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Designing BELBIC to Stabilize Gyro Chaotic System

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***Abstract*—One of the most significantphenomenon in some systems is chaos; so control chaotic system is troublesomeand shows the abilities of control methods. Brain emotional learning based intelligent controller (BELBIC) is an intelligent controller based on the model of emotional part of brain. In this article, BELBIC is applied to stabilize Gyro chaotic system. The contribution of BELBIC in improving the control system performance is shown by in comparison with results obtained from backstepping controller. BELBIC stabilizes Gyro Chaos with Shorter Setting Time and Lower Control Signal than backstepping controller.**

***Index Terms*—Stability, belbic, arneodo Chaos, backstepping method**

I. Introduction

Chaos, as an significant theme in nonlinear proficiency, has been examined and studied in arithmetical and physical communities in the recent years and the research attempts have dedicated to chaos control and chaos synchronization problems in abundant dynamical systems.

In [1] suggested a more effective technique which uses a time-delayed feedback to certain dynamical variables of the system. Control of spatiotemporal chaos in partial differential equations was also regarded [2], [3]. On the other side, sliding manner control, backstepping control, feedback linearization and active control can be mentioned as some often used techniques of the second type [4]-[7].

In recent years, the uses of biologically inspired methods such as the evolutionary algorithm have been increasingly employed to solve and analyze complex computational problems. The main contribution of this article is controlling chaos in Arneodo system using Brain emotional learning based intelligent controller (BELBIC). BELBIC is an intelligent controller dependent upon the model of sentimental part of brain.

The paper is organized as follows. Section 2 describes Gyro chaotic system. Section 3 presents a brain emotional based teach intelligent controller (BELBIC) and it is applied to stabilize Gyro chaotic system. In section 4 simulation results of Gyro chaotic system is represented. In section 5 the overall discussion of the simulation results for different systems presented. Section 6 provides conclusion of the study.

II. Gyro Chaotic System

The model system which we study is the gyroscope which has attributes of great utility to navigational, aeroneutical and space engineering, and has been widely studied. Generally, gyros are understood to be devices which rely on inertial measurement to determine changes in the orientation of an object. Gyros are recently finding application in automotive systems for Smart Braking System, in which different brake forces are applied to the rear tyres to correct for skids.

Recently, presented the dynamic behavior of a symmetric gyro with linear-plus-cubic damping, which is subjected to a harmonic excitation and the Lyapunov direct method was used to obtain the sufficient conditions of the stability of the equilibrium points of the system.

The equation governing the motion of the gyro after necessary transformation is given by[8]:

$$\dot{x}_1 = x_2 \tag{1}$$

$$x_2 = g(x_1) - ax_2 - bx_2^3 + \beta \sin \sin x_1 \; x_2 +$$
$$f \sin \sin \omega t \sin \sin x_1 + u$$

where $g(x_1) = -\alpha^2 \frac{(1-\cos x_1)^2}{sin^3 x_1}$ and u is control input. The parameters of the system are chosen $\alpha^2 = 100, \beta = 1, a = 0.5, b = 0.05, \omega = 2, f = 35.5$ and the initial condition is $(x_1, x_2) = (1, -1)$. The nonlinear gyro given by equation.1 exhibits varieties of dynamic behavior including chaotic motion without control signal is displayed in "Fig.1" and "Fig.2".

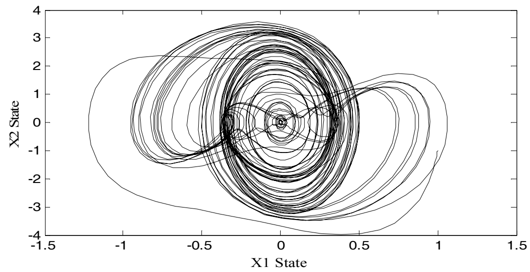

Fig. 1. Show the phase portrait of gyro system

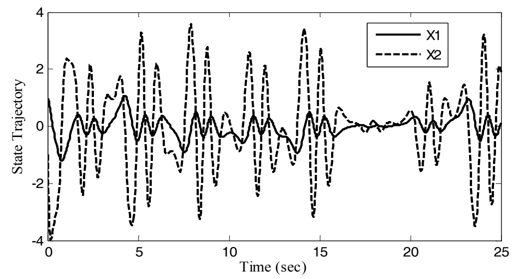

Fig. 2. Show the states trajectory variation for gyro system

III. BELBIC Controller

BELBIC is the abbreviation for brain emotional learning based intelligent controller [9], [10]. Motivated by the

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success in functional modeling of emotions in control engineering applications, a structural model based on the limbic system of mammalian brain, for decision making and control engineering applications has been developed [11]. The main parts that are responsible for performing the learning algorithms are orbitofrontal cortex and amygdala.

BELBIC controller has some sensory inputs. One of the designer's tasks is to determine the sensory inputs. BELBIC controller has two states for each sensory input. One of these two is amygdala's output and another is the output of orbitofrontal cortex. Therefore the number of sensory inputs has a key role in BELBIC controller. Usually the sensory inputs are rich signals [12].

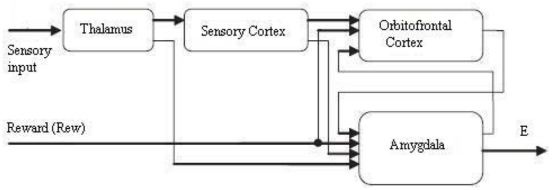

Fig. 3.computational model of emotional learning in the amygdala

Consider the i-th sensory input as s_i. Amygdala and orbitofrontal cortex outputs are as follows:

$$A_i = s_i v_i$$

$$O_i = s_i w_i \quad (2)$$

$v, w$are two states for the related sensory input. These two will be updated by following equations:

$$\Delta v_i = \alpha . s_i . max\left(0, rew - \sum A_i\right)$$
$$\Delta w_i = \beta . s_i . \left(rew - \sum A_i - \sum O_i - max(s_i)\right) \quad (3)$$

In these equations a and b are training coefficients. In BELBIC controller there is a function named Reward. This function has a great role in BELBIC controllers. Reward is like its name. The controller strives to increase this reward. Therefore the designer must define a reward function that has its maximum values in the most desired regions. This reward function could be either a frequency domain function or a normal mathematical function.

Amygdala acts as an actuator and orbitofrontal cortex acts as a preventer. Therefore the control effort of BELBIC controller is:

$$u = \sum A_i - \sum O_i \quad (4)$$

BELBIC is a controller that has only one output. Therefore for systems with more than one control inputs designer must use one BELBIC controller for each control input. As it can be seen there are several tuning parameters for each sensory input. The general algorithm for tuning these parameters is trial and error.

The continuous form of BELBIC has been used in this paper. In continuous form the BELBIC states are updated with not a discrete relation but a continuous one. These continuous relations are:

$$\dot{v}_i = \alpha . s_i . (rew - A_i)$$
$$\dot{w}_i = \beta . s_i . (rew + s_i + O_i - A_i) \quad (5)$$

The reward function for this BELBIC was chosen to be

$$REW = -3.5 e_1 + 2.3 e_2 + 0.6 \quad (6)$$

IV. Numerical Simulation

This section presents numerical simulations Gyro system. The Brain Emotional Learning Based Intelligent Controller (BELBIC) is applied to control Chaos in Gyro system and eventually the results of this Controller would be compared with the Chaos control result of Backstepping method (BM) [13]. "Fig.4" shows that x_1 state of Gyro system can be stabilized with the BELBIC to the origin point$(0,0)$. "Fig.5" shows that x_2 state of Gyro system can be stabilized with the BELBIC to the origin point$(0,0)$."Fig.6" shows the control law of BELBIC to the origin point$(0,0)$.

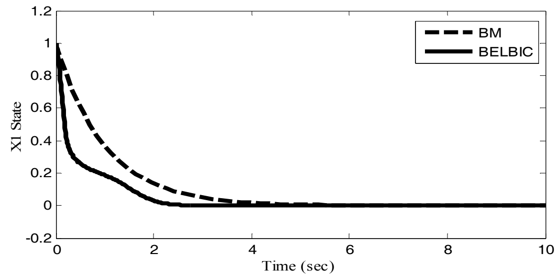

Fig. 4. show the x_1 state trajectory variation for gyroscope system

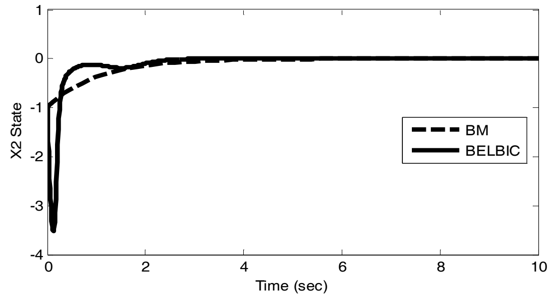

Fig. 5. show the x_2 state trajectory variation for gyroscope system

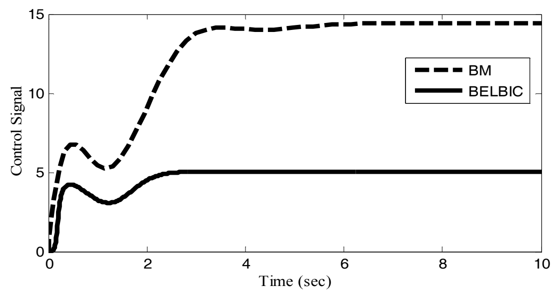

Fig. 6. show the control signal trajectory variation for gyroscope system

V. Discussion

By comparing the figures, the following results can be obtained.

- In the BELBIC in relation to the Backstepping Method [13],the system states are stabilized by a more limited control signal. Consequently, it is less possible that the control signal to be saturated.
- In the BELBIC in relation to the Backstepping Method [13], Control will be accomplished in a much shorter time and overshoot.

Considering the results obtained from simulations, the much more efficiency of BELBIC in relation to the Backstepping Method will be demonstrated.

VI. Conclusion

In this paper, a brain emotional based learning intelligent controller (BELBIC) was applied to control in Gyro chaotic system. The results obtained from BELBIC to control Gyro chaotic system were improved in proportion of those from gained backstepping controller. BELBIC could stabilize Gyro Chaos with Shorter Setting Time and Lower Control Signal than backstepping controller. The numerical results obtained showed the BELBIC was very effective and could Guarantee the Stability of the system.

References

[1] K. Pyragas, "Continuous control of chaos by self-controlling feedback," *Phys. Lett. A*, vol. 170, pp. 421-428, 1992.

[2] G. Hu and K. He, "Controlling chaos in systems described by partial differential equations," *Phys. Rev. Let*, vol. 71, pp. 3794-3797, 1993.

[3] S. Boccaletti, C. Grebogi, Y. C. Lai, H. Mancini, and D. Maza, "The control of chaos: Theory and applications," *Phys. Rep.*, vol. 329, pp. 103-197, 2000.

[4] H. Huijberts, "Linear Controllers for the Stabilization of Unknown Steady States of Chaotic Systems," *IEEE Trans. Circuits Syst.* I: Reg*ular Papers*, vol. 53, no. 10, 2006.

[5] G. Chen and X. Yu, "On time-delayed feedback control of chaotic systems," *IEEE Trans. Circuits Syst. I: Fundam. Theory Appl*, vol. 46, no. 6, pp. 767-772, 1999.

[6] K. M. Chang, "Adaptive control for a class of chaotic systems with nonlinear inputs and disturbances," *Chaos, Solitons and Fractals*, vol. 36, pp. 460-468, 2008.

[7] S. Dadras, H. R. Momeni, and V. JohariMajd, "Sliding mode control for uncertain new chaotic dynamical system," *Chaos, Solitons& Fractals*, in press.

[8] H. K. Chen, "Chaos and Chaos Synchronization of a symmetric gyro with linear-plus-cubic damping," *J. SoundVib.* vol. 255, no. 4, pp. 719-740, 2002.

[9] S. Jafarzadeh, R. Mirheidari, M. R. Jahed Motlagh, and M. Barkhordari, "Designing PID and BELBIC Controllers in Path Tracking Problem," Int. J. *of Computers, Communications & Control*, Vol. III, Suppl. issue: Proceedings of ICCCC 2008, pp. 343-348, 2008.

[10] S. Jafarzadeh, R. Mirheidari, M. R. Jahed Motlagh, and M. Barkhordari, "Intelligent Autopilot Control Design for a 2-DOF Helicopter Model," *Int. J. of Computers, Communications & Control*, vol. III, Suppl. issue: Proceedings of ICCCC 2008, pp. 337-342, 2008.

[11] J. Moren and C. Balkenius, "A Computational Model of Emotional Conditioning in the Brain," in *Proc. Workshop on Grounding Emotions in* Adaptive *Systems*, Zurich, 1998.

[12] C. Lucas, D. Shahmirzadi, and N. Sheikholeslami, "Introducing BELBIC: Brain Emotional Learning Based Intelligent Controller," International *Journal of Intelligent Automation and Soft Computing*, vol. 10, no. 1, pp.11-22, 2004.

[13] U. E. V. B. A. Idowu and A. N. Njah, "Control and synchronizationof chaos in nonlinear Gyros via backstepping design," *International Journal of Nonlinear Science*, 2008.