行政院國家科學委員會專題研究計畫 成果報告

易經渾沌及渾沌同步與控制
研究成果報告(精簡版)

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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

易經渾沌及渾沌同步與控制

Yi Classic Chaos with Chaos Synchronization and control

計畫類別：■個別型計畫 □整合型計畫

計畫編號：NSC 99－2221－E－009－019－

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計畫參與人員：張登順　紀亭宇　李健華　黃啟任

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中　華　　民　國　　100　年　　10　月　　10　日

一、研究計畫中英文摘要：

（一） 計畫中文摘要。（五百字以內）

關鍵詞：易經，渾沌，同步，控制

自 Lorenz 在 1963 年發現渾沌現象以來，已達四十六年。有關渾沌之理論、性質及特徵等之研究及渾沌控制、渾沌化、渾沌同步等應用研究，汗牛充棟，不可勝數。但所有研究皆限於諸渾沌系統在時間正向流逝(t → +∞)中之研究。在真實物理中，時間知倒流迄今尚未發現。然而在數學中，為了研究的完整性，時間倒流(t → -∞)須研究之範圍。2009 年 9 月，本人與李仕宇(本人之博士研究生)首次發表時間倒流(t → -∞)中的Lorenz 渾沌於期刊論文。個人認為此舉對渾沌研究具有劃時代之意義。打一個也許不甚確切的比喻：哥倫布之前，大多數人類活動範圍皆集中於東半球。哥倫布之後，人類活動範圍乃擴展至西半球，即擴展至整個地球矣。由是觀之，以往僅就 t → +∞ 之極多渾沌研究實屬片面，應補充t：0 → -∞ 之研究，方為全面之研究。僅此一點即可產生難以計量之有價值之研究論文。

再者，中國哲學之源頭是易經。易經不僅是五經之首，也是五經之始。易經之基本原理為太一出兩儀(即陰陽)兩儀出四象，四象出八卦。三爻為一掛。八掛經三爻排列組成64 掛。易經的根本範疇是陰陽。陰指負，柔，保守等；陽指正，剛，進取等。陰與陽相反相成，異中有同，同中有異。上述論文已驗證了陰渾沌(t：0 → -∞)與陽渾沌(t：0 → +∞)的異中有同，同中有異之特徵。這可能也是陰陽學說第一次在精確的科學中得到證實。本研究計畫嚴格限於易經之科學理論，決不涉及迷信附會。

當然，孤證不足行。本計劃之主要宗旨在於尋求多種之渾沌系統的陰渾沌之存在(這是很困難的，只有系統參數湊的正好，才能找到陰陽渾沌)，及其陰、陽渾沌之異同，試圖找出其間的規律性(如果有的話)。此其一。宗旨之二為應用陰渾沌研究渾沌同步及控制，及應用陰陽渾沌之搭配，研究以上諸新渾沌系統之渾沌同步及控制。三爻為一掛及八掛皆可實現。六十四掛由八掛之排列組合皆可實見。

研究重點為：

1. 覓求*Lorenz*、*Rössler*、*Chen*、*Lü* 及 *Chen-Li* 諸自治系統太一渾沌
2. 覓求*Lorenz* 系統、*Rössler* 系統、*Chen* 系統、*Lü* 系統及*Chen-Li* 諸系統之陰渾沌。比較其陰陽渾沌之異同，試圖找出陰陽渾沌之間之規律特徵。
3. 利用陰渾沌本身及陰陽渾沌之搭配得出以上諸新系統之渾沌同步，渾沌控制等。

由於申請時為三年計畫，批准為一年計畫，故研究重點為以上三點。

（二） 計畫英文摘要。（五百字以內）

Key words: Yi Classic, Chaos, Synchronization, Control

Since Lorenz discovered chaos in 1963, 46 years passed. In these 46 years, uncountable papers studied the theories, properties and characteristics of chaos, chaos controls, chaos anticontrols and chaos synchronizations. However, all these studies were limited to the investigations of chaotic systems for positive time direction ($t \to +\infty$). In real physical world, the backward time is still not discovered, but in mathematics, the backward study actually must be studied for completeness. In 2009, I and Shih-Yu Li (my doctoral graduate student) published a paper concerning forward and backward Lorenz chaos in a well-known journal firstly. This is epoch-making for chaos study, because for completeness of study, the uncountable studies for $t \to +\infty$must be studied again for $t \to -\infty$. Give a maybe unexact metaphor: Before Columbus, the activity of mankind concentrated in east hemisphere; after Columbus, the activity expanded to west hemisphere, i.e. to the whole globe. Therefore the study of chaos, for completeness, must concerns both $t \to +\infty$, and $t \to -\infty$. In the very past, the studies only for $t \to +\infty$ are all unilateral.

The fundamental principle of Yi is that Great one borns two ultimates,two ultimates born four quadrants four quadrants light hexagrams, eight hexagrans born $8 \times 8 = 64$ hexagrams.

In addition, the origin of Chinese Philosophy is the Yi classic which is the first and beginning of Chinese Five Classical Books. The fundamental categories of the Yi classic are Yin and Yang. Yin means negative, soft and conservative; Yang means positive, strong and aggressive. They are both contrary and complementary to each other. They appear both sameness with difference and difference with sameness. The above-mentional paper exactly verify these characteristics of Yin ($t \to -\infty$)and Yang($t \to +\infty$). This may be the first time to verify the theory of Yin-Yang in exact science. The project is strictly limited to the scientific principle of Yi classic, does not concerns the superastitious interpretation.

Of course, single verification is far from soundness of a statement. The main aim of this project is to find a lot of Yin chaos for chaotic systems, with the similar but different Yin-Yang chaos try to find certain regulation between them if possible and give the application of Yin chaos and Yin-Yang chaos with their combinations and permutations, for chaos synchronizations, chaos controls.

The main parts of our study are:

1. Find The Yin chaos of four autonomous chaotic systems, i.e. Find great one chaos of *Lorenz* system, *Rössler* system, *Chen* system, *Lü* system and *Chen-Li* system. Try to find out the regulation between the Yin chaos and Yang chaos of these four new systems.
2. Find The Yin chaos of four autonomous chaotic systems, i.e. *Lorenz* system, *Rössler* system, *Chen* system, *Lü* system and *Chen-Li* system. Try to find out the regulation between the Yin chaos and Yang chaos of these four new systems.
3. Apply the Yin chaos and Yin chaos plus Yang chaos with their combination and permutation for chaos synchronizations chaos control and chaotizations.

（三）研究方法及內容

背景及目的：

2009 年9 月，本人與李仕宇(本人之博士研究生)首次發表時間倒流(t → -∞)中的Lorenz渾沌於期刊論文。個人認為此舉對渾沌研究具有劃時代之意義。打一個也許不甚確切的比喻：哥倫布之前，大多數人類活動範圍皆集中於東半球。哥倫布之後，人類活動範圍乃擴展至西半球，即擴展至整個地球矣。由是觀之，以往僅就 t → +∞ 之極多渾沌研究實屬片面，應補充 t：0 → -∞ 之研究，方為全面之研究。僅此一點即可產生難以計量之有價值之研究論文。

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渾沌系統之研究除了在理論上的重要價值外，在物理、化學、生理學及各種工程等方面皆有廣泛之應用。*Lorenz* 系統、*Rössler* 系統、*Chen* 系統與非線性*Lü* 系統及*Chen-Li* 系統都是重要的典型渾沌系統。對於這些重要系統的渾沌現象及渾沌同步都已有豐富的研究成果[1-49]。1997年，本計畫為了對上述三個著名系統，擴大其研究範圍並深化其研究內容，對上述四種新系統，首先引用其為陽渾沌系統(t →+∞)，其次尋覓其陰渾沌行為(t → -∞)。

渾沌控制與控制化(又稱反控制)及同步在物理系統、化學系統、生物系統、各種工程系統、秘密通訊、神經網路、自我組織系統等方面有長足之應用[50-100]。本計畫研究四種新渾沌系統的陰渾沌及陽渾沌及其渾沌同步，控制，兩種新渾沌同步方法，對這些新系統加以研究。

三、研究成果

以 *Lorenz* 系統為例，來說明研究之成果。普通的 *Lorenz* 系統即陽 *Lorenz* 系統(t：0 →+∞)為

$$\begin{cases} \frac{dx}{dt} = \sigma(y - x) \\ \frac{dy}{dt} = rx - xz - y \\ \frac{dz}{dt} = xy - bz \end{cases}$$

取初始條件為$(x_0, y_0, z_0) = (-0.1, 0.2, 0.3)$，陽參數 σ = 10, b = 8/3 and r = 28。其渾沌相圖見 Fig. 1.

陰 Lorenz 系統(t：0 → -∞)為

$$\begin{cases} \frac{dx(-t)}{d(-t)} = -\frac{dx(-t)}{dt} = \sigma(y(-t) - x(-t)) \\ \frac{dy(-t)}{d(-t)} = -\frac{dy(-t)}{dt} = rx(-t) - x(-t)z(-t) - y(-t) \\ \frac{dz(-t)}{d(-t)} = -\frac{dz(-t)}{dt} = x(-t)y(-t) - bz(-t) \end{cases}$$

取初始條件為$(x_0, y_0, z_0) = (-0.1, 0.2, 0.3)$，陰參數 σ = −10, b = -8/3 and r = -28。其渾沌相圖見 Fig. 2.

陰陽系統之分歧圖及 Lyapunov 指數圖見 Figs. 3~4. 若增加一參數 μ，可得一族 Lorenz 系統：

$$\begin{cases} \frac{-dx(-t)}{dt} = \sigma(y(-t) - x(-t)) \\ \frac{-dy(-t)}{dt} = rx(-t) - x(-t)z(-t) - y(-t) \\ \frac{-dz(-t)}{dt} = x(-t)y(-t) - bz(-t) \end{cases}$$

對不同之 μ 可得一族不同之相圖，見 Fig. 5. 表 1、2、3 表示陰陽 Lorenz 系統的渾沌之異同。

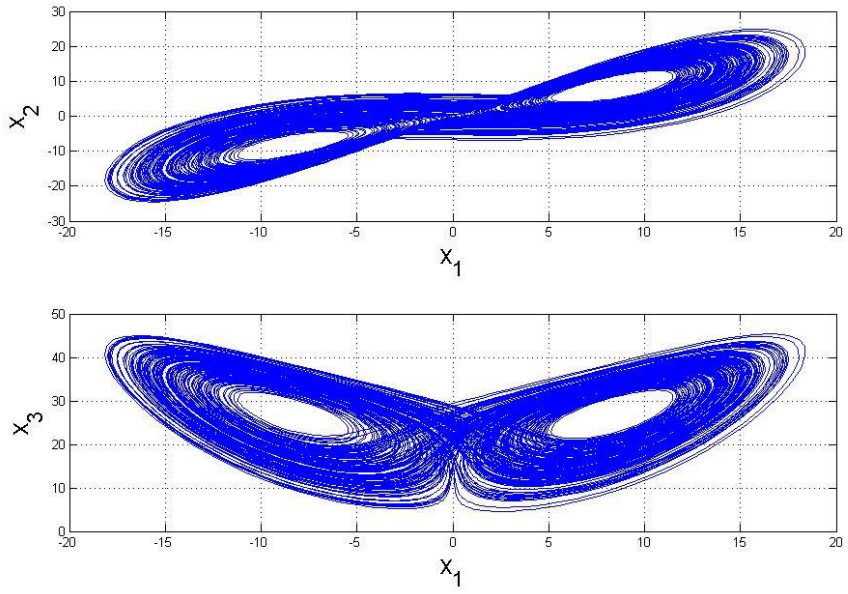


Fig.1. Projections of phase portrait of chaotic *Yang* Lorenz system with σ *=10, b=8/3* and *r=28.*

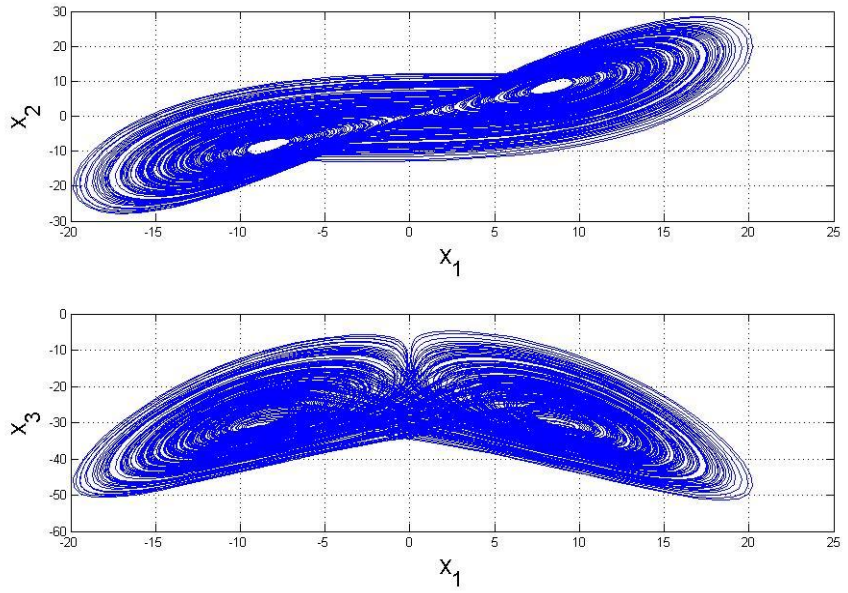


Fig.2. Projections of phase portrait of chaotic *Yin* Lorenz system with *Y*in parameters σ *=-10, b=-8/3* and *r=-28.*

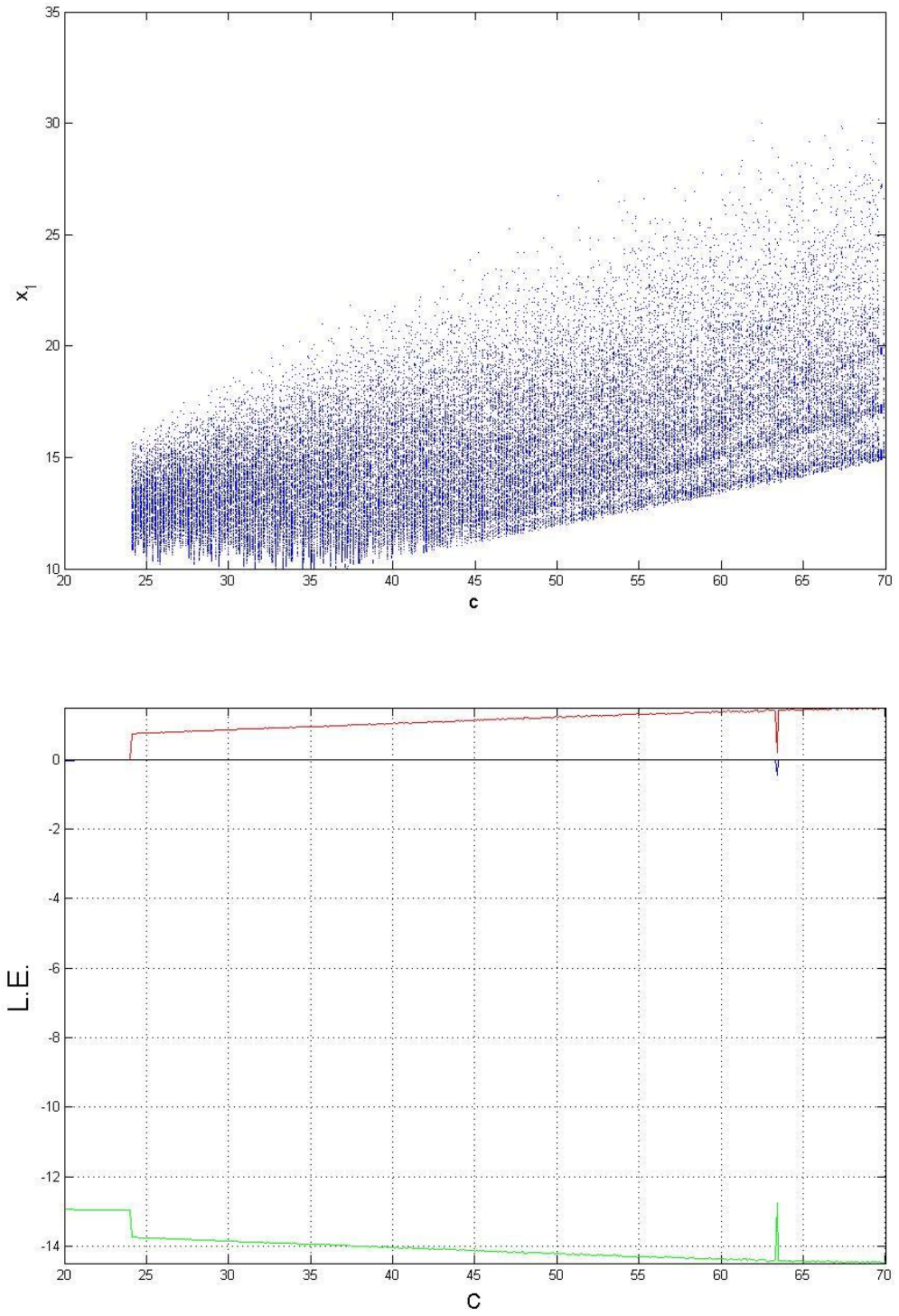


Fig.3. Bifurcation and Lyapunov exponents of chaotic *Yang* Lorenz system with *b=8/3* and σ *=10.*

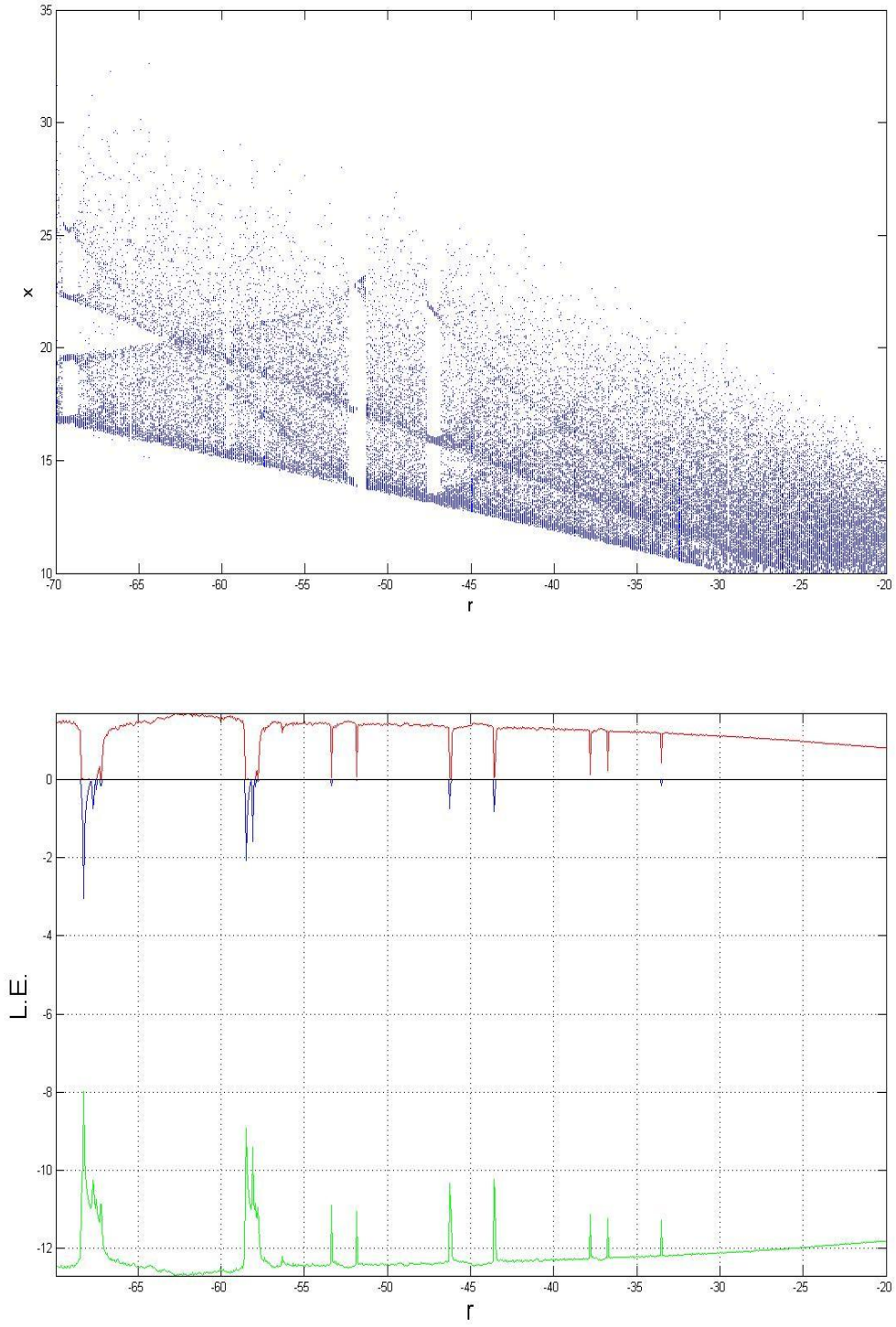
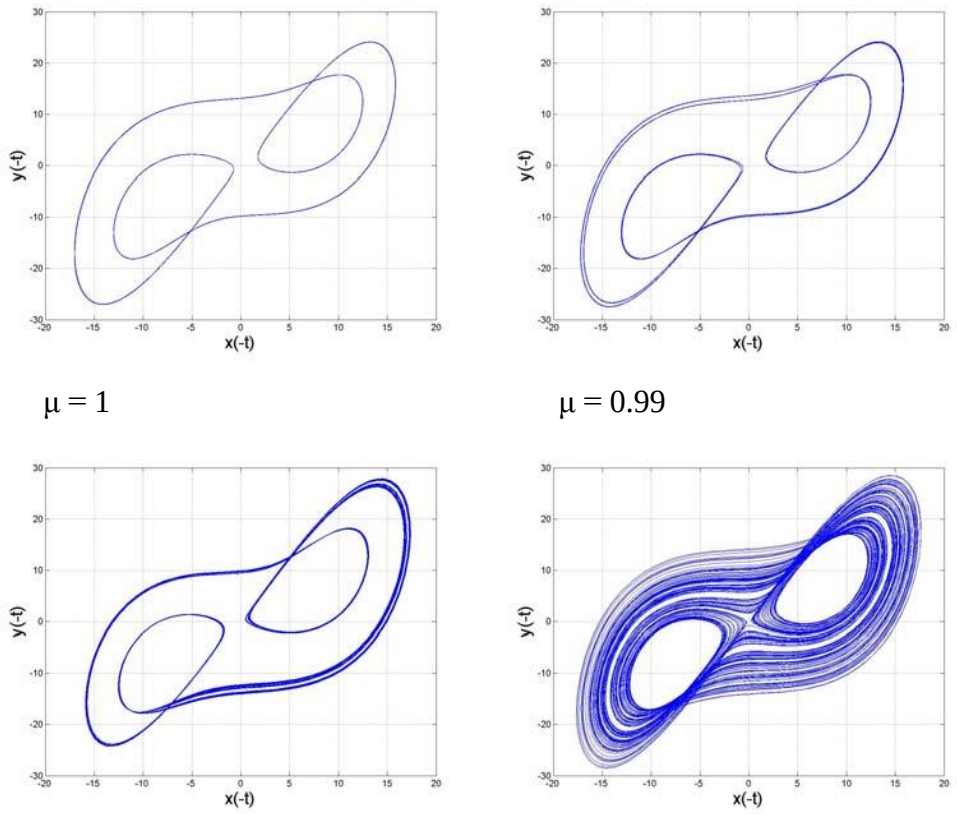


Fig.4. Bifurcation diagram and Lyapunov exponents of chaotic *Yin* Lorenz system with $b=-8/3$ and $\sigma=-10$.



μ = 1 μ = 0.99

μ = 0.98 μ = 0.7

Fig.5. Projections of phase portraits of family of *Yin* Lorenz system with σ =*-6*, *b=-8/3* and *r=-28*.

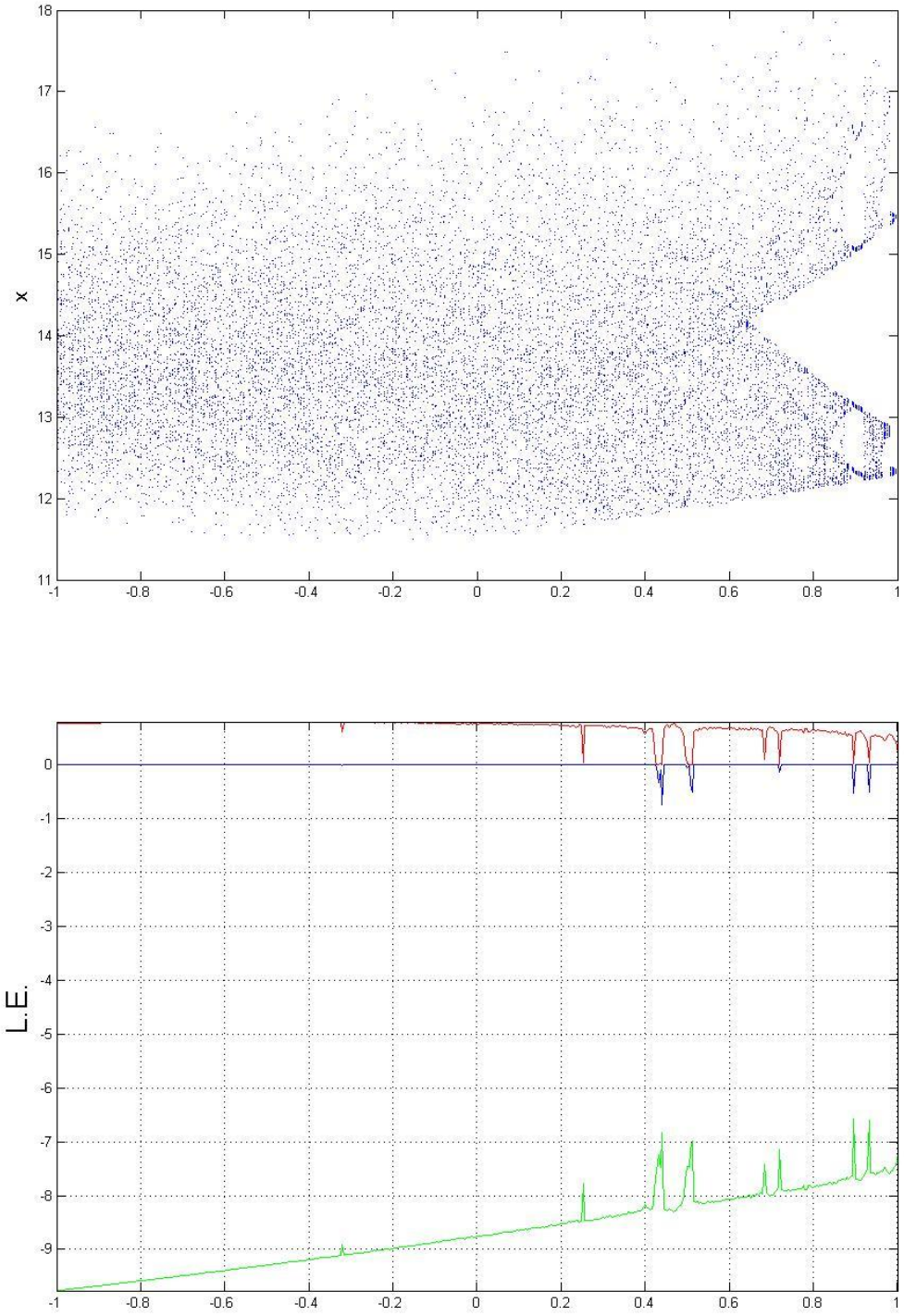


Fig.6. Bifurcation diagram and Lyapunov exponents of family of *Yin* Lorenz system with σ =-*6*, *b*=-*8/3* and r=-28.(varied by μ)

Table 1 Dynamic behaviors of *Yin* Lorenz system for different signs of parameters

σ	b	c	states
-	+	+	Approach to infinite
+	-	+	Approach to infinite
+	+	-	periodic
-	-	+	Approach to infinite
-	+	-	Approach to infinite
-	-	-	Chaos and periodic

Table 2 Range of parameter r of *Yang* Lorenz system

20.0~24.1	Converge to a fixed point
24.1~70.0	Chaos

Table 3 Range of parameter r of *Yin* Lorenz system

-20.0~-46.8	Chaos
-46.8~-47.7	Periodic trajectory
-47.7~-51.3	Chaos
-51.3~-52.4	Periodic trajectory
-52.4~-59.5	Chaos
-59.5~-59.8	Periodic trajectory
-59.8~-68.3	Chaos
-68.3~-69.6	Periodic trajectory
After -69.6	Chaos

計畫中預期之成果已完成。

References

1. É. L. Mathieu, 1868, “Mémoire sur le mouvement vibratoire d’une membrane de forme elliptique”, J.Math. Pures Appl., Vol. 13, pp. 137–203.
2. M. Mond, G. Cederbaum, P. B. Khan, and Y. Zarmi, 1993, “Stability Analysis Of The Non-Linear Mathieu Equation”, Journal of Sound and Vibration, Vol. 167, pp. 77-89.
3. J. W. Norris, 1994, “The Nonlinear Mathieu Equation”, International Journal of Bifurcation and Chaos,Vol. 4, pp. 71-86.
4. Yusry O. El-Dib, 2001, “Nonlinear Mathieu Equation and Coupled Resonance Mechanism”, Chaos, Solitons and Fractals, Vol. 12, pp. 705-720.
5. Leslie Ng and Richard Rand, 2002, “Bifurcations in a Mathieu Equation with Cubic Nonlinearities”, Chaos, Solitons and Fractals, Vol. 14, pp. 173-181.
6. Zheng-Ming Ge and Cheng-Hsiung Yang, 2008, “Synchronization of Chaotic Systems with Uncertain Chaotic Parameters by Linear Coupling and Pragmatical Adaptive Tracking”, Chaos, Vol. 18, 043129. (
7. Zheng-Ming Ge and Chun-Yu Chiang, 2008, “Chaos Control and Anticontrol of Tachometer System byGYC Partial Region Stability Theory”, Proceedings of the Institution of Mechanical Engineering, Part C,Journal of Mechanical Engineering Science, Vol. 223, pp. 1069-1082.
8. F. Battelli and K. J. Palmer, 1993, “Chaos in the Duffing Equation”, Journal of Differential Equations, Vol. 101, pp. 276-301.
9. G. Osipov, L. Glatz and H. Troger, 1998, “Suppressing Chaos in the Duffing Oscillator by Impulsive Actions”, Chaos, Solitons and Fractals, Vol. 9, pp. 307-321.
10. S. Paul Raj, S. Rajasekar, and K. Murali, 1999, “Coexisting Chaotic Attractors, Their Basin of Attractionsand Synchronization of Chaos in Two Coupled Duffing Oscillators”, Physics Letters A, Vol. 264, pp.283-288.
11. B.R. Nana Nbendjo, R. Tchoukuegno, and P. Woafo, 2003, “Active Control with Delay of Vibration and Chaos in a Double-well Duffing Oscillator”, Chaos, Solitons and Fractals, Vol. 18, pp. 345-353.
12. B.R. Nana Nbendjo, Y. Salissou, and P. Woafo, 2005, “Active Control with Delay of Catastrophic Motionand Horseshoes Chaos in a Single Well Duffing Oscillator”, Chaos, Solitons and Fractals, Vol. 23, pp. 809-816.
13. Chunbiao Gan, “Noise-Induced Chaos and Basin Erosion in Softening Duffing Oscillator”, 2005, Chaos, Solitons and Fractals, Vol. 25, pp. 1069-1081.
14. Zheng-Ming Ge, Chun-Lai Hsiao and Yen-Sheng Chen, 2005, “Nonlinear Dynamics and Chaos Control for a Time Delay Duffing System”, International Journal of Nonlinear Sciences and Numerical Simulation, Vol. 6, No. 2, pp. 187-199.
15. Cunli Wu, Youming Lei, and Tong Fang, 2006, “Stochastic Chaos in a Duffing Oscillator and Its Control”, Chaos, Solitons and Fractals, Vol. 27, pp. 459-469.
16. Ruiqi Wang, Jin Deng, and Zhujun Jing, 2006, “Chaos Control in Duffing System”, Chaos, Solitons and Fractals, Vol. 27, pp. 249-257.

17. Zhongkui Sun, Wei Xu, Xiaoli Yang, and Tong Fang, 2006, “Inducing or Suppressing Chaos in a Double-Well Duffing Oscillator by Time Delay Feedback”, Chaos, Solitons and Fractals, Vol. 27, pp. 705-714.
18. Samuel Bowong, F. M. Moukam Kakmeni, and Jean Luc Dimi, 2006, “Chaos Control in the Uncertain Duffing Oscillator” Journal of Sound and Vibration, Vol. 292, pp. 869-880.
19. Cunli Wu, Tong Fang, Haiwu Rong, 2007, “Chaos Synchronization of Two Stochastic Duffing Oscillators by Feedback Control”, Chaos, Solitons and Fractals, Vol. 32, pp. 1201-1207.
20. Zheng-Ming Ge and Cheng-Hsiung Yang, 2009, “Symplectic Synchronization of Different Chaotic Systems”, Chaos, Solitons and Fractals, Vol. 40, pp. 2532-2543.
21. Zheng-Ming Ge and Cheng-Hsiung Yang, 2009, “Chaos Synchronization and Chaotization of Complex Chaotic Systems in Series Form by Optimal Control”, Chaos, Solitons and Fractals, Vol. 42, pp. 994-1002.
22. B. van der Pol, 1920, “A Theory of the Amplitude of Free and Forced Triode Vibrations”, Radio Review, Vol. 1, 701-710.
23. B. van der Pol and J. van der Mark, 1927, “Frequency Demultiplication”, Nature, Vol. 120, pp. 363-364.
24. B. van der Pol, 1927, “Forced Oscillations in a Circuit with Non-Linear Resistance (Reception with Reactive Triode)”, The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science Ser. 7, Vol. 3, pp. 65-80.
25. Y. Ashkenazy, C. Goren, and L. P. Horwitz, 1998, “Chaos of the Relativistic Parametrically Forced van der Pol Oscillator”, Physics Letters A, Vol. 243, pp. 195-204.
26. Gamal M. Mahmoud, Ahmed A. M. Farghaly, 2004, “Chaos Control of Chaotic Limit Cycles of Real and Complex van der Pol Oscillators”, Chaos, Solitons and Fractals, Vol. 21, pp. 915-924.
27. Munehisa Sekikawa, Naohiko Inaba, and Takashi Tsubouchi, 2004, “Chaos via Duck Solution Breakdown in a Piecewise Linear van der Pol Oscillator Driven by an Extremely Small Periodic Perturbation”, Physica D, Vol. 194, pp. 227-249.
28. F. M. Moukam Kakmeni, Samuel Bowong, Clement Tchawoua, and Ernest Kaptouom, 2004, “Chaos Control and Synchronization of a Φ6-van der Pol Oscillator”, Physics Letters A, Vol. 322, pp. 305-323.
29. M. Siewe Siewe, F. M. Moukam Kakmeni, C. Tchawoua, and P. Woafo, 2005, “Bifurcations and Chaos inthe Triple-Well Formula Not Shown -van der Pol Oscillator Driven by External and Parametric Excitations”, Physica A, Vol. 357, pp. 383-396.
30. Cristina Stan, C. P. Cristescu, and M. Agop, 2007, “Golden Mean Relevance for Chaos Inhibition in a System of Two Coupled Modified van der Pol Oscillators”, Chaos, Solitons and Fractals, Vol. 31, pp.1035-1040.
31. Zheng-Ming Ge and Guo-Hua Lin, 2007, “The Complete, Lag and Anticipated Synchronization of a BLDCM Chaotic System”, Chaos, Solitons and Fractals, Vol. 34, pp. 740-764.
32. Zheng-Ming Ge and Yen-Sheng Chen, 2007, “Synchronization of Mutual Coupled Chaotic Systems via Partial Stability Theory”, Chaos, Solitons and Fractals, Vol. 34, pp. 787-794.
33. Zheng-Ming Ge and Chang-Xian Yi, 2007, “Chaos in a Nonlinear Damped Mathieu System, in a Nano Resonator System and in Its Fractional Order Systems”, Chaos, Solitons and Fractals, Vol. 32, pp. 42-61.
34. K. Ikeda, 1979, “Multiple-Valued Stationary State and Its Instability of the Transmitted Light by a Ring

Cavity System", Optics Communications, Vol. 30, pp. 257-261.
35. K. Ikeda, H. Daido, and O. Akimoto, 1980, "Optical Turbulence: Chaotic Behavior of Transmitted Light from a Ring Cavity", Physical Review Letters, Vol. 45, pp. 709-712.
36. J. García-Ojalvo and R. Roy, 1997, "Intracavity Chaotic Dynamics in Ring Lasers with an Injected Signal", Physics Letters A, Vol. 229, pp. 362-366.
37. E. M. Shahverdiev, R. A. Nuriev, R. H. Hashimov, and K. A. Shore, 2005, "Parameter Mismatches, Variable Delay Times and Synchronization in Time-Delayed Systems", Chaos, Solitons and Fractals, Vol. 25, pp. 325-331.
38. M. C. Mackey and L. Glass, 1977, "Oscillation and Chaos in Physiological Control Systems", Science, Vol. 197, pp. 287-289.
39. L. Glass and M. C. Mackey, 1988, From Clocks to Chaos: The Rhythms of Life, Princeton University Press.
40. A. Namajunas, K. Pyragas, and A. Tamaševicius, 1995, "Stabilization of an Unstable Steady State in a Mackey-Glass System", Physics Letters A, Vol. 204, pp. 255-262.
41. A. Namajunas, K. Pyragas, and A. Tamaševicius, 1995, "An Electronic Analog of the Mackey-Glass System", Physics Letters A, Vol. 201, pp. 42-46.
42. E. Liz, E. Trofimchuk, S. Trofimchuk, 2002, "Mackey–Glass Type Delay Differential Equations Near the Boundary of Absolute Stability", Journal of Mathematical Analysis and Applications, Vol. 275, pp. 747-760.
43. E. M. Shahverdiev, R. A. Nuriev, L. H. Hashimova, E. M. Huseynova, and R. H. Hashimov, 2005, "Chaos Synchronization in the Multifeedback Mackey-Glass Model", International Journal of Modern Physics B, Vol. 19, pp. 3613-3618.
44. L. Berezansky and E. Braverman, 2006, "Mackey-Glass Equation with Variable Coefficients", Computers and Mathematics with Applications, Vol. 51, pp. 1-16.
45. Zheng-Ming Ge and Yu-Ting Wong, 2006, "Chaos in Integral and Fractional Order Double Mackey-Glass Systems", accepted by Mathematical Methods, Physical Models and Simulation in Sicience & Technology.
46. E. M. Shahverdiev, 2004, "Synchronization in Systems with Multiple Time Delays", (Ikeda Systems), Physical Review E, Vol. 70, pp. 067202.
47. E. M. Shahverdiev and K. A. Shore, 2005, "Generalized Synchronization in Time-Delayed Systems", (Ikeda Systems), Physical Review E, Vol. 71, pp. 016201.
48. E. M. Shahverdiev et al, 2006, "Inverse Chaos Synchronization in Linearly Coupled Systems with Multiple Time-Delays", (Ikeda Systems), Chaos, Solitons, and Fractals, Vol. 29, pp. 838-844.
49. Chil-Min Kim, Won-Ho Kye, Sunghwan Rim, and Soo-Young Lee, 2004, "Communication Key Using Delay Times in Time-Delayed Chaos Synchronization", Physics Letters A Vol. 333, pp. 235-240.
50. Atsushi Uchida and Shigeru Yoshimori, 2004, "Synchronization of Chaos in Microchip Lasers and Its Communication Applications", Comptes Rendus Physique, Vol. 5, pp. 643-656.
51. E. N. Sanchez, L. J. Ricalde, 2003, "Chaos Control and Synchronization, with Input Saturation, viaRecurrent Neural Networks", Neural Networks, Vol. 16, pp. 711-717.
52. Yao-Chen Hung, Ming-Chung Ho, Jiann-Shing Lih, and I-Min Jiang, 2006, "Chaos Synchronization of

Two Stochastically Coupled Random Boolean Networks", Physics Letters A, Vol. 356, pp. 35-43.
53. A. Raffone and C. van Leeuwen, 2003 "Dynamic Synchronization and Chaos in an Associative Neural Network with Multiple Active Memories", Chaos, Vol. 13, pp. 1090-104.
54. Kanako Suzuki, Yoh Imai, 2004, "Periodic Chaos Synchronization in Slave Subsystems Using Optical Fiber Ring Resonators", Optics Communications, Vol. 241, pp. 507-512.
55. Er-Wei Bai, Karl E. Lonngren, and J. C. Sprott, 2002, "On the Synchronization of a Class of Electronic Circuits that Exhibit Chaos", Chaos, Solitons and Fractals, Vol. 13, pp. 1515-1521.
56. Y. Zhang, S. Q. Hu, and G. H. Du, 1999, "Chaos Synchronization of Two Parametrically Excited Pendulums", Journal of Sound and Vibration, Vol. 223, pp. 247-254.
57. A. Uchida, S. Kinugawa, and S. Yoshimori, 2003, "Synchronization of Chaos in Two Microchip Lasers by Using Incoherent Feedback Method", Chaos, Solitons and Fractals, Vol. 17, pp. 363-368.
58. Fan Zhang and Pak L. Chu, 2004, "Effect of Coupling Strength on Chaos Synchronization Generated by Erbium-Doped Fiber Ring Laser", Optics Communications, Vol. 237, pp. 213-219.
59. Yan-Ni Li, Lan Chen, Zun-Sheng Cai, and Xue-zhuang Zhao, 2004, "Experimental Study of Chaos Synchronization in the Belousov–Zhabotinsky chemical system", Chaos, Solitons and Fractals, Vol. 22, pp. 767-771.
60. A. Ucar, K. E. Lonngren, and Er-Wei Bai, 2007, "Chaos Synchronization in RCL-Shunted Josephson Junction via Active Control", Chaos, Solitons and Fractals, Vol. 31, pp. 105-111.
61. Y. Imai, H. Murakawa, and T. Imoto, 2003, "Chaos Synchronization Characteristics in Erbium-Doped Fiber Laser Systems", Optics Communications, Vol. 217, pp. 415-420.
62. R. McAllister, A. Uchida, R. Meucci, R. Roy, 2004, "Generalized Synchronization of Chaos: Experiments on a Two-Mode Microchip Laser with Optoelectronic Feedback", Physica D, Vol. 195, pp. 244-262.
63. Z.-M. Ge and T.-N. Lin, 2001, "Chaos, Chaos Control and Synchronization of Gyrostat System", Journal of Sound and Vibration, Vol. 251, pp.519-542.
64. Zheng-Ming Ge, Tsung-Chih Yu and Yen-Sheng Chen, 2003, "Chaos Synchronization of a Horizontal Platform System", Journal of Sound and Vibration, Vol. 268, pp. 731-749.
65. Z.-M. Ge and T.-N. Lin, 2003, "Chaos, Chaos Control and Synchronization of Electro-Mechanical Gyrostat System", Journal of Sound and Vibration, Vol.259, pp. 585-603.
66. Z.-M. Ge and Hong-Wen Wu, 2004, "Chaos Synchronization and Chaos Anticontrol of a Suspended Track with Moving Loads", Journal of Sound and Vibration, Vol. 270, pp. 685-712.
67. Zheng-Ming Ge and Yen-Sheng Chen, 2004, "Synchronization of Unidirectional Coupled Chaotic Systems via Partial Stability", Chaos, Solitons and Fractals, Vol. 21, pp. 101-111.
68. Zheng-Ming Ge, Chia-Yang Yu and Yen-Sheng Chen, 2004, "Chaos Synchronization and Anticontrol of a Rotationally Supported Simple Pendulum", JSME International Journal, Series C, Vol. 47, No. 1, pp. 233-241.
69. Zheng-Ming Ge and Wei-Ying Leu, 2004, "Anti-Control of Chaos of Two-degrees-of- Freedom Louderspeaker System and Chaos Synchronization of Different Order Systems", Chaos, Solitons & Fractals, Vol. 20, pp.503-521.
70. Zheng-Ming Ge and Chien-Cheng Chen, 2004, "Phase Synchronization of Coupled Chaotic Multiple

Time Scales Systems", Chaos, Solitons & Fractals, Vol. 20, pp. 639-647.
71. Z.-M. Ge and C.-M. Chang, 2004, "Chaos Synchronization and Parameters Identification of Single Time Scale Brushless DC Motors", Chaos, Solitons and Fractals, Vol. 20, pp. 883-903.
72. Zheng-Ming Ge and Wei-Ying Leu, 2004, "Chaos Synchronization and Parameter Identification for Loudspeaker System", Chaos, Solitons & Fractals, Vol. 21, pp. 1231-1247.
73. Zheng-Ming Ge, Chui-Chi Lin and Yen-Sheng Chen, 2004, "Chaos, Chaos Control and Synchronization of Vibrometer System", Journal of Mechanical Engineering Science, Vol.218, pp.1001-1020.
74. Zheng-Ming Ge, Jui-Wen Cheng and Yen-Sheng Chen, 2004, "Chaos Anticontrol and Synchronization of Three Time Scales Brushless DC Motor System", Chaos, Solitons & Fractals Vol. 22, pp.1165-1182.
75. Zheng-Ming Ge and Jui-Kai Lee, 2005, "Chaos Synchronization and Parameter Identification for Gyroscope System", Applied Mathematics and Computation, Vol. 163, pp. 667-682.
76. Z.-M. Ge and C.-I Lee, 2005, "Anticontrol and Synchronization of Chaos for an Autonomous Rotational Machine System with a Hexagonal Centrifugal Governor", Journal of Sound and Vibration Vol. 282, pp. 635-648.
77. Zheng-Ming Ge and Ching-I Lee, 2005, "Control, Anticontrol and Synchronization of Chaos for an Autonomous Rotational Machine System with Time-Delay", Chaos, Solitons and Fractals Vol.23, pp.1855-1864.
78. Zheng-Ming Ge and Jui-Wen Cheng, 2005, "Chaos Synchronization and Parameter Identification of Three Time Scales Brushless DC Motor System", Chaos, Solitons and Fractals Vol. 24, pp.597-616.
79. Zheng-Ming Ge and Ching-I Lee, 2005, "Control, Anticontrol and Synchronization of Chaos for an Autonomous Rotational Machine System with Time-Delay", Chaos, Solitons and Fractals Vol.23, pp.1855-1864.
80. Zheng-Ming Ge, Yen-Sheng Chen, 2005, "Adaptive Synchronization of Unidirectional and Mutual Coupled Chaotic Systems", Chaos, Solitons and Fractals. Vol. 26, pp. 881-888.
81. Z.-M. Ge, C.-M. Chang, Y.-S. Chen, 2006, "Anti-Control of Chaos of Single Time Scale Brushless DC Motor and Chaos Synchronization of Different Order Systems", Chaos, Solitons and Fractals, Vol. 27, pp.1298-1315
82. Zheng-Ming Ge, Jui-Wen Cheng and Yen-Sheng Chen, 2004, "Chaos Anticontrol and Synchronization of Three Time Scales Brushless DC Motor System", Chaos, Solitons & Fractals Vol. 22, pp.1165-1182.
83. Zheng-Ming Ge and Jui-Kai Lee, 2005, "Chaos Synchronization and Parameter Identification for Gyroscope System", Applied Mathematics and Computation, Vol. 163, pp. 667-682.
84. Z.-M. Ge and C.-I Lee, 2005, "Anticontrol and Synchronization of Chaos for an Autonomous Rotational Machine System with a Hexagonal Centrifugal Governor", Journal of Sound and Vibration Vol. 282, pp.635-648.
85. Zheng-Ming Ge, Chun-Lai Hsiao and Yen-Sheng Chen, 2005, "Nonlinear Dynamics and Chaos Control for a Time Delay Duffing System", Intternational Journal of Nonlinear Sciences and Numerical Simulation, Vol. 6, No. 2, pp. 187-199.
86. M.T.Yassen, 2005, "Controlling chaos and synchronization for new chaotic system using linear feedback control", Chaos, Solitons and Fractals, Vol. 26, pp. 913-920.
87. Cristina Morel, Marc Bourcerie and FranÃ Ã ois Chapeau-Blondeau, 2005, "Generating independent

chaotic attractors by chaos anticontrol in nonlinear circuits “, Chaos, Solitons and Fractals, Vol. 26, pp. 541-549.

88. Hongtao Lu and Xinzhen Yu, 2005, “Local bifurcations in delayed chaos anticontrol systems”, Journal of Computational and Applied Mathematics, Vol. 181, pp. 188-199.
89. Yinping Zhang and Jitao Sun, 2005, “Controlling chaotic Lu systems using impulsive control”, Physics Letters A, Vol. 342, pp. 256-262.
90. Yuxia Li, Xinzhi Liu and Hongtao Zhang, 2005, “Dynamical analysis and impulsive control of a new hyperchaotic system”, Mathematical and Computer Modelling, Vol. 42, , pp. 1359-1374.
91. Niranjan Chakravarthy, Kostas Tsakalis , Leon D Iasemidis and Andreas Spanias, 2006, ” A multi-dimensional scheme for controlling unstable periodic orbits in chaotic systems”, Physics Letters A, Vol. 349, pp. 116-127.
92. Chaohai Tao, Chunde Yang, Yan Luo, Hongxia Xiong and Feng Hu, 2005, “Speed feedback control of chaotic system”, Chaos, Solitons and Fractals, Vol. 23, pp. 259-263.
93. Ju H. Park, 2005, “Controlling chaotic systems via nonlinear feedback control”, Chaos, Solitons and Fractals, Vol. 23, pp. 1049-1054.
94. Aria Alasty and Hassan Salarieh, 2007, “Nonlinear feedback control of chaotic pendulum in presence of saturation effect”, Chaos, Solitons and Fractals, Vol. 31, pp. 292-304.
95. Jia Hu, Shihua Chen and Li Chen, 2005, “Adaptive control for anti-synchronization of Chua's chaotic system”, Physics Letters A, Vol. 339, pp. 455-460.
96. Zheng-Ming Ge and Ching-I Lee, 2005, “Control, anticontrol and synchronization of chaos for an autonomous rotational machine system with time-delay”, Chaos, Solitons and Fractals, Vol. 23, pp. 1855-1864.
97. Jun Guo Lu, 2006, “Chaotic behavior in sampled-data control systems with saturating control”, Chaos, Solitons and Fractals, Vol. 30, pp. 147-155.
98. R. Yamapi and S. Bowong, 2006, “Dynamics and chaos control of the self-sustained electromechanical device with and without discontinuity”, Communications in Nonlinear Science and Numerical Simulation, Vo. 11, pp. 355-375.
99. E. M. Elabbasy, H. N. Agiza, and M. M. El-Dessoky, 2005, “Global Synchronization Criterion and Adaptive Synchronization for New Chaotic System”, Chaos, Solitons and Fractals, Vol. 23, pp. 1299-1309.
100. Ju H. Park, 2005, “Adaptive Synchronization of Rössler System with Uncertain Parameters”, Chaos, Solitons and Fractals, Vol. 25, pp. 333-338.
101. Ju H. Park, 2005, “Adaptive Synchronization of Hyperchaotic Chen System with Uncertain Parameters”, Chaos, Solitons and Fractals, Vol. 26, pp. 959-964.
102. E. M. Elabbasy, H. N. Agiza, and M. M. El-Desoky, 2006, “Adaptive Synchronization of a Hyperchaotic System with Uncertain Parameter”, Chaos, Solitons and Fractals, Vol. 30, pp. 1133-1142.
103. Jianwen Feng, Shihua Chen, and Changping Wang, 2005, “Adaptive Synchronization of Uncertain Hyperchaotic Systems Based on Parameter Identification”, Chaos, Solitons and Fractals, Vol. 26, pp. 1163-1169.
104. A. El-Gohary and R. Yassen, 2006, “Adaptive Control and Synchronization of a Coupled Dynamo

System with Uncertain Parameters", Chaos, Solitons and Fractals, Vol. 29, pp. 1085-1094.
105. Z.-M. Ge and J.-S. Shiue, 2002, "Nonlinear Dynamics and Control of Chaos for Tachometer", Journal of Sound and Vibration Vol. 253, No. 4. (SCI, Impact Factor: 0.821).
106. Ju H. Park, 2006, "Chaos synchronization of nonlinear Bloch equations", Chaos, Solitons and Fractals, Vol. 27, pp. 357-361.
107. Hsien-Keng Chen, 2005, "Global chaos synchronization of new chaotic systems via nonlinear control", Chaos, Solitons and Fractals, Vol. 23, pp. 1245-1251.
108. Youming Lei, Wei Xu and Hongchan Zheng, 2005, "Synchronization of two chaotic nonlinear gyros using active control", Physics Letters A, Vol. 343, pp. 153-158.
109. Weiwei Wang and Jinde Cao, 2006, "Synchronization in an array of linearly coupled networks with time-varying delay", Physica A: Statistical Mechanics and its Applications, Vol. 366, pp. 197-211.
110. Jinde Cao, Ping LI and Weiwei Wang, 2006, "Global synchronization in arrays of delayed neural networks with constant and delayed coupling", Physics Letters A, Vol. 353, pp. 318-325.
111. F.M. Moukam Kakmeni, Samuel Bowong and Clement Tchawoua, 2006, "Nonlinear adaptive synchronization of a class of chaotic systems", Physics Letters A, Vol. 355, pp. 47-54.
112. Chao-Jung Cheng, Teh-Lu Liao and Chi-Chuan Hwang, 2005, "Exponential synchronization of a class of chaotic neural networks", Chaos, Solitons and Fractals, Vol. 24, pp. 197-206.
113. Yong Xiao, Kuanyi Zhu and Hwee Choo Liaw, 2005, "Generalized synchronization control of multi-axis motion systems", Control Engineering Practice, Vol. 13, pp. 809-819.
114. Anmar Khadra, Xinzhi Liu and Xuemin Shen, 2005, "Impulsive control and synchronization of spatiotemporal chaos", Chaos, Solitons and Fractals, Vol. 26, pp. 615-636.
115. Qing Yun Wang, Qi Shao Lu, Guan Rong Chen and Ding Hui Guo, 2006, "Chaos synchronization of coupled neurons with gap junctions", Physics Letters A, Vol. 356, pp. 17-25.
116. Zheng-Ming Ge, Jung-Kui Yu and Yu-Jung Chen, 1999, "Pragmatical Asymptotical stability Theorem with Application to Satellite System", Japanese Journal of Applied Physics, Vol.38, Part 1, No. 10.
117. Zheng-Ming Ge and Jung-Kui Yu, 2000, "Pragmatical Asymptopical Stability Theorem on Pratial Region and for Partial Variables with Applications to Gyroscopic Systems", The Chinese Journal of Mechanics, Vol. 16, No. 4.
118. Hassan K. Khalil, *Nonlinear Systems*, 2002, Prentice Hall.

國科會補助計畫衍生研發成果推廣資料表

日期:2011/10/11

國科會補助計畫	計畫名稱: 易經渾沌及渾沌同步與控制
	計畫主持人: 戈正銘
	計畫編號: 99-2221-E-009-019- 學門領域: 動力與控制

無研發成果推廣資料

99 年度專題研究計畫研究成果彙整表

計畫主持人：戈正銘	計畫編號：99-2221-E-009-019-
計畫名稱：易經渾沌及渾沌同步與控制	

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	4	100%	篇	
		研究報告/技術報告	0	1	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	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	4	100%	人次	
		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	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

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。)	具有重要學術價值。

	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)
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) 具有重要學術價值