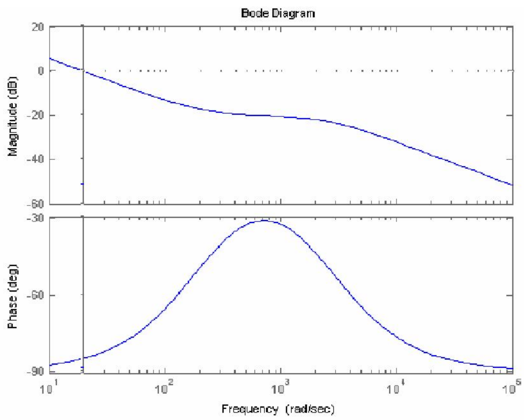


圖 20 系統 2 使用 Case 3 之波得圖

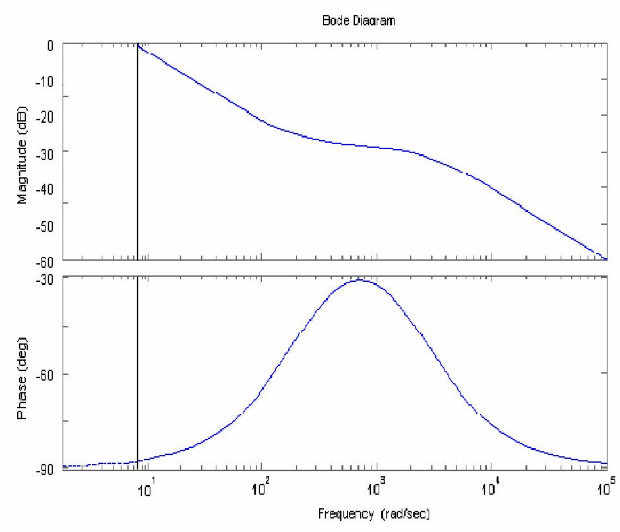


圖 21 系統 2 使用 Case 4 之波得圖

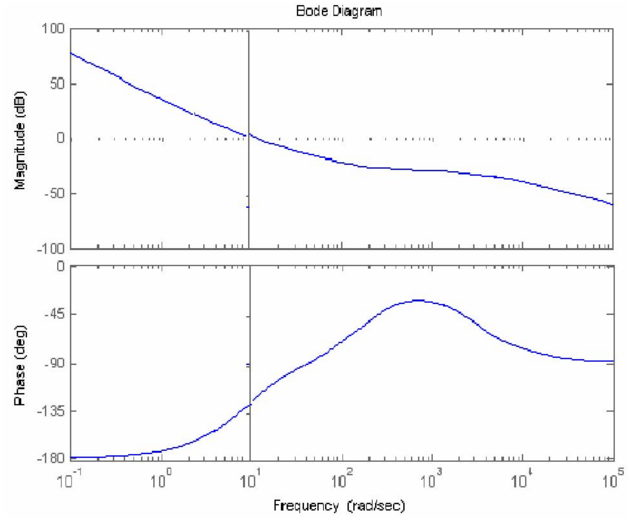


圖 22 系統 2 使用 Case 8 之波得圖

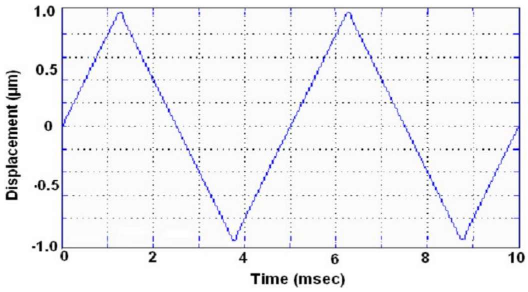


圖 23 系統 2 使用 Case 1 之輸出響應(D=0.3)

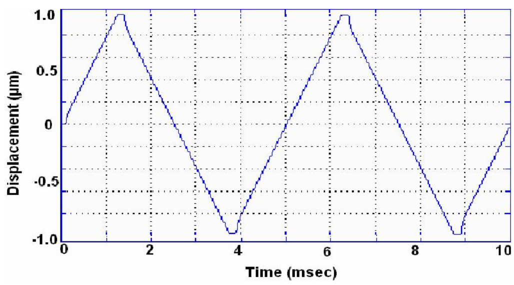


圖 24 系統 2 使用 Case 3 之輸出響應(D=0.3)

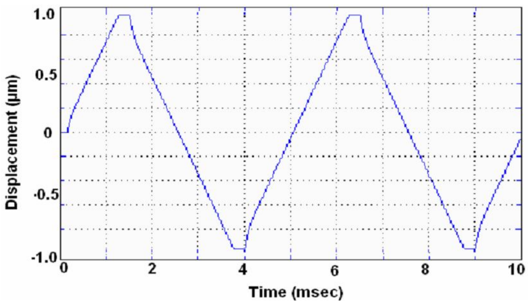


圖 25 系統 2 使用 Case 4 之輸出響應(D=0.3)

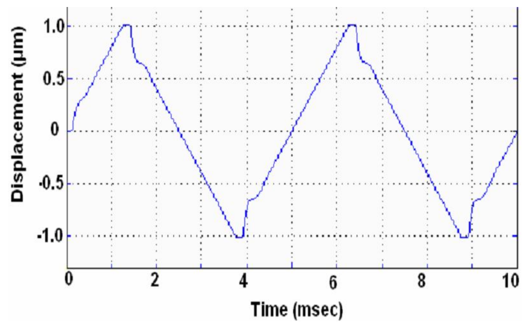


圖 26 系統 2 使用 Case 8 之輸出響應(D=0.3)

最後運用圖 10(系統 3，不用 LVT) 之 PID 模糊控制器，進行 SPM 系統設計，此步驟是利用 IF-THEN RULE 定義出以下控制規則：

R1：IF e is NB AND Δe is NB THEN y is NB
R2：IF e is NB AND Δe is Z THEN y is NM
R3：IF e is NB AND Δe is PB THEN y is Z
R4：IF e is Z AND Δe is NB THEN y is NM
R5：IF e is Z AND Δe is Z THEN y is Z
R6：IF e is Z AND Δe is PB THEN y is PM
R7：IF e is PB AND Δe is NB THEN y is Z
R8：IF e is PB AND Δe is Z THEN y is PM
R9：IF e is PB AND Δe is PB THEN y is PB

其中 NB, NM, NS, ZE, PS, PM,及PB是表示Negative Big（超過很多）、Negative Middle（中等超過）、Negative Small（少量超過），Zero（無偏差）、Positive Small（少量不足）、Positive Middle（中等不足），及Positive Big（不足很多）。而模糊PD控制器的輸出及輸入響應規則，如表 3。模糊PD控制器的控制誤差E、誤差的微分ΔE，及輸入U之歸屬函數(Relationship Function)定義，如表 4 及圖 27-29。為減少計算時間，用於計算模糊控制器，歸屬函數的高斯函數，本文以三角波函數取代。

表 3 模糊 PD 控制器之輸入及輸出規則

$E/\Delta E$	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NM	NM	NS	NS	ZE
NM	NB	NM	NM	NS	NS	ZE	PS
NS	NM	NM	NS	NS	ZE	PS	PS
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NS	NS	ZE	PS	PS	PM	PM
PM	NS	ZE	PS	PS	PM	PM	PB
PB	ZE	PS	PS	PM	PM	PB	PB

表 4 模糊 PD 控制器之規則參數

Item	Parameter E	Parameter ΔE	Parameter U
Negative Big (NB)	[-1 -1 -0.75 -0.3]	[-4.5 -4.5 -3.375 -1.35]	[-12 -12 -9.6 -8.4]
Negative Medium (NM)	[-0.75 -0.3 -0.15]	[-3.375 -1.35 -0.72]	[-9.6 -8.4 -7.2]
Negative Small (NS)	[-0.15 -0.1 0]	[-1 -0.5 0]	[-8.4 -4.8 0]
Zero (ZE)	[-0.05 0 0.05]	[-0.25 0 0.25]	[-4.8 0 4.8]
Positive Small (PS)	[0 0.1 0.15]	[0 0.5 1]	[0 4.8 8.4]
Positive Medium (PM)	[0.15 0.3 0.75]	[0.72 1.35 3.375]	[7.2 8.4 9.6]
Positive Big (PB)	[0.3 0.75 1 1]	[1.35 3.375 4.5 4.5]	[8.4 9.6 12 12]

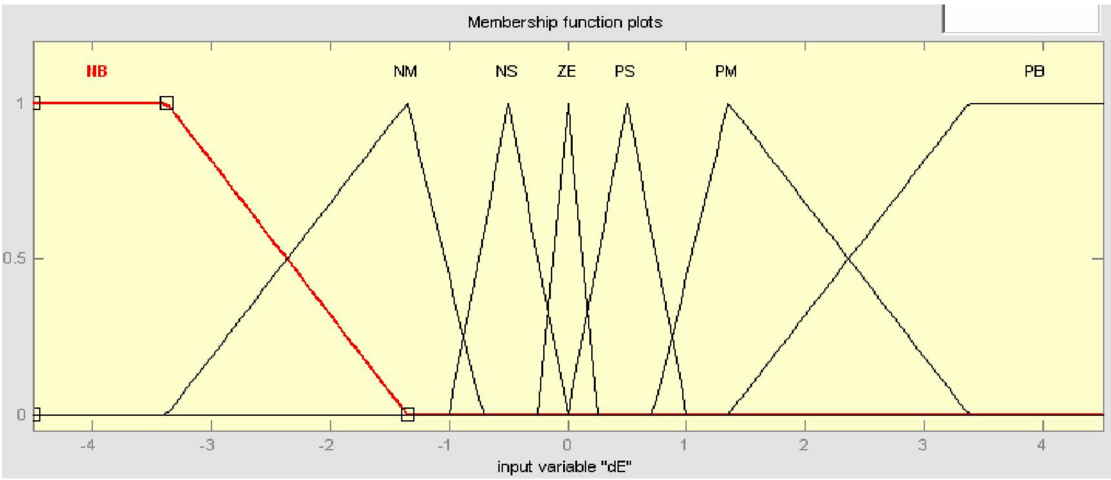


圖 27 誤差 E 的關係函數

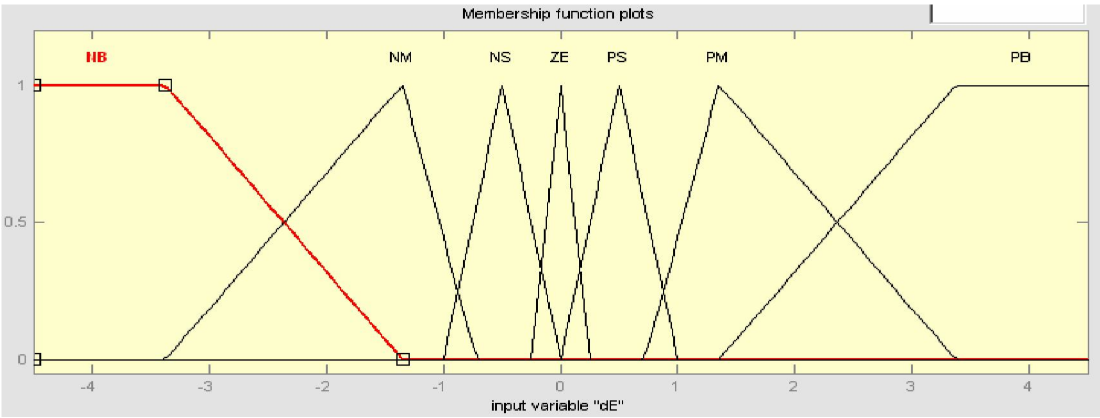


圖 28 誤差 ΔE 的關係函數數值

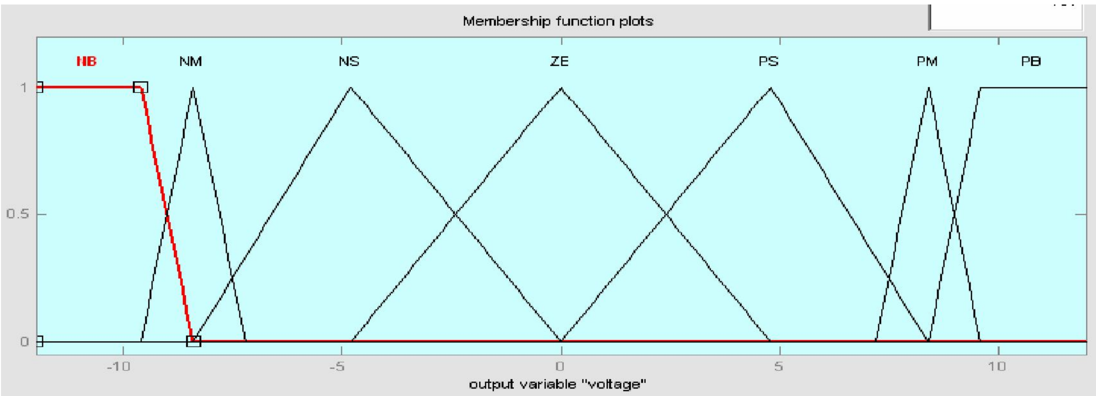


圖 29 模糊控制器輸出的關係函數

在做了幾次試誤法之後，找出系統 3 的 PI 及 PD 的增益補償值，分別為 K1f=10， K2f=10，K3f=0.001，及 K4f=10，圖 30 及 31 為 D=0.3 及 D=0.5 的輸出響應。可知磁滯效應幾乎不見了，所以此種模式的控制器，可以證明是一種非常優秀的控制器。

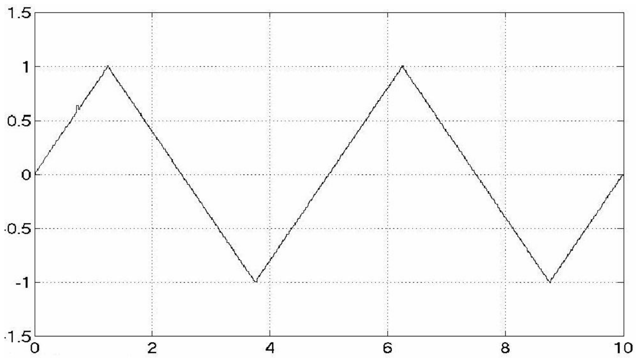


圖 30　模糊控制器輸出響應(D=0.3)

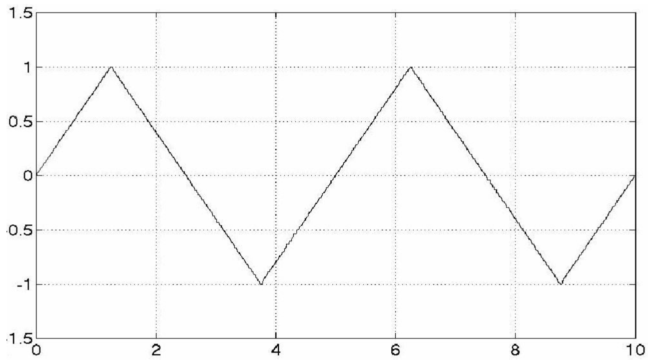


圖 31　模糊控制器輸出響應(D=0.5)

系統設計與討論

系統測試，分成幾個部份，第一步驟是磁力音圈探針控制桿，初始位置的調整。這一部份可以透過調整磁力音圈的電流來實現。當磁力音圈連桿連桿負載接觸力，輸出處於 100 毫克的時候，調整程序便宣告完成，如圖 32。如果表面粗度更低的時候，這個數值還可以更小，這時候就能夠將大量存在於磁力音圈的雜訊全部去除。系統測試流程，如圖 33。

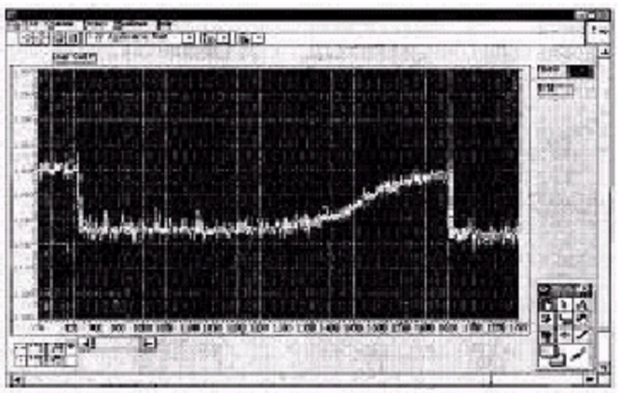


圖 32 磁力音圈連桿連桿負載接觸力輸出上升至 100 毫克

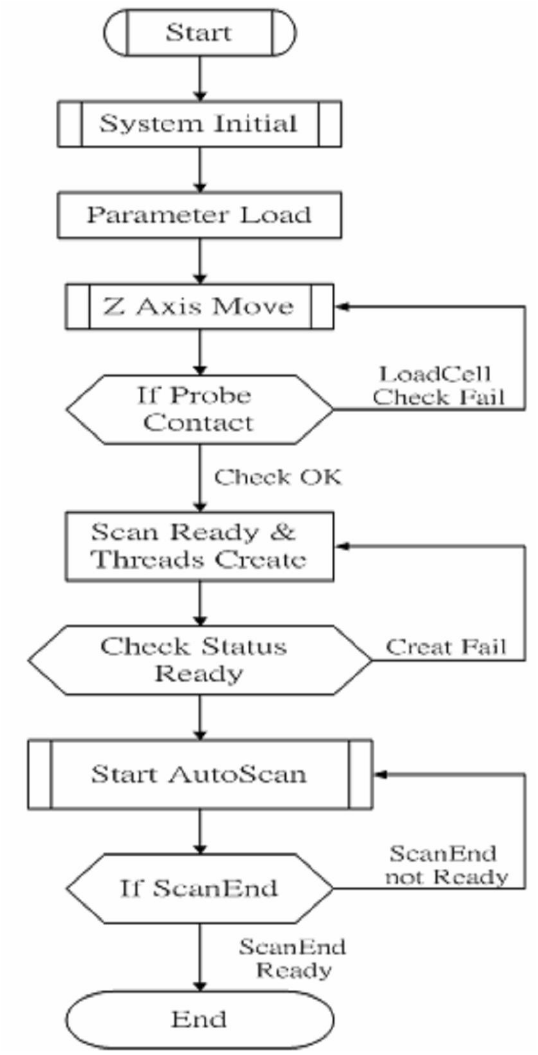
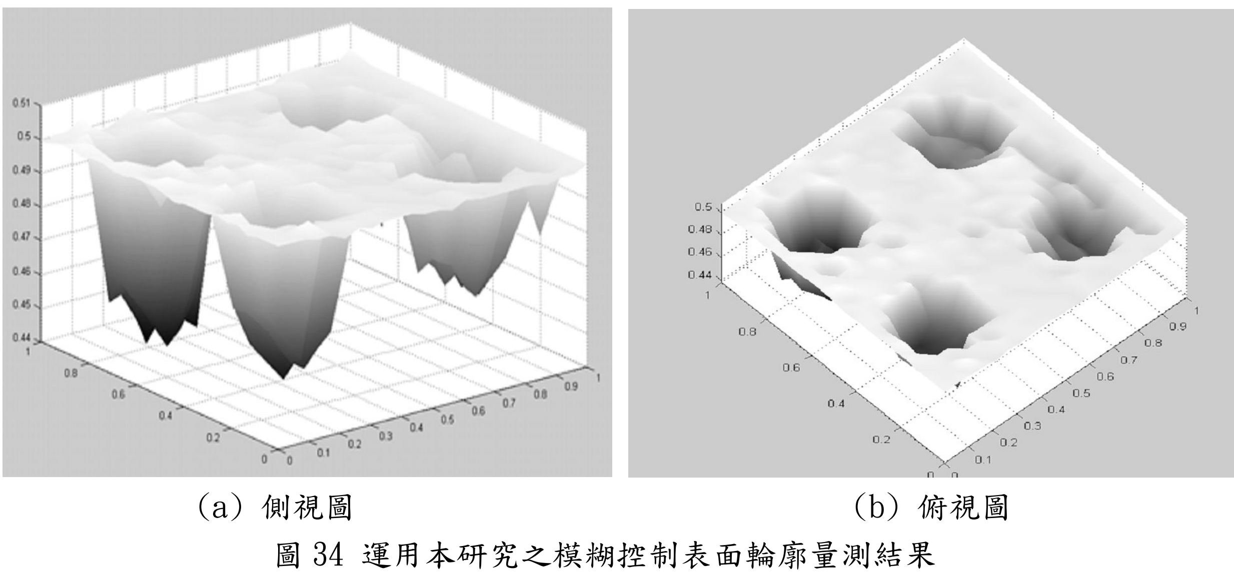


圖 33 系統設計流程圖

完成之後，我們可以令底下的XY平台，隨水平方向(X方向)或是垂直方向(Y方向)移動掃描。最後，由磁力音圈所量到的表面粗度樣本，側視圖以及上視圖如圖 34 (a)及(b)所表示。同樣也可以對照於商品ET-4000 的輸出，表面特性表示於圖 35，可以看到系統的特性表現非常好。



(a) 側視圖　　(b) 俯視圖

圖 34 運用本研究之模糊控制表面輪廓量測結果

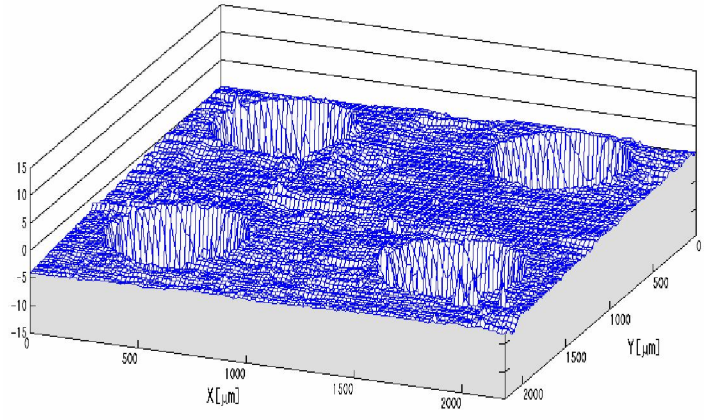


圖 35 商用 ET-4000 表面輪廓量測結果

結論

本次研究是在設計，掃描式探針（SPM）系統之 PI 及 PD 模糊控制器。而且也有與搭載 LV 進行內迴路迴授的控制器，進行比較。另外也發現：在有磁力音圈磁滯現象的情況之下，本研究之 PI 及 PD 模糊控制器，表現依然不差。

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附件二

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■ 達成目標

□ 未達成目標（請說明，以 100 字為限）

　□ 實驗失敗

　□ 因故實驗中斷

　□ 其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：■已發表 □未發表之文稿 □撰寫中 □無

專利：□已獲得 ■申請中 □無

技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

本次的研究目標，是使用PI控制器與PD控制器、以及模糊控制器，針對磁力音圈探針(LVT)，以及 掃描探針顯微術設計(Scanning Probe Microscopy, SPM)，在針對磁滯效應的處裡方面，能有更好的成果。本次的研究實踐是基於使用套裝軟體MATLAB進行表面粗度的模擬來完成實踐的，所以系統表現更為強健。相比於之前的設計方針，本次研究目標的設計，去除掉了磁力音圈探針(LVT)的內迴路補償系統也在研究範圍內，所以新的設計能夠更加的泛用，也更有價值。

由於可控制接觸力之掃描探針顯微系統，複雜性比前述之 SPM 檢測設備低，環境容忍能力也較高。而檢測的精度可以利用機構的設計，數值處理的手法，以及電路方面的提升，而具有開發的潛力。本研究已經完成一套精度可達 1μm 的接觸式掃描探針顯微系統。本計畫的目的是將量測的精度，提升一個數量級。

附件三

國科會補助計畫衍生研發成果推廣資料表

日期：100 年 10 月 19 日

<table>
<tr><td rowspan="1">國科會補助計畫</td><td colspan="3">計畫名稱：掃描探針輪廓儀音圈力致動器有參數變化及磁滯效應時之智慧型設計研究
計畫主持人：林君明
計畫編號：NSC 99-2221-E-216-020　領域：控制學門</td></tr>
<tr><td rowspan="2">研發成果名稱</td><td colspan="3">（中文）
1. 林君明,“應用無線射頻識別標籤技術之熱氣泡式角加速儀及其製備方法,” 中華民國專利(申請中)，2009 年 10 月 29 號提出申請，申請號為：中華民國第 098136612 號發明專利申請案，智慧財產局發明公開公報，公開日期 2011 年 5 月 1 日，公開號碼為「201114678」。

2. 2. 林君明,“應用無線射頻識別標籤技術之熱氣泡式角加速儀及其製備方法,”中國大陸專利(CN5950)，2009 年 11 月 10 號提出申請，申請號為： 200910212138.7。國家知識產權局公報，公開日期 2011 年 5 月 11 日，公開號碼「CN102053167A」。

3.</td></tr>
<tr><td colspan="3">（英文）
3. Jium-Ming Lin, “RFID Based Thermal Bubble Type Accelerometer and Method of Manufacturing the Same,”美國專利(申請中)， 2010 年 4 月 26 日送件，案號：12/767597。

4. Jium-Ming Lin, “Thermal Bubble Type Angular Accelerometer,”美國專利(申請中)。已於「2011 年 5 月 5 日」公開，公開號碼經編列為「US-2011-0100123-A1」。C07305/US1121</td></tr>
<tr><td>成果歸屬機構</td><td>中華大學</td><td>發明人
(創作人)</td><td>林君明</td></tr>
</table>

技術說明	（中文） 加速儀是一種用來量測物體受外力，產生運動位移的一種感測儀器，廣泛用在汽車、導航、國防、以及定位等多種領域。傳統的加速儀多半採取電容式的感測方式，於加速儀內部存在有一組質量塊(Proof Mass)。當外部受力作用於物體上的時候，加速儀內部的質量塊會因慣性，產生不同於加速儀外殼(Chassis)的位移。加速儀利用電容以及靜電感應所產生的電壓變化訊號，經由晶片偵測解調，轉換成加速度的大小。再經由積分運算，換算成位移。但因為存在有質量塊，當加儀所受到的力道過於猛烈，質量塊的固定端就會受損。同時內部質量塊結構複雜，製程當中容易損壞，使得加速儀晶片的良率偏低，連帶使得單價過高，不易推廣於民間使用。 相反的，熱汽泡式加速儀內部是以一加熱器、兩組與熱電堆相同製程的溫度感應器，安裝於注有感應氣體的空腔之中，加熱器經由電流熱效應，產生空腔內部氣體對流。當加速儀外殼受力作用的時候，於空腔中對流的感應氣體，就會隨著外殼受力移動而產生變化，使兩組溫度感應器(熱電堆)處於不同的環境溫度，進而產生不同的電壓。經由晶片解讀，即可將電壓換算成加速度，再由晶片進行積分運算，換算成位移，以便獲得物體位置移動的訊息。但是傳統熱汽泡式加速儀空腔中，是充以空氣或二氧化碳，對加熱器及熱感測器，都會產生氧化作用而容易老化，甚至影響壽期。 *本發明之熱氣泡式加速儀，提出下列五大創新設計，其內容及優點，說明如下： *首度提出不懸空式設計，構造簡單，大幅提升製造良率及大衝擊時的可靠度。 *首度使用低價的塑膠做為基板，隔熱效果好，使用時也比較省電，降低成本。 *首度提出圓形或圓柱形流線型頂蓋，氣流運動更為穩定。 *首度提出更為廉價的製程，降低商品售價。 *首度提出空腔中改填充惰性氣體，如氬(Ar)及氙(Xe)，沒有氧化作用的問題。 （200-500 字）

（英文）

This research proposes a wireless RFID-based thermal bubble accelerometer design, and relates more particularly for the technology to manufacture and package it on a flexible substrate. The key technology is to integrate both a thermal bubble accelerometer and a wireless RFID antenna on the same substrate, such that the accelerometer is very convenient for fabrication and usage. In this paper the heaters as well as the thermal sensors are directly adhering on the surface of the flexible substrate without the traditional floating structure. Thus the structure is much simpler and cheaper for manufacturing, and much more reliable in large acceleration impact condition. In addition, the inner boundary shape of the chamber is changed as a semi-cylindrical or semi-spherical one instead of the conventional rectangular type. Comparisons are also made, one can see the sensitivity of the proposed semi-cylindrical design filled with inert gas such as Xe or the traditional carbon dioxide is better.

The most distinguished one is that the device is direct adhering on the substrate without making the floating structure which will reduce the reliability as well as increase the cost of fabrication. By the way the chamber is filled with inert gas such as Xe or Ar to avoid the oxidizing effect produced by the previous commercial ones with carbon dioxide or air that will reduce the reliability as well as the life cycle of the heater. In addition, the internal shape of the chamber uses semi-spherical or semi-cylindrical one to speed up the fluid flow for heat convection such that the bandwidth of the new structure is larger than the traditional one with rectangular package. One the other hand the outer shape of the package uses the rectangular type for easy marking the part and series numbers. Finally, the device is also augmented with RFID tag technique to make the accelerometer as wireless one for easy application in various fields, such as sports, hospital monitoring, air bag, game, remote navigation and guidance, exercising, etc. Comparisons with the conventional thermal bubble accelerometer with rectangular-shaped internal chamber and

	filled with carbon dioxide are also made. We have shown that the sensitivity of the newly proposed semi-cylindrical design is better. The paper organization is as follows: the first section is introduction. The second one is fabrication and packaging steps. The third one is simulation results and discussion. The last part is the summary.
產業別	導航、控制、娛樂及通訊產業應用
技術/產品應用範圍	導航、控制、娛樂及通訊產業應用
技術移轉可行性及預期效益	本發明之熱汽泡式加速儀是與無線射頻識別標籤技術整合，可以無線方式運作，大幅提升應用場合，如運動，醫療照顧，水平或垂直畫面切換，遊戲機，及貴重物品的監控。具有下列七大創新設計，其內容及優點，說明如下： 1. 首度提出不懸空式設計，加熱器及溫度感測器是直接和基板接觸，構造簡單，不需鏤空之製程，可大幅提升製造速度、良率，及大衝擊時的可靠度。 2. 首度使用低價的塑膠做為基板，隔熱效果好，使用時也比較省電，可降低成本。 3. 首度提出氣室內部為圓球形或圓柱形，而外部為長方體之構裝設計，氣流運動會更為穩定。 4. 首度提出將一般氣室之二氧化碳或空氣，改填充惰性氣體，如氬(Ar)及氙(Xe)，沒有二氧化碳或空氣，會有氧化及老化作用的問題。 5. 首度提出在塑膠基板上，以低溫電子槍製程製作加熱器及 K、J、E 及 T 型熱電堆。 6. 將無線射頻識別標籤，整合於 X、Y 及 Z 軸熱氣泡式加速儀之塑膠基板製程中，使其成為無線方式運作，用途更廣、更方便。

註：本項研發成果若尚未申請專利，請勿揭露可申請專利之主要內容。

附件四

國科會補助專題研究計畫項下出席國際學術會議心得報告

日期：100 年 4 月 23 日

計畫編號	NSC 99－2221－E－216－020－		
計畫名稱	掃描探針輪廓儀音圈力致動器有參數變化及磁滯效應時之智慧型設計研究		
出國人員姓名	林君明	服務機構及職稱	中華大學
會議時間	100 年 4 月 14 日 100 年 4 月 15 日	會議地點	法國巴黎第七大學 Université Denis Diderot (Paris 7)
會議名稱	(中文)2011 國際電子電機工程師協會控制及自動化計算機智能研討會 (英文)2011 IEEE Symposium on Computational Intelligence in Control and Automation (CICA 2011)		
發表論文題目	(中文)以 PD 型模糊控制器進行移動式天線追蹤系統有參數變化之設計 (英文)Intelligent PD-Type Fuzzy Controller Design for Mobile Satellite Antenna Tracking System with Parameter Variations Effect		

報告內容應包括下列各項：

1、 參加會議經過

此次論文研討會，是聯合國際電子電機工程師協會(IEEE)計算機智能有關的34個研討會，同時舉行。由此可見此會議之規模，及受國際重視的程度。相關論文將收錄於 IEEE Xplore 及 Engineering Index (EI) 網站，由此可見此會議的重要性。(The extended abstracts of all paid/registered papers will be included in the IEEE Xplore database and Engineering Index (EI)).

這次參加研討會的文章，是以海報方式展出(Poster)，由林君明教授，與工程科學博士學位學程，博士班研究生張博光所合寫的，題目是：Intelligent PD-Type Fuzzy Controller Design for Mobile Satellite Antenna Tracking System with Parameter Variations Effect (以 PD 型模糊控制器進行移動式天線追蹤系統有參數變化之設計) 。

這種以 PD 型模糊控制器，進行移動式天線追蹤系統設計的好處是:它可以使移動式天線追蹤系統，在追蹤衛星時，不會受到天線追蹤系統有參數變化的影響，例如馬達的遲滯效應(Hysteresis Effect)。經過模擬分析，這種天線的追蹤效果，會比傳統天線追蹤系統的控制效果更好。這論文在經過審查修改之後，終於獲得接受，並核定是以海報方式展出，比口頭報告，可以更接近參與的專家，所以感覺挑戰更大，實在收穫很多。

這篇報告是在 4 月 12 日下午 4 點至 4 點 30 分舉行。同一個會場屬於 CICA 2011 的有 3 篇，其餘是其他計算機智能研討會所推選出來的。結果台灣來以海報方式展出的，只有我這篇，實在非常榮幸。他們把這種以海報方式展出的論文報告時間，排在所有研討會的議程之最前端，而會議論文編排的順序，也是依此排列。結果我的論文，是在論文頁次的第一頁，可見大會重視的程度，故令我感到非常榮幸。在來法國參加之前，特別排演準備了數次，想像聽眾可能會問的問題，並加強臨場的表達能力。本人發表論文時會場的情況，如圖 1-4。

此次會議有碰到同樣來自台灣的學術單位，如國立台南大學資訊工程學系教授及兼任研發處研發長的李健興教授，帶領一個研發團隊及學生，如電子計算中心王元良技士，及台灣棋院九段的周俊勳職業棋士，來此研討會，展示他們研發的計算機，與人腦進行圍棋大賽，互有勝負。非常引人注意，也讓世界各國人士了解我國在計算機智慧技術開發方面的進步，留下深刻的印象，也是一項很好的國民外交。

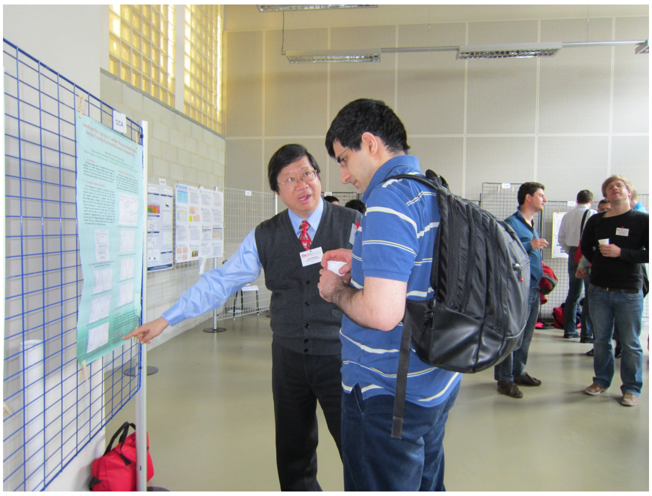

圖 1　林君明教授發表論文時之現場情況(1)

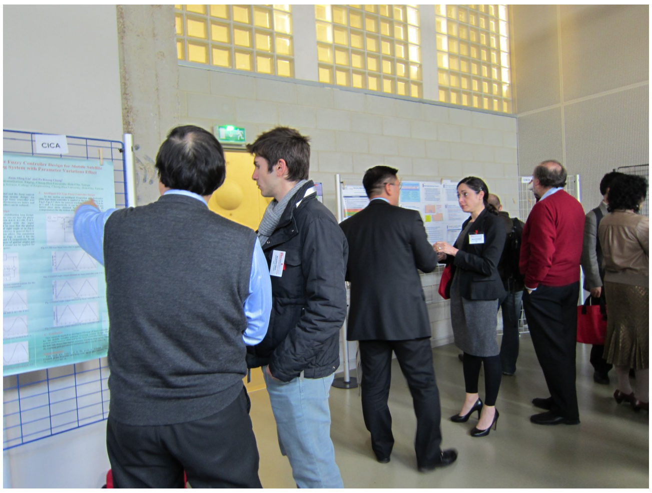

圖 2　林君明教授發表論文時之現場情況(2)

圖 3　林君明教授發表論文時之現場情況(3)

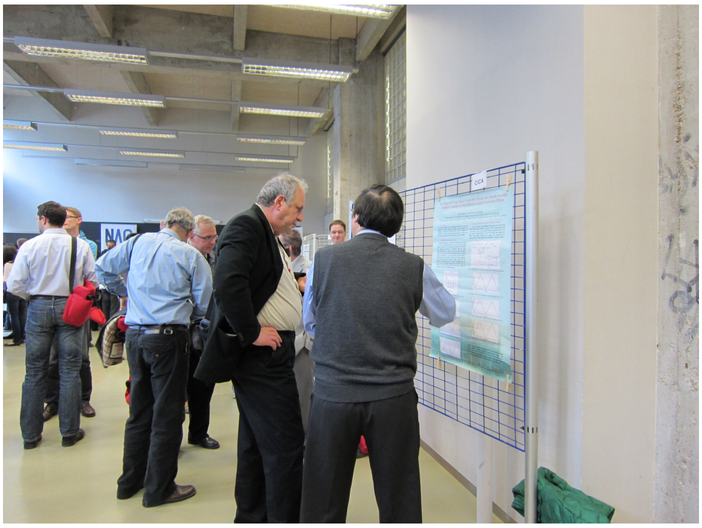

圖 4　林君明教授發表論文時之現場情況(4)

2、 與會心得

大會第一及第二天早上 9 點 30 分，即在大學的演講廳，揭開一天的序幕。9 點 30 分至 10 點 30 分，及 11 點 3 至 13 點，進行當天研討會上午的兩場專題演講(Keynote Speech)，相關議題及內容都非常精采。下午 14 點至 18 點 30 分，也有其他領域的類似兩場專題演講，或穿插每天的研討會，分 33 個會場同時進行，場地佈置、資訊取得，及寬廣舒適性都是一流，這是大會非常成功的地方，有此可見法國人辦活動的魄力，值得我們學習。我對模糊智慧型控制有興趣，所以就參加這方面的研討會場次，令人收穫頗多。

三、考察參觀活動(無是項活動者省略)

無。

四、建議

出國參加國際會議，的確可以磨鍊一下發表文章的技巧，及吸收別人寶貴的經驗，發掘一些新的研究靈感與題目，所以是非常值得鼓勵的事。而平常自已也要充實英文的能力，屆時才會有更大的收穫。這次有機會進行海報報告，實在是一次很好磨鍊英文及組織能力的機會。因為事先要先練習所要宣讀會議的論文，找出一些可以討論的題目，這樣在會議中，就可以從容的回答問題，這樣聽眾及報告人都會有更大的收穫，而場面也不會顯得冷清。還好終於圓滿結束，而收穫最多的，其實就是自己。

五、攜回資料名稱及內容

1. 此次攜回的資料有會議手冊一份，光碟一片。
2. 下一年度研討會海報 Call For Paper: 2012 IEEE Symposium on Computational Intelligence in Control and Automation (CICA 2012) 。

六、其他

Intelligent PD-Type Fuzzy Controller Design for Mobile Satellite Antenna Tracking System with Parameter Variations Effect

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***Abstract*—This research applied both the traditional and the fuzzy control methods for mobile satellite antenna tracking system design. Firstly, the antenna tracking and the stabilization loops were designed according to the traditional bandwidth and phase margin requirements. However, the performances would be degraded if the tacking loop gain is reduced due to parameter variations. On the other hand a PD-type fuzzy controller was also applied for tracking loop design. It can be seen that the system performances obtained by the fuzzy controller were better for both low and high antenna tracking loop gains, and the tracking loop gain parameter variations effect can be reduced.**

Keywords-antenna tracking loop; stabilization loop; PD-type fuzzy controller; PI compensator

I. INTRODUCTION

In order to cope with the satellite Ka-band and broadband mobile communication requirements, the capacity is five times of Ku-band before. The mobile antenna needs to lock on the satellite in spite of disturbances, thus the performances of antenna tracking as well as stabilization loops of Ku-band should be raised [1-3], and e.g. the tracking rate, pointing precision as well as stabilization should be upgraded. The traditional PI (Proportion and Integration) compensator was applied for the tracking and stabilization loops design of mobile antennas to lock on the satellites [4]. The fuzzy controller was applied for the tracking loop design [5], and the relationship functions of Gaussian distribution were applied for six degrees of freedom simulation, thus the computation loading was very large. In addition, the noise and wind disturbance was taken into antenna design consideration.

This paper applied both the traditional and the fuzzy control methods [6-7] for mobile antenna tracking system design. Firstly, the antenna tracking and the stabilization loops were designed with the traditional bandwidth and phase margin requirements. Then applying a simplified model for the antenna control system design, both time and frequency domain analyses are studied to obtain the key parameters of antenna tracking and stabilization loops. The stabilization loop was designed by using proportion and PI compensators for comparison. Noted the performances with PI compensation method were better. However, if taking tracking loop gain degradation effect into consideration, then the performances becomes worse for the cases of lower tracking loop gains.

Thus this research proposed an intelligent control law by using PD-type fuzzy controller. The results show that the performances are better, and the tracking gain parameter variation effect can be reduced. By the way to reduce computer loading for practical implementation, the simplified triangular distribution relationship functions of the fuzzy controller was applied.

The organization of this paper is as follows: the first section is introduction. The second one is for traditional design of antenna tracking and stabilization loops. The antenna performance analyses with a traditional design are given in Section 3. The PD-type fuzzy controller design and performance analyses are given in Section 4. The last part is the conclusions.

II. TRADITIONAL ANTENNA TRACKING LOOP AND STABILIZATION LOOP DESIGN

The detailed block diagram of a satellite antenna tracking system is very lousy [8]. It is very difficult to obtain the key parameters for analyses and simulation. Thus in general a simplified model of antenna pitching or yawing control system is applied to speed up the design and obtaining the key parameters, in which the tracking loop is modeled as a simple gain, and the stabilization loop is replaced by a pure integration, or PI compensators as in Figs. 1 and 2. Then this research made the time and frequency domain analyses firstly, to obtain the key parameters of antenna tracking and stabilization loops. The stabilization loop was designed by using proportion and PI compensators for comparison as shown in Figs. 1(a) and (b). The tracking loop time constant (T) is set as 0.1 seconds of the practical value.

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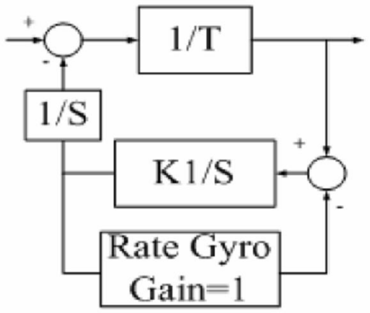

Figure 1. Simplified block diagrams of antenna control systems for the stabilization loop with a pure integration compensator.

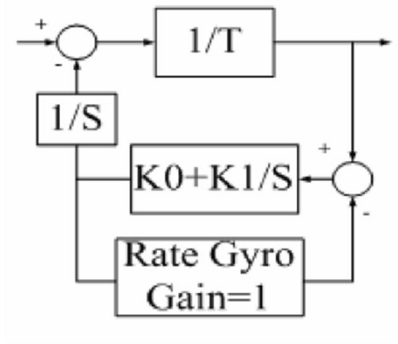

Figure 2. Simplified block diagrams of antenna control systems for the stabilization loop with a PI compensator.

A. *Stabilization loop with (a) pure integration compensator, and (b) PI compensator.*

Firstly, the stabilization loop is designed with pure integration compensator. Let the integrator gain (K1) of stabilization loop be 25, 50, 75 and 100, respectively, then the Bode plots are in Fig.3. The gain margins are ∞. Although the phase margin would be increased with larger K1, the increasing rate approaches saturation for K1=100.

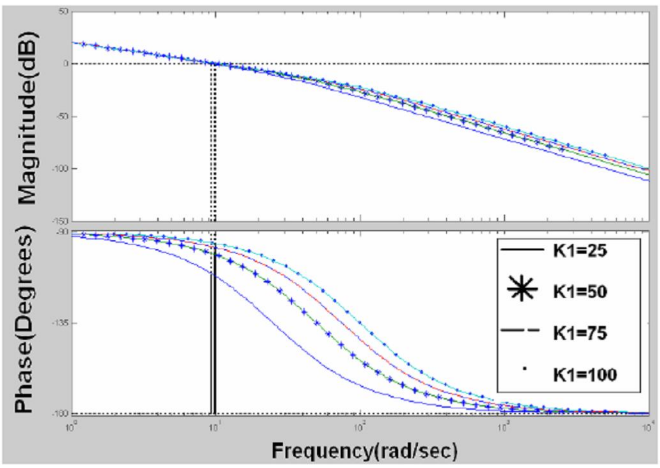

Figure 3. Bode plots for K1 are as 25, 50, 75 and 100.

B. *Stabilization Loop Design with PI Compensator*

Secondly, the PI compensator is applied for the stabilization loop design. The gains of the proportion and integration terms are denoted as K0 and K1, respectively. Fig. 4 shows the Bode plots for several K0's with T=0.1 and K1=100. The phase margin is larger for K0=5. Fig. 5 shows that the phase margin is insensitive with K1 (T=0.1 and K0=5), but the steady-state error can be eliminated with the larger K1's. By some trial-and-error one can see that the phase margins are larger (132° and 133°) for the cases with K0=5, K1=50, T=0.1 and K0=5, K1=25, T=0.2, respectively. The former is chosen for faster response.

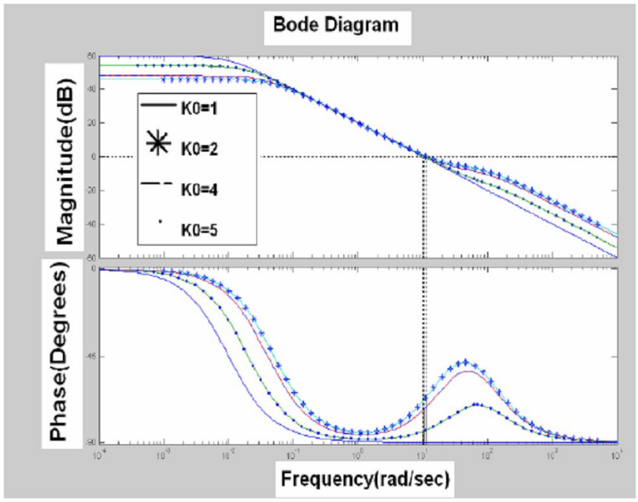

Figure 4. Bode plots for several K0's with T=0.1 and K1=100.

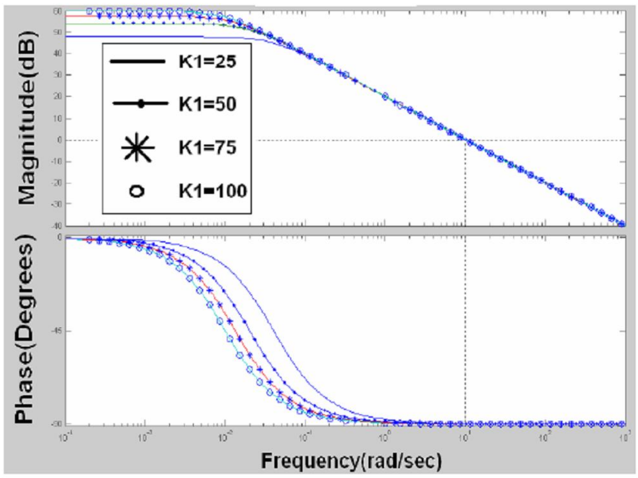

Figure 5. Bode plots for several K1's with K0=5.

III. PERFORMANCE ANALYSES WITH TRADITIONAL METHOD

In this section the antenna performance is analyzed by simulation with the block diagram in Fig.6. The input line-of-sight angle is a triangle one with amplitude and period respectively as 1 radian and 5 seconds. It can be seen that the gimbal angle can track with the input line-of sight angle as in Fig.7, thus the performance is very good.

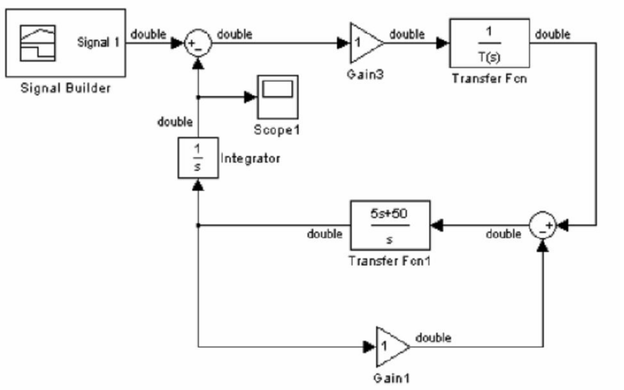

Figure 6. Block diagram of traditional system design.

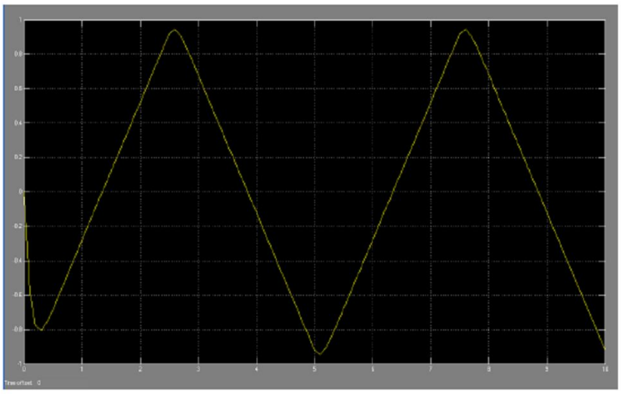

Figure 7. Gimbal angle output with T=0.1

However, in general there is tracking loop gain parameter variation effect. The simulation results with this effect are shown in Figs. 8 and 9 for the parameter T changing from 0.1 to 1 and 1.5, respectively. It can be seen that the tracking performances of gimbal angles are reduced. Thus the traditional method would not be applied for the systems with lower tracking loop gains.

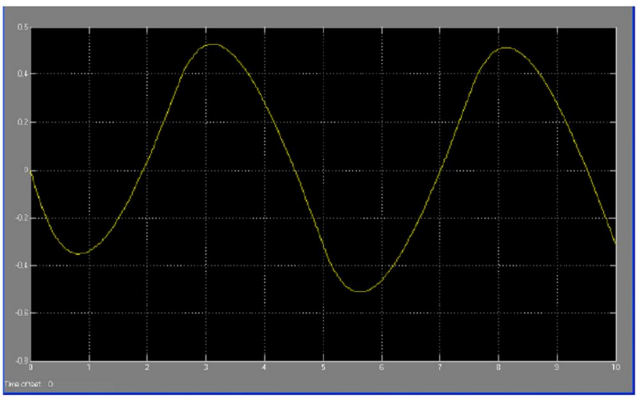

Figure 8. Gimbal angle output obtained by traditional method with T=1.

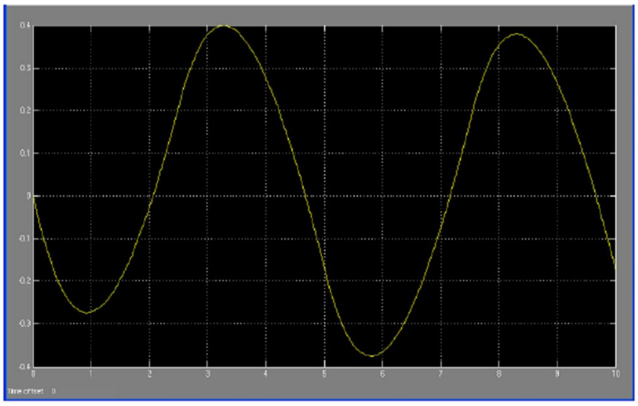

Figure 9. Gimbal angle output obtained by traditional method with T=1.5.

IV. PD-TYPE FUZZY CONTROLLER DESIGN AND ANALYSES

A. Fuzzy Controller Relationship Functions Design

In this section a Proportion and Derivative (PD) type fuzzy controller [6-7] is applied in the tracking loop as in Fig.10. It is well-known that fuzzy controller is based on the IF-THEN RULE as follows.

R1: IF E is NB AND ΔE is NB THEN U is NB,

R2: IF E is NB AND ΔE is ZE THEN U is NM,

R3: IF E is NB AND ΔE is PB THEN U is ZE,

R4: IF E is ZE AND ΔE is NB THEN U is NM,

R5: IF E is ZE AND ΔE is ZE THEN U is ZE,

R6: IF E is ZE AND ΔE is PB THEN U is PM,

R7: IF E is PB AND ΔE is NB THEN U is ZE,

R8: IF E is PB AND ΔE is ZE THEN U is PM,

R9: IF E is PB AND ΔE is PB THEN U is PB,

where NB, NM, NS, ZE, PS, PM, and PB respectively stand for negative big, negative middle, negative small, zero, positive small, positive middle, and positive big.

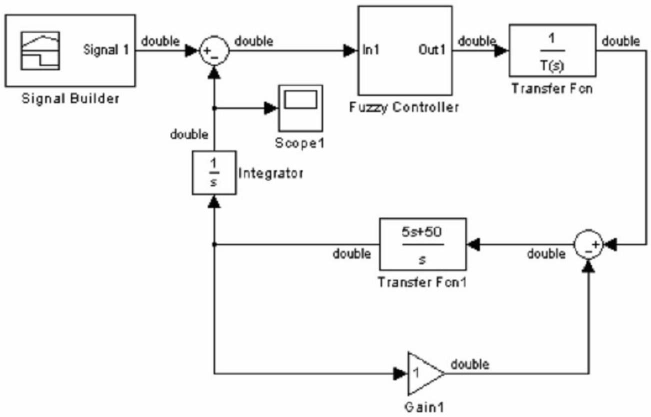

Figure 10. A PD-type fuzzy controller is applied in the tracking loop design.

The detailed cross reference rules for the inputs and output of the PD-type fuzzy controller are defined in Table I. According to fuzzy control design method the relationship functions of boresight error E, ΔE (deviations of present E and the previous E), and U (control input) are defined at first, which are listed in Table II. To reduce the computation time the triangular distribution functions are applied in fuzzy controller relationship functions calculation instead of using the traditional Gaussian ones.

B. *Performance Analyses with PD-Type Fuzzy Controller*

Then the antenna performance is analyzed by simulation. Figs.11-13show the antenna tracking responses for T to be as 0.1, 1 and 1.5, respectively. It can be seen that the results are better than those obtained by using the traditional PI compensators for all the three values of T.

TABLE I. PD-TYPE FUZZY CONTROLLER CROSS REFERENCE RULES.

E, ΔE	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NM	NM	NS	NS	ZE
NM	NB	NM	NM	NS	NS	ZE	PS
NS	NM	NM	NS	NS	ZE	PS	PS
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NS	NS	ZE	PS	PS	PM	PM
PM	NS	ZE	PS	PS	PM	PM	PB
PB	ZE	PS	PS	PM	PM	PB	PB

TABLE II. RELATIONSHIP FUNCTIONS OF E, ΔE AND U.

Item	Parameter E	Parameter ΔE	Parameter U
Negative Big (NB)	[-1 -1 -0.75 -0.3]	[-4.5 -4.5 -3.375 -1.35]	[-12 -12 -9.6 -8.4]
Negative Medium (NM)	[-0.75 -0.3 -0.15]	[-3.375 -1.35 -0.72]	[-9.6 -8.4 -7.2]
Negative Small (NS)	[-0.15 -0.1 0]	[-1 -0.5 0]	[-8.4 -4.8 0]
Zero (ZE)	[-0.05 0 0.05]	[-0.25 0 0.25]	[-4.8 0 4.8]
Positive Small (PS)	[0 0.1 0.15]	[0 0.5 1]	[0 4.8 8.4]
Positive Medium (PM)	[0.15 0.3 0.75]	[0.72 1.35 3.375]	[7.2 8.4 9.6]
Positive Big (PB)	[0.3 0.75 1 1]	[1.35 3.375 4.5 4.5]	[8.4 9.6 12 12]

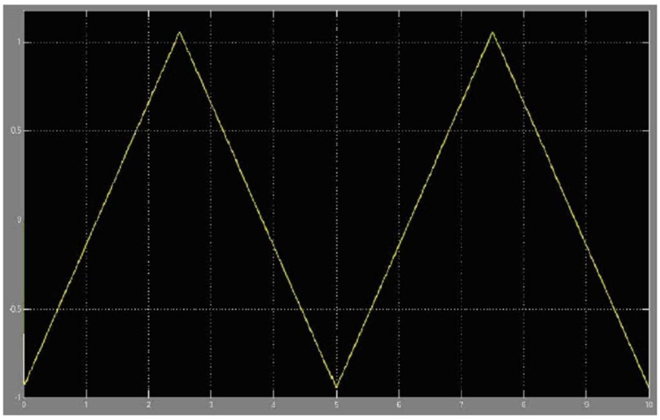

Figure 11. Gimbal angle output obtained by fuzzy controller with T=0.1.

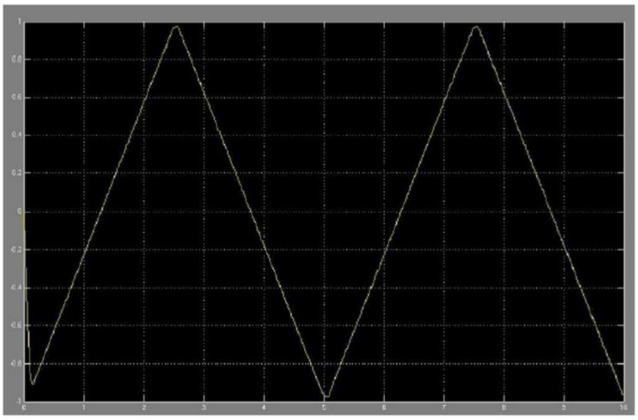

Figure 12. Gimbal angle output obtained by fuzzy controller with T=1.

V. CONCLUSIONS

This research applied both the traditional compensator as well as the PD-type fuzzy control methods for mobile satellite tracking antenna system design. Since the detailed block diagram of a satellite antenna tracking system is very lousy, it is very difficult to obtain the key parameters for analyses and simulation. Thus, a simplified model of antenna pitching or yawing control system is applied to speed up the design and obtain the key parameters. The antenna tracking and the stabilization loops were designed firstly according to the traditional bandwidth and phase margin requirements. However, the performance would be degraded if the tacking loop gain is reduced due to parameter variations. On the other hand a PD-type of fuzzy controller was also applied for the design. It can be seen that the system performances obtained by the fuzzy controller were better for not only lower but higher antenna tracking loop gains. Thus the tracking gain parameter variations effect can be reduced.

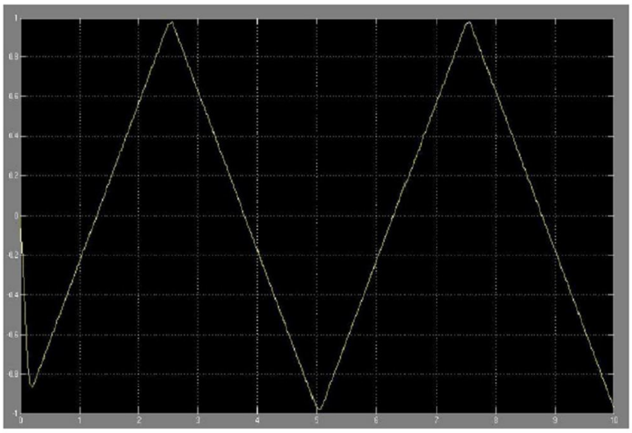

Figure 13. Gimbal angle output obtained by fuzzy controller with T=1.5.

ACKNOWLEDGMENT

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Integration both PI and PD Type Fuzzy Controllers for a Scanning Probe Microscope System Design

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***Abstract*—This research is to use a Proportion and Integration (PI) as well as a Proportion and Derivative (PD) type of fuzzy controllers to reduce the hysteresis effect of a force actuator for a Scanning Probe Microscope (SPM). This improvement has been verified by MATLAB simulation and practical implementation to reduce the hysteresis effect of the force actuator. Comparisons with the previous designs with and without Linear Velocity Transducer (LVT) for inner-loop feedback compensation are also made. Thus the new design is cheaper and valuable.**

Keywords- PI type fuzzy controller; PD type fuzzy controller; SPM; Hysteresis effect

I. INTRODUCTION

The SPM has been developed rapidly in last three decade [1-10]. Its usage is very extensive, e. g. the measurements of physical distribution and material property such as surface profile, roughness, static charge, magnetic dipole, friction, elasticity, and thermal conductivity. As the block diagrams in Figs.1 and 2 of previous researches [11-12], a balance with stylus probe, force actuator, LVDT, load cell, personal computer, and XYZ-stages were integrated into a contact-force- controlled SPM, such that the surface of the sample would not be destroyed by the contact force produced by the stylus probe. To reduce the hysteresis effect of the force actuator this research in Fig. 3 applied a Proportion and Integration (PI) as well as a Proportion and Derivative (PD) type of fuzzy controllers [13-16] for the same SPM system design.This improvement has been verified by MATLAB simulation and practical implementation of a surface profiler. Comparisons with the previous designs with LVT for inner-loop feedback are also made. The concept of the new design is valuable. The organization of this paper is as follows: the first section is introduction. The second and the third ones are for the review of previous researches and the proposed fuzzy controller design. The test results and discussions are given in Section 4. The last part is the conclusion.

II. REVIEW OF PREVIOUS SYSTEM DESIGN

The force actuator is consisted of a coil and a spring, as the left in Fig.4 the rod returns to the initial place when the force actuator de-energized, when a voltage is applied across the coil, then there is current in the coil, and a force is generated to compress the spring and make the rod pull down as the right of Fig.4. The relationship of the applied voltage and displacement is shown in Fig.5. To reduce the hysteresis-effect of the force actuator in Fig.5, this research is to use only a fuzzy controller the newly system model is shown in Fig. 3. TABLE I listed the previous PI compensators [11] for inner and outer loops design (steady state errors are equal to zero for inner and outer loops) in Fig 1. In addition, the gain margins, phase margins of the inner (GM1, PM1) and outer (GM2, PM2) loops as well as the phase cross-over frequency ω_c are also included. The outputs of LVDT for saw tooth shaped input (as in Fig.6) are shown from Figs. 7 to 10 for comparison (with hysteresis effect parameter D be 0.3).

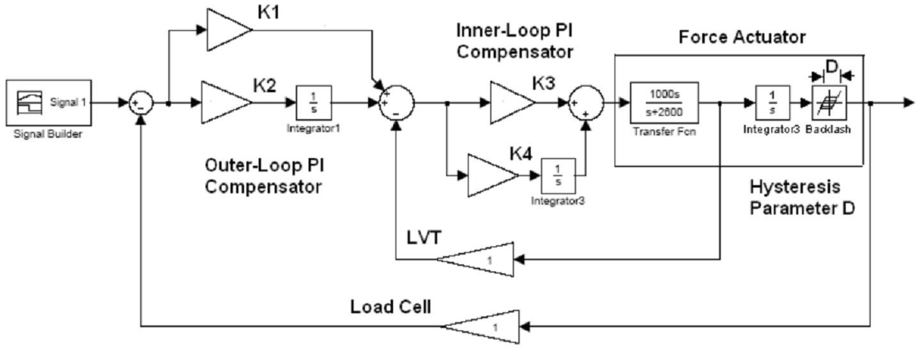

Figure 1. Block diagram of SPM with LVT for inner-loop feedback in the previous research [11].

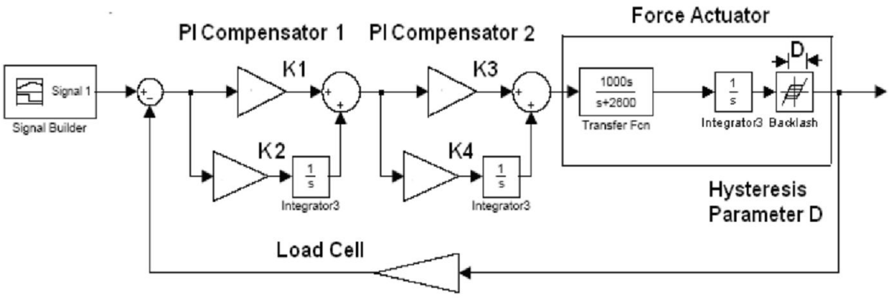

Figure 2. Block diagram of SPM without LVT for inner-loop feedback in the previous research [12].

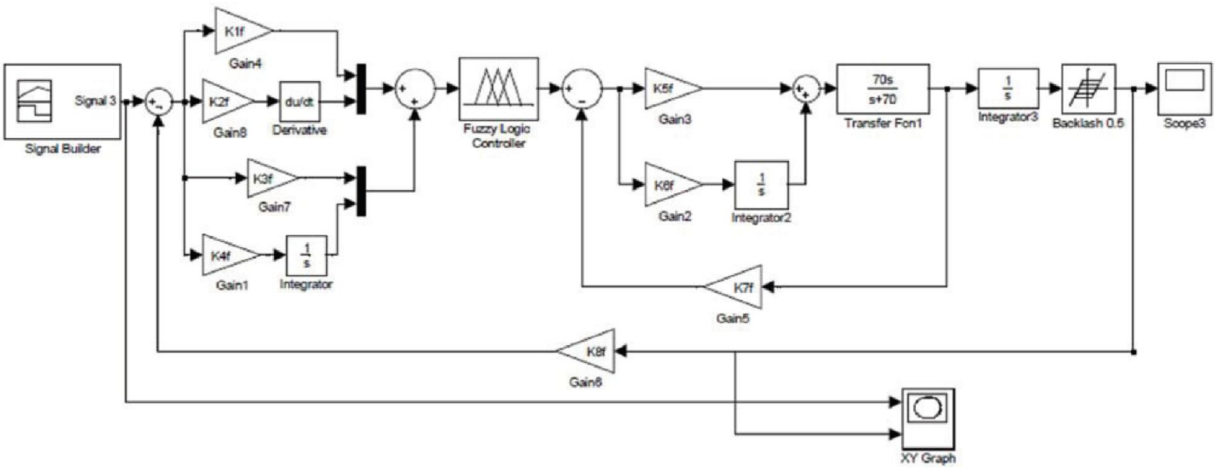

Figure 3. Block diagram of SPM with a fuzzy controller and without LVT in this research.

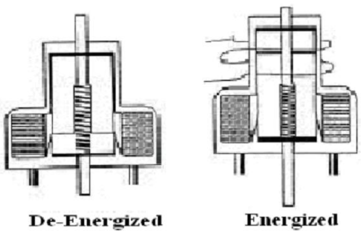

Figure 4. Actuator operation states.

One can see that the larger the outer-loop phase margin, the lower the hysteresis effect, but all the hysteresis effects are still very dominant. The reason is ω_c are very large for these cases, and then the time and phase delays produced by the hysteresis effect would be increased. Thus the stability can even be degraded by adding the hysteresis effect to push the resulting phase margins zero. Now consider the second previous design [12] without LVT for inner-loop feedback in Fig. 2. TABLE II also listed the inner and outer loop gains. In addition, the gain margin, phase margin and ω_c are also included. In addition, the outputs for saw tooth-shaped input are in Figs. 11-14 (D = 0.3). One can see the hysteresis effect is lower for case 1 with larger phase margin, while still bad for cases 3, 4 and 8. The reason is that the phase margins as well as the magnitudes of ω_c are larger for case 1, thus the system responses are quicker, and the hysteresis effect and phase delay would be smaller as in Fig. 11. However, the magnitudes of ω_c as well as the phase margin are much smaller for cases 3 and 4, thus the hysteresis effects are larger as in Figs. 12 and 13.

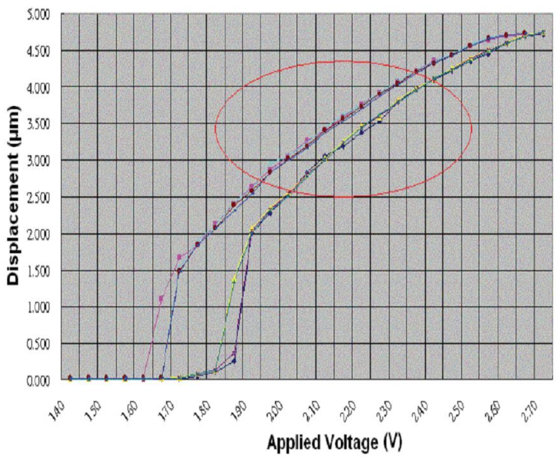

Figure 5. Actuator applied voltage vs. displacement.

TABLE I. PREVIOUS DESIGN RESULTS OF SYSTEM IN FIG 1.

Case	K1	K2	K3	K4	GM1	PM1(Deg)	GM2	PM2(Deg)	ω_c(r/sec)
1	12	120	1	200	∞	73	∞	85	9840
2	10	100	0.8	180	∞	75	∞	70	7500
3	15	100	1.5	200	∞	65	∞	88	20000
4	20	150	2	150	∞	63	∞	89.5	40000
5	8	80	0.5	300	∞	85	∞	60	30000
6	18	200	1.3	220	∞	70	∞	90	30000

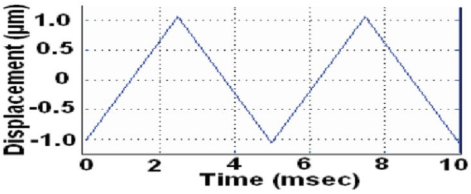

Figure 6. A saw tooth shaped displacement command as input.

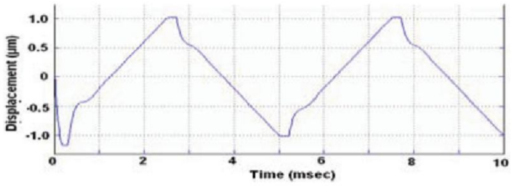

Figure 7. Previous design output of case 1 in Fig. 1 (D = 0.3).

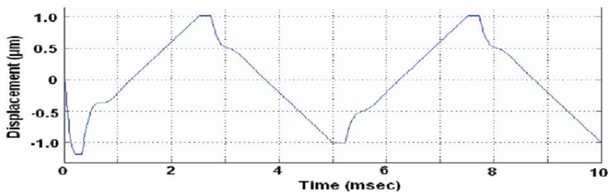

Figure 8. Previous design output of case 2 in Fig. 1 (D = 0.3).

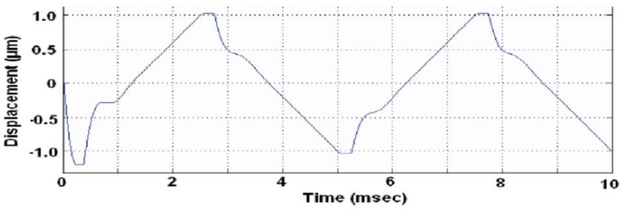

Figure 9. Previous design output of case 5 in Fig. 1 (D = 0.3).

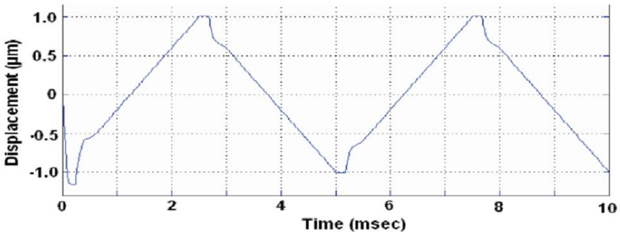

Figure 10. Previous design output of case 6 in Fig. 1 (D = 0.3).

TABLE II . PREVIOUS DESIGN RESULTS OF SYSTEM IN FIG 2.

Case	K1	K2	K3	K4	GM	PM (Deg)	ω_c (r/sec)
1	1	0	1	200	∞	109	80
2	0.5	0	1	200	∞	100	40
3	0.25	0	1	200	∞	98	20
4	0.1	0	1	200	∞	90	8
5	1	0.2	1	200	∞	110	90
6	0.5	0.4	1	200	∞	92	30
7	0.25	0.6	1	200	∞	89	20
8	0.1	0.8	1	200	∞	50	9

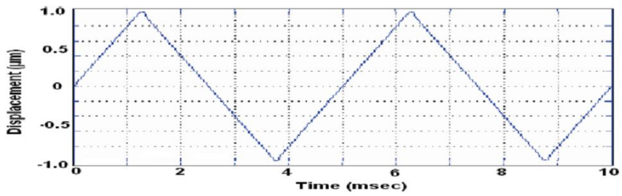

Figure 11. Previous design output of case 1 in Fig. 2 (D = 0.3).

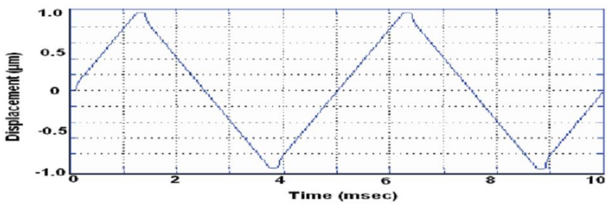

Figure 12. Previous design output of case 3 in Fig.2 (D = 0.3).

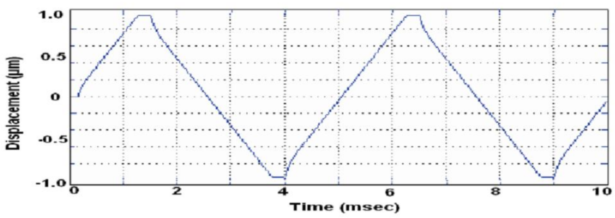

Figure 13. Previous design output of case 4 in Fig. 2 (D = 0.3).

In addition, since the original phase margin as well as the magnitudes of ω_c are too smaller of case 8, thus as Fig. 14 shows that the stability can even be degraded by adding the hysteresis effect to push the phase margin approaching zero.

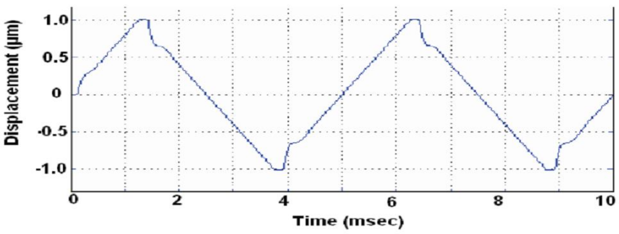

Figure 14. Previous design output of case 8 in Fig. 2 (D = 0.3)

III. Fuzzy Controller Design

A. *Relationship Functions Design*

In this section a PD type fuzzy controller [13-16] is applied in the forward loop as in Fig.3. It is well-known that fuzzy controller is based on the IF-THEN RULE as follows:

R1: IF E is NB AND ΔE is NB THEN U is NB,

R2: IF E is NB AND ΔE is ZE THEN U is NM,

R3: IF E is NB AND ΔE is PB THEN U is ZE,

R4: IF E is ZE AND ΔE is NB THEN U is NM,

R5: IF E is ZE AND ΔE is ZE THEN U is ZE,

R6: IF E is ZE AND ΔE is PB THEN U is PM,

R7: IF E is PB AND ΔE is NB THEN U is ZE,

R8: IF E is PB AND ΔE is ZE THEN U is PM,

R9: IF E is PB AND ΔE is PB THEN U is PB,

where NB, NM, NS, ZE, PS, PM, and PB respectively stand for negative big, negative middle, negative small, zero, positive small, positive middle, and positive big.

The detailed cross reference rules for the inputs and output of fuzzy controller are defined in TABLE III. According to fuzzy control design method the membership function parameters of error E, ΔE (deviations of present E and the previous E), and U (control input) are defined at first, which are listed in TABLE IV. To reduce the computation time the triangular distribution functions are applied in fuzzy controller relationship functions calculation instead of using the traditional Gaussian ones.

TABLE III. Fuzzy controller cross reference rules.

E /ΔE	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NM	NM	NS	NS	ZE
NM	NB	NM	NM	NS	NS	ZE	PS
NS	NM	NM	NS	NS	ZE	PS	PS
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NS	NS	ZE	PS	PS	PM	PM
PM	NS	ZE	PS	PS	PM	PM	PB
PB	ZE	PS	PS	PM	PM	PB	PB

TABLE IV. Membership function parameters of E, ΔE and U.

Item	**Parameter E**	**Parameter ΔE**	**Parameter U**
Negative Big (NB)	[-1 -1 -0.75 -0.3]	[-4.5 -4.5 -3.375 -1.35]	[-12 -12 -9.6 -8.4]
Negative Medium (NM)	[-0.75 -0.3 -0.15]	[-3.375 -1.35 -0.72]	[-9.6 -8.4 -7.2]
Negative Small (NS)	[-0.15 -0.1 0]	[-1 -0.5 0]	[-8.4 -4.8 0]
Zero (ZE)	[-0.05 0 0.05]	[-0.25 0 0.25]	[-4.8 0 4.8]
Positive Small (PS)	[0 0.1 0.15]	[0 0.5 1]	[0 4.8 8.4]
Positive Medium (PM)	[0.15 0.3 0.75]	[0.72 1.35 3.375]	[7.2 8.4 9.6]
Positive Big (PB)	[0.3 0.75 1 1]	[1.35 3.375 4.5 4.5]	[8.4 9.6 12 12]

B. *Fuzzy Controller Performance Analysis*

After some trial-and-error method one has K1f=10, K2f=10, K3f=0.001, K4f=10. Figs. 15 and 16 showed the output response for D = 0.3 and D = 0.5, respectively.

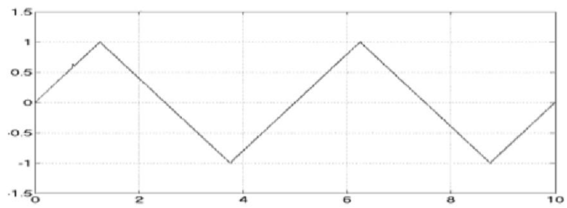

Figure 15. Output response with fuzzy controller (D = 0.3).

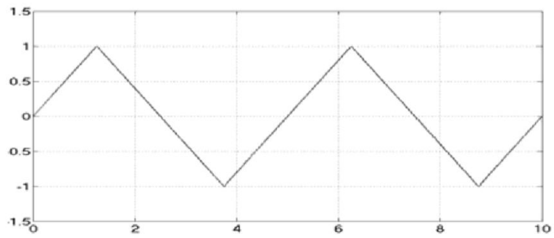

Figure 16. Output response with fuzzy controller (D = 0.5).

It can be seen that the hysteresis effects are almost disappeared, so that this method is better than those obtained by the previous controllers.

IV. TEST RESULTS AND DISCUSSIONS

The operation steps are summarized as follows. The first step of test is initial levelling of the balance lever arm, which is achieved by adjusting the current through the coil of force actuator. Since the lever arm weight at the stylus probe (contact with the sample) side is heavier than the other side (contact with actuator) intentionally, thus the force actuator should push down to make the balance lever arm even. The contact point of the lever arm on the load cell is installed right at the calibrated-levelling height. This adjustment process stops when the value of load cell output increases from 0 mg to 40 mg. This value for the weight discrimination can be lowered if the circuit routing condition is better, thus the noise amplitude at the load cell output can be reduced.

The next step is to load the sample on the holder which is fixed on the piezo-stage as well as XYZ-stages, and then setting the XY-stages (the resolution is 34 nm in either axis) to make the first sampled point just right under the tip of the stylus probe, then raising the piezo-stage upward until the sampled point touching with the probe. The value of the probe contact force on the sample can be obtained by the load cell. In order to make sure that the probe contacts with the sample while not destroy it, the maximum contact force is limited to 100 mg, i.e., if the magnitude of contact force is smaller than 100 mg, then moving the piezo-stage upward by one step (the resolution is 10 nm), otherwise, stop. Then by scanning the XY-stages in either x- or y-axis, and finally, the surface profile of the sample can be obtained as shown in Figs. 17 and 18 for side view and top view, respectively.

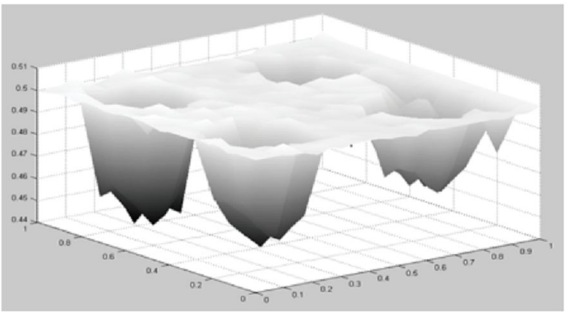

Figure 17. Side view of a sample with the proposed method.

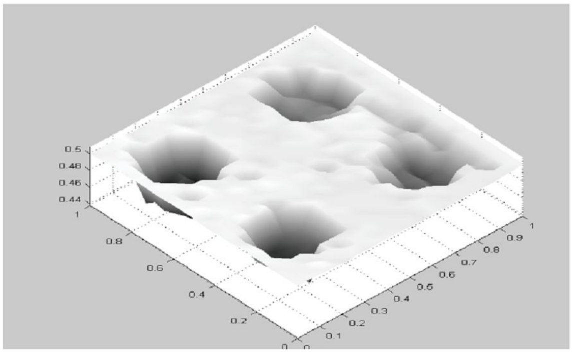

Figure 18. Top view of a sample with the proposed method.

V. CONCLUSION

This research applied a PI as well as a PD type of fuzzy control method for a Scanning Probe Microscope (SPM) system design. In addition, the actuator hysteresis effect was taken into consideration. Comparisons with two previous works with and without Linear Velocity Transducer (LVT) for inner-loop feedback compensation are also made, it can be seen that the system performance obtained by the proposed fuzzy controller is much better, especially in reducing the actuator hysteresis effect. This improvement has been verified by MATLAB simulation and practical implementation of a surface profiler. Finally, the profile of the object surface is displayed on a 3D graph.

ACKNOWLEDGMENT

This research was supported by National Science Council under the grant of NSC 97-2221-E-216- 013-MY2.

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[2] P. K. Chang and J. M. Lin, "Scanning probe microscope system design with linear velocity transducer for feedback compensation," SICE Annual Conference 2008 in Tokyo, pp. 2382–2387, August 20-22, 2008.

[3] P. K. Chang and J. M. Lin, "Scanning probe microscope system design with fuzzy control," Proceedings of the 9th WSEAS International Conference on Automation and Information (ICAI'08), Bucharest, Romania, pp. 548–553, June 24-26, 2008.

[4] H. Zhang and D. Liu, Fuzzy Modeling & Fuzzy Control, New York: Springer-Verlag, 2006.

[5] P. K. Chang and J. M. Lin, "Integrating traditional and fuzzy controllers for mobile satellite antenna tracking system design," Proceedings of WSEAS Conference on Advances in Applied Mathematics, Systems, Communications and Computers, selected papers from Circuits, Systems and Signals 2008, Marathon Beach, Attica, Greece, pp. 102–108, June 1-3, 2008.

附件四

國科會補助專題研究計畫項下出席國際學術會議心得報告

日期：100 年 4 月 23 日

計畫編號	NSC 99－2221－E－216－020－		
計畫名稱	掃描探針輪廓儀音圈力致動器有參數變化及磁滯效應時之智慧型設計研究		
出國人員姓名	林君明	服務機構及職稱	中華大學
會議時間	100 年 4 月 14 日 100 年 4 月 15 日	會議地點	法國巴黎第七大學 Université Denis Diderot (Paris 7)
會議名稱	(中文)2011 國際電子電機工程師協會控制及自動化計算機智能研討會 (英文)2011 IEEE Symposium on Computational Intelligence in Control and Automation (CICA 2011)		
發表論文題目	(中文)以 PD 型模糊控制器進行移動式天線追蹤系統有參數變化之設計 (英文)Intelligent PD-Type Fuzzy Controller Design for Mobile Satellite Antenna Tracking System with Parameter Variations Effect		

報告內容應包括下列各項：

1、 參加會議經過

此次論文研討會，是聯合國際電子電機工程師協會(IEEE)計算機智能有關的 34 個研討會，同時舉行。由此可見此會議之規模，及受國際重視的程度。相關論文將收錄於 IEEE Xplore 及 Engineering Index (EI) 網站，由此可見此會議的重要性。(The extended abstracts of all paid/registered papers will be included in the IEEE Xplore database and Engineering Index (EI)).

這次參加研討會的文章，是以海報方式展出(Poster)，由林君明教授，與工程科學博士學位學程，博士班研究生張博光所合寫的，題目是：Intelligent PD-Type Fuzzy Controller Design for Mobile Satellite Antenna Tracking System with Parameter Variations Effect (以 PD 型模糊控制器進行移動式天線追蹤系統有參數變化之設計) 。

這種以 PD 型模糊控制器，進行移動式天線追蹤系統設計的好處是:它可以使移動式天線追蹤系統，在追蹤衛星時，不會受到天線追蹤系統有參數變化的影響，例如馬達的遲滯效應(Hysteresis Effect)。經過模擬分析，這種天線的追蹤效果，會比傳統天線追蹤系統的控制效果更好。這論文在經過審查修改之後，終於獲得接受，並核定是以海報方式展出，比口頭報告，可以更接近參與的專家，所以感覺挑戰更大，實在收穫很多。

這篇報告是在 4 月 12 日下午 4 點至 4 點 30 分舉行。同一個會場屬於 CICA 2011 的有 3 篇，其餘是其他計算機智能研討會所推選出來的。結果台灣來以海報方式展出的，只有我這篇，實在非常榮幸。他們把這種以海報方式展出的論文報告時間，排在所有研討會的議程之最前端，而會議論文編排的順序，也是依此排列。結果我的論文，是在論文頁次的第一頁，可見大會重視的程度，故令我感到非常榮幸。在來法國參加之前，特別排演準備了數次，想像聽眾可能會問的問題，並加強臨場的表達能力。本人發表論文時會場的情況，如圖 1-4。

此次會議有碰到同樣來自台灣的學術單位，如國立台南大學資訊工程學系教授及兼任研發處研發長的李健興教授，帶領一個研發團隊及學生，如電子計算中心王元良技士，及台灣棋院九段的周俊勳職業棋士，來此研討會，展示他們研發的計算機，與人腦進行圍棋大賽，互有勝負。非常引人注意，也讓世界各國人士了解我國在計算機智慧技術開發方面的進步，留下深刻的印象，也是一項很好的國民外交。

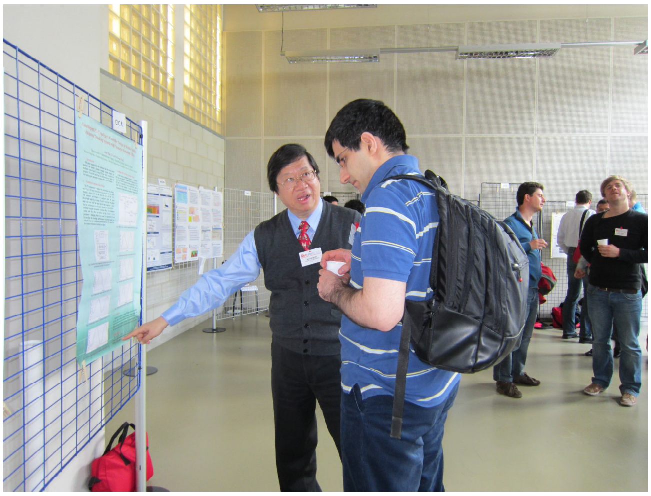

圖 1　林君明教授發表論文時之現場情況(1)

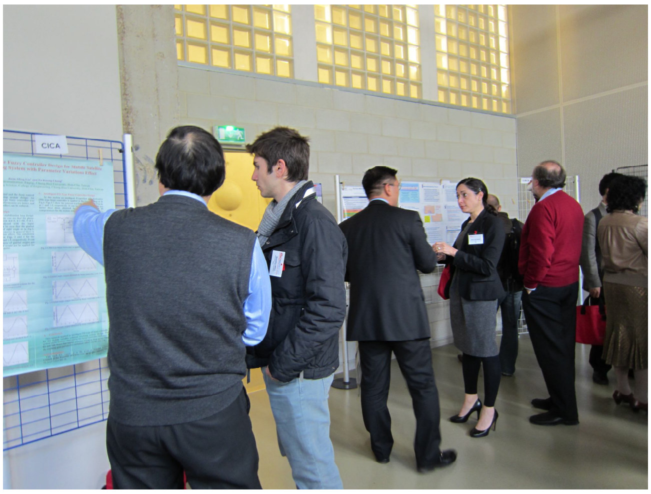

圖 2　林君明教授發表論文時之現場情況(2)

圖 3　林君明教授發表論文時之現場情況(3)

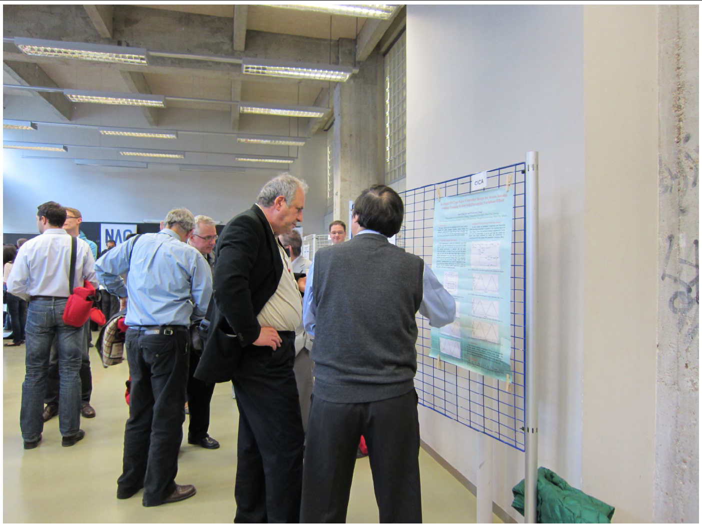

圖 4　林君明教授發表論文時之現場情況(4)

2、 與會心得

大會第一及第二天早上 9 點 30 分，即在大學的演講廳，揭開一天的序幕。9 點 30 分至 10 點 30 分，及 11 點 3 至 13 點，進行當天研討會上午的兩場專題演講(Keynote Speech)，相關議題及內容都非常精采。下午 14 點至 18 點 30 分，也有其他領域的類似兩場專題演講，或穿插每天的研討會，分 33 個會場同時進行，場地佈置、資訊取得，及寬廣舒適性都是一流，這是大會非常成功的地方，有此可見法國人辦活動的魄力，值得我們學習。我對模糊智慧型控制有興趣，所以就參加這方面的研討會場次，令人收穫頗多。

三、考察參觀活動(無是項活動者省略)

無。

四、建議

出國參加國際會議，的確可以磨鍊一下發表文章的技巧，及吸收別人寶貴的經驗，發掘一些新的研究靈感與題目，所以是非常值得鼓勵的事。而平常自已也要充實英文的能力，屆時才會有更大的收穫。這次有機會進行海報報告，實在是一次很好磨鍊英文及組織能力的機會。因為事先要先練習所要宣讀會議的論文，找出一些可以討論的題目，這樣在會議中，就可以從容的回答問題，這樣聽眾及報告人都會有更大的收穫，而場面也不會顯得冷清。還好終於圓滿結束，而收穫最多的，其實就是自己。

五、攜回資料名稱及內容

1. 此次攜回的資料有會議手冊一份，光碟一片。
2. 下一年度研討會海報 Call For Paper: 2012 IEEE Symposium on Computational Intelligence in Control and Automation (CICA 2012) 。

六、其他

國科會補助計畫衍生研發成果推廣資料表

日期:2011/09/22

<table>
<tr><td rowspan="3">國科會補助計畫</td><td>計畫名稱: 掃描探針&#儀音圈力致動器有參數變化及磁滯效應時之智慧型設計研究</td></tr>
<tr><td>計畫主持人: 林君明</td></tr>
<tr><td>計畫編號: 99-2221-E-216-020- 學門領域: 精密動態控制</td></tr>
<tr><td colspan="2">無研發成果推廣資料</td></tr>
</table>

99 年度專題研究計畫研究成果彙整表

計畫主持人：林君明 | 計畫編號：99-2221-E-216-020-

計畫名稱：掃描探針　器有參數變化及磁滯效應時之智慧型設計研究

成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	0%	篇	
		研究報告/技術報告	1	1	100%		完成一份研究報告。
		研討會論文	0	0	0%		
		專書	0	0	0%		
	專利	申請中件數	1	1	100%	件	申請中件數為 1 份。
		已獲得件數	0	0	0%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	4	1	400%	人次	參與計畫人力增加為 4 人。
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	3	1	300%	篇	EI 有兩篇，一般 1 篇。
		研究報告/技術報告	0	0	0%		
		研討會論文	6	2	300%		6 篇為 EI 等級。
		專書	0	0	0%	章/本	
	專利	申請中件數	1	1	100%	件	申請中件數為 1 份。
		已獲得件數	1	1	100%		獲得件數為 1 份。
	技術移轉	件數	0	0	0%	件	
		權利金	0	0	0%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	0%	人次	
		博士生	0	0	0%		
		博士後研究員	0	0	0%		
		專任助理	0	0	0%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	獲得 2011 俄羅斯阿基米得發明展銀牌 1 座。

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

　□實驗失敗

　□因故實驗中斷

　□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：■已發表 □未發表之文稿 □撰寫中 □無

專利：□已獲得 ■申請中 □無

技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

Jium-Ming Lin and Po-Kuang Chang, ’Ziegler-Nichols Based Intelligent Fuzzy Control of a SPM System Design with Parameters Variation,’ Advanced Materials Research, Vols. 201-203, 2011, pp. 2113-2118, (EI), doi:10.4028/www.scientific.net/AMR.201-203.2113, ISSN: 1022-6680, ISSN/ISO.

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

本次的研究目標，是使用 PI 控制器與 PD 控制器、以及模糊控制器，針對磁力音圈探針(LVT)，以及 掃描探針顯微術設計(Scanning Probe Microscopy, SPM)，在針對磁滯效應的處裡方面，能有更好的成果。本次的研究實踐是基於使用套裝軟體 MATLAB 進行表面粗度的模擬來完成實踐的，所以系統表現更為強健。相比於之前的設計方針，本次研究目標的設計，去除掉了磁力音圈探針(LVT)的內迴路補償系統也在研究範圍內，所以新的設計能夠更加的泛用，也更有價值。

由於可控制接觸力之掃描探針顯微系統，複雜性比前述之 SPM 檢測設備低，環境容忍能力也較高。而檢測的精度可以利用機構的設計，數值處理的手法，以及電路方面的提升，而具有開發的潛力。本研究已經完成一套精度可達 1μm 的接觸式掃描探針顯微系統。本計畫的目的是將量測的精度，提升一個數量級。