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The Driven Synchronization in the Chaotic Mobile Robot

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Abstract - In this paper, we propose a method to a synchronization of chaotic mobile robots that have unstable limit cycles in a chaos trajectory surface. We assume all obstacles in the chaos trajectory surface have a VDP (Van der Pol) equation with an unstable limit cycle. The proposed methods are assumed that if one of two chaotic mobile robot receives the synchronization command, the other robot also follows the same trajectory during the chaotic robot search on the arbitrary surface.

1. INTRODUCTION

Chaos theory has been drawing a great deal of attention in the scientific community for almost two decades. Remarkable research efforts have been spent in recent years, trying to export concepts from Physics and Mathematics into real world engineering applications. Applications of chaos are being actively studied in such areas as chaos control [1]-[2], chaos synchronization and secure/crypto communication [3]-[7], Chemistry [8], Biology [9] and robots and their related themes [10].

Recently, Nakamura, Y. et al [10] proposed a chaotic mobile robot where a mobile robot is equipped with a controller that ensures chaotic motion and the dynamics of the mobile robot are represented by an Arnold equation. They applied obstacles in the chaotic trajectory, but they did not mention obstacle avoidance methods.

In this paper, we propose a method to a synchronization of chaotic mobile robots that have unstable limit cycles in the chaos trajectory surface. We assume that all obstacles in the chaos trajectory surface have a Van der Pol equation with an unstable limit cycle. When chaotic mobile robots meet obstacles among their arbitrary wandering in the chaos trajectory, which is derived using chaos circuit equations such as the Lorenz equation, the obstacles reflect the chaotic mobile robots.

2.CHAOTIC MOBILE ROBOT

2.1 Mobile robot

As the mathematical model of mobile robots, we assume a two- wheeled mobile robot as shown in Fig. 1

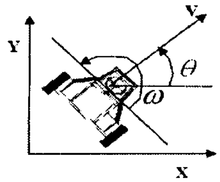


Fig. 1 two-wheeled mobile robot

Let the linear velocity of the robot v[m/s] and angular velocity [rad/s] be the inputs in the system. The state equation of the two-wheeled mobile robot is written as follows:

$$\begin{pmatrix} \dot{x}_1 \\ \dot{y}_1 \\ \dot{\theta} \end{pmatrix} = \begin{pmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} v \\ \omega \end{pmatrix} \quad (1)$$

where (x,y) is the position of the robot and θ is the angle of the robot.

2.2 Lorenz equation

We define the Lorenz equation as follows:

$$\begin{aligned} \dot{x} &= \sigma(y-x) \\ \dot{y} &= \gamma x - y - xz \\ \dot{z} &= xy - bz \end{aligned} \quad (2)$$

where $\sigma = 10, r = 28, b = 8/3$. The Lorenz equation describes the famous chaotic phenomenon.

2.3 Chaotic Lorenz robot

Combination of equation (1) and (2), we define and use the following state variables:

$$\begin{pmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x} \\ \dot{y} \end{pmatrix} = \begin{pmatrix} \sigma(y-x) \\ \gamma x - y - xz \\ xy - bz \\ v\cos x_3 \\ v\sin x_3 \end{pmatrix} \quad (3)$$

Using equation (3), we obtain the Lorenz chaotic robot trajectories with Lorenz equation.

3. CHAOS ROBOT SYNCHRONIZATION

3.1 Lorenz system synchronization

In order to apply to coupled-synchronization theory in the Lorenz robot, we compromised to state equation of Lorenz robot is written as follows:

$$\begin{aligned} \dot{x} &= \sigma(y-x) \\ \dot{y} &= \gamma x - y - xz \\ \dot{z} &= xy - bz \end{aligned} \tag{4}$$

As shown by Pecora and Carroll, the Lorenz systems is decomposable into stable subsystems. Specifically, a stable (x_1, z_1) response system can be defined by

$$\begin{aligned} \dot{x_1} &= \sigma(y-x_1) \\ \dot{z_1} &= x_1 y - bz_1 \end{aligned} \tag{5}$$

and a second stable (y_2, z_2) response system by

$$\begin{aligned} \dot{y_2} &= \gamma x - y_2 - xz_2 \\ \dot{z_2} &= xy_2 - bz_2 \end{aligned} \tag{6}$$

Equation (4) can be interpreted as the driven system, since its dynamics are independent of the response systems. Equations (5) and (6) represent dynamical response systems that are driven by the driven signal $y(t)$ and $x(t)$, respectively.

3.2 Chaos Lorenz robot synchronization

In order to apply to Driven-synchronization theory in the Lorenz's robot, we compromised to state equation of Lorenz's robot is written as follows:

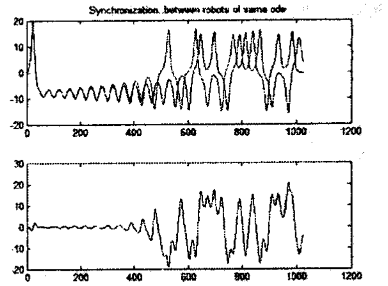
The state equation of main robot

$$\begin{aligned} \dot{x_1} &= \sigma(y-x) \\ \dot{x_2} &= \gamma x - y - xz \\ \dot{x_3} &= xy - bz \\ \dot{x} &= \nu \cos x_3 \\ \dot{y} &= \nu \sin x_3 \end{aligned} \tag{7}$$

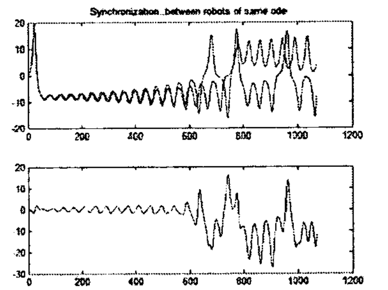
The state equation of auxiliary robot

$$\begin{aligned} \dot{x_1} &= \sigma(y-x) \\ \dot{x_2} &= \gamma x - y - xz \\ \dot{x} &= \nu \cos x_3 \\ \dot{y} &= \nu \sin x_3 \end{aligned} \tag{8}$$

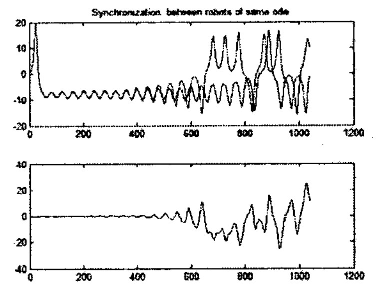
From equation (7) and (8), we can get the results of Lorenz robots synchronization such as no obstacle, fixed obstacle and hidden obstacle are shown in Fig.2, respectively.



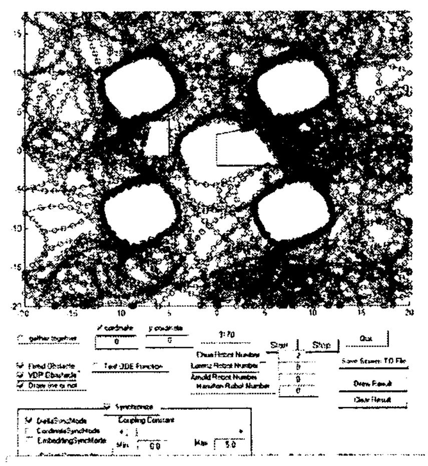
(a) No obstacle synchronization



(b)Fixed obstacle synchronization



(c) Hidden obstacle synchronization



(d) Lorenz robot trajectory

Fig. 2 Lorenz robot synchronization

From Fig. 2 we can recognize synchronization result is generalized synchronization and also we can see that there are different synchronization results according to different obstacle such as fixed and hidden obstacles.

4. CONCLUDING REMARK

In this paper, we proposed a chaotic robots, which employs a robots with Lorenz equation trajectories, and also proposed a robot synchronization methods in which driven synchronization.

We designed chaotic robot trajectories such that the total dynamics of the robots was characterized by a Lorenz equation, and we also designed the chaotic robot trajectories to include an obstacle avoidance method. As a result, we realized that the result of synchronization is generalized synchronization.

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