UACEE International Journal of Advancements in Electronics and Electrical Engineering – IJAEEE
Volume 2 : Issue 2 [ISSN 2319 – 7498]
Publication Date : 05 June 2013

Hybrid Structure of Lorenz and Chen's Attractor

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***Abstract*— In this paper, the results finding out the hybrid structure of a new chaotic attractor. This new chaotic attractor is combination of Lorenz chaotic attractor and Chen's attractor. This new chaotic attractor obtained by merging Lorenz and Chen's attractors. This will give the applications of both Lorenz chaotic attractor and Chen's attractor.**

***Keywords*— chaos, bifurcations, chatic systems, limit cycle**

I. Introduction

The first chaotic attractor introduced by Lorenz in 1963 and this chaotic attractor found in three-dimensional autonomous system [1–3]. In 1999,a chaotic attractor found by Chen and Ueta [4,5] and which is not equal to first chaotic attractor, this can be considered as dual to the Lorenz attractor, that means the condition $\alpha_{12}\alpha_{21} > 0$ should satisfies the Lorenz attractor and this is formulated by vanecek and celikovsky [6] whilst Chen's attractor should satisfies this condition $\alpha_{12}\alpha_{21} < 0$,where α_{12},α_{21} elements in the corresponding constant matrix A=$\left[\alpha_{ij}\right]_{3\times 3}$ for the linear part of the system [6]. In very recent times Lu et al.[7,8] introduced a new chaotic system and this new chaotic attractor will satisfies the condition is $\alpha_{12}\alpha_{21} = 0$,this new chaotic attractor is like bridge between Lorenz chaotic attractor and Chen's attractor .

There are there scientists named as Elwakil and Kennedy [9] and Ozoguz et al. [10], they found modified Lorenz system and the hybrid nature of its chaotic attractor was analyzed .Lu et al. [11] followed their approach and analyzed the compound structure of its chaotic attractor. To continue this analysis further this present paper gives the different behaviors of an new chaotic attractor found in [7].

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II. Compound Structure of new Chaotic Attractor

The new chaotic attractor, which is compound structure of Lorenz and Chen's attractors, is described by

$$\begin{aligned} \dot{a} &= \alpha(b - a), \\ \dot{b} &= -ac + \gamma b, \\ \dot{c} &= ab - \beta c, \end{aligned} \tag{1}$$

The chaotic attractor is shown in below fig 1 when $\alpha = 36$, $\beta = 36$, $\gamma = 36$. Lu et al [8] have been analyzed its dynamics.

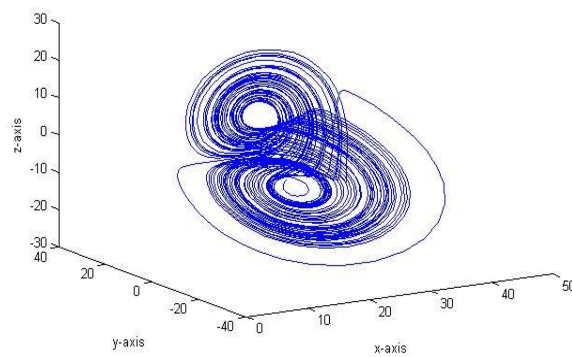

Figure 1. The new chaaotic attractor when u=0

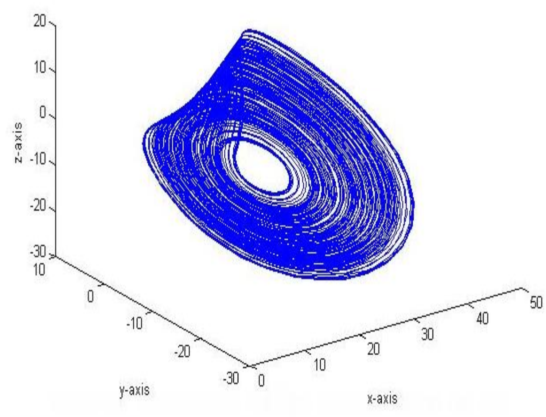

Figure 2. The new chaaotic attractor when u= -11

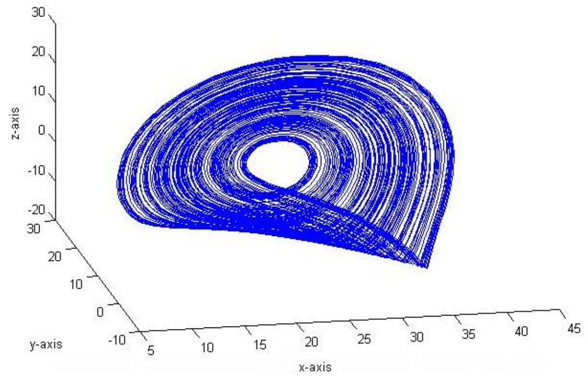

Figure 3. The new chaaotic attractor when u=11

In order to know the compound and the topological structure of this chaotic attractor, consider its controlled system:

$$\dot{a} = \alpha(b - a),$$
$$\dot{b} = -ac + \gamma b + u, \qquad (2)$$
$$\dot{c} = ab - \beta c,$$

When u = -11, one obtained attractor is the left-attractor of the original attractor as shown in Fig. 2; while when u = 11, the obtained one is mirror image of left attractor , i.e. the right –attractor as shown in Fig. 3. From the detailed numerical and theoretical analysis, then it can get conform that the new chaotic attractor is compound structure is obtained by merging together these simple left-and right-attractors through a mirror operation.

III. Forming mechanism of the new chaotic attractor

The new chaotic attractor and its forming mechanism is depending on the dynamical structure of the controlled system (2) and also to know the dynamical structure of controlled system (2) here further studied. Here u is the parameter and can be called as "controller" and by varying this parameter we can get different dynamical behaviors. In below summary it can be seen the parameter ranges for different dynamical behaviors ,from this summary one can clarify that (i) when |u| is large or a sufficient amount, e.g., $u \geq 48$, obviously the system converges to a point; (ii)In this case, when |u| decreases gradually, then there appear limit cycle and period-doubling bifurcations can see in Fig 4 and Fig 5 and further, the attractor evolves into only one half of the unique attractor; (iii) If |u| is relatively small, then the attractor becomes partial but is still bounded; (iv) when |u| is small or an adequate amount of |u|, a complete attractor is obtained.

A. *Parameter range*

The summary of the parameter range for system (2) as determined by both theory and computation

For $|u| \geq 48$, the system converges to a point

For $14.8 \leq |u| \leq 47$, the system is having a limit cycle (Fig. 4)

For $11.5 \leq |u| \leq 14.7$, here the result is period-doubling bifurcations (Fig. 5–6)

For $10.9 \leq |u| \leq 11.5$, the attractor is a left-attractor (or right-attractor) (Fig. 2 and Fig. 3)

For $3 \leq |u| \leq 10.8$, the system is having a partial attractor, which is bounded (Fig. 8)

For $|u| \leq 2$, the system is having a complete attractor.

B. *Phase Portraits of System*

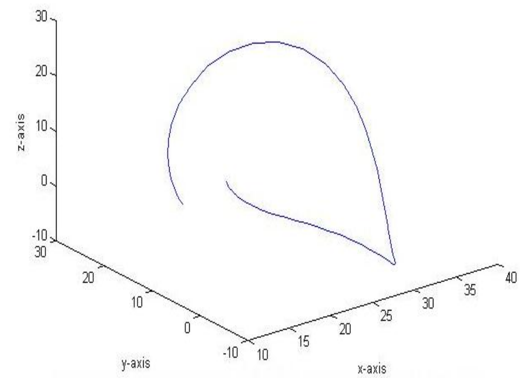

Figure 4. When u=15

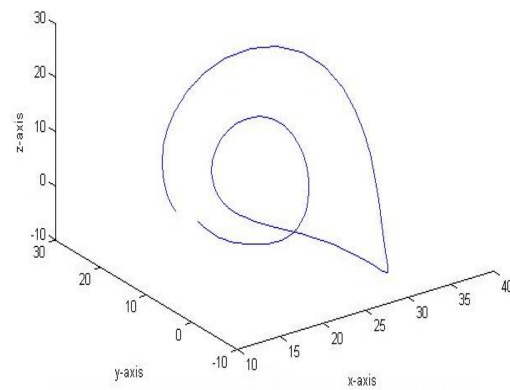

Figure 5. When u=13

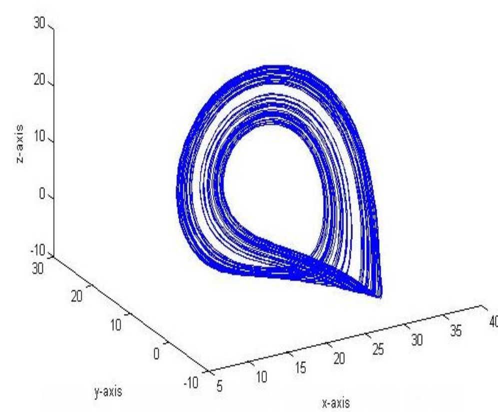

Figure 6. When u=12

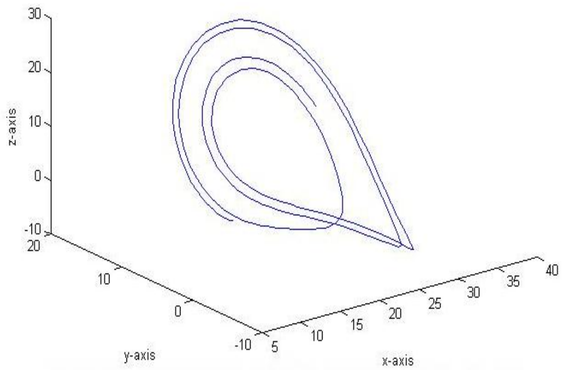

Figure 7 . when u=12.5

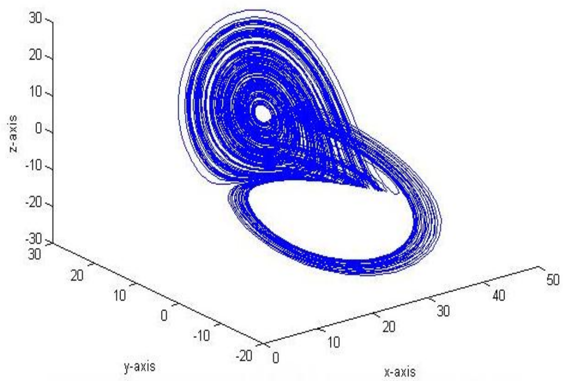

Figure 8. When u=10

According to Fig. 4–Fig. 8, one can see that the new attractor
According to Fig. 4–Fig. 8, one can see that the new attractor
has a compound structure, composed of two simple attractors and each emerges from some simple limit cycle (see Fig. 4). Furthermore, the two simple attractors are simpler than forming Chen's attractors [11], implying that Chen's attractor has a more sophisticated topological structure.

IV. Conclusion

Recently, a new chaotic attractor is bridging between the Lorenz and Chen attractors is coined and investigated. This paper has further studied the hybrid structure of this new attractor and explored its forming mechanism. There seems to be plentiful and complex dynamical behaviors of this new attractor, this may contribute to a better understanding of all similar and closely related chaotic systems.

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