Target searching method in the UAV

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ABSTRACT

In this paper, we propose a method to target searching method that have unstable limit cycles in a chaos trajectory surface. We assume all targets in the chaos trajectory surface have a Van der Pol equation with an unstable limit cycle. When a chaos UAV meet the target in the Arnold equation, Chua' s equation trajectory, the target absorptive the UAV

Key words : Chaos, Chua's equation, UAV, Arnold equation

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 target search using 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 stable limit cycle. When chaos UAV(Unmanned Aerial Vehicles) meet target among their arbitrary wandering in the chaos trajectory, which is derived using chaos circuit equations such as the Arnold equation, Chua' s equation, the target absorptive the chaos UAVs.

2. Chaotic UAV Equation

2.1 UAV[24]

We assume that each UAV is equipped with standard autopilots for heading hold and mach hold. In order to focus on the essential issues, we will assume that altitude is held constant. Let $(x,y),\psi,$ and v denote the inertial position, heading angle, and velocity for the UAV respectively. Then the resulting kinematics equations of motion are

$$\begin{aligned} \dot{x} &= v\cos(\psi) \\ \dot{y} &= v\sin(\psi) \\ \dot{\psi} &= \alpha_{\psi}(\xi^{c}-\psi) \\ \dot{v} &= \alpha_{v}(v^{c}-v) \end{aligned} \tag{1}$$

where ψ^c and v^c are the commanded heading angle and velocity to the autopilots, and α_ψ and α_v are positive constraints [22,23].

Assuming that α_v is large compared to α_ψ, Eq. (1) reduces to

$$\begin{aligned} \dot{x} &= v\cos(\psi) \\ \dot{y} &= v\sin(\psi) \\ \dot{\psi} &= \alpha_{\psi}(\xi^{c}-\psi) \end{aligned} \tag{2}$$

Letting $\psi^c = \psi + (1/\alpha_\psi)\omega$ and $v^c \approx v$, Eq. (2) becomes

$$\begin{aligned} \dot{x} &= v \cos(\psi) \\ \dot{y} &= v \sin(\psi) \\ \dot{\psi} &= \omega \end{aligned} \quad (3)$$

Eq.(3) rewritten as follows,

$$\begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{\psi} \end{pmatrix} = \begin{pmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} v \\ \omega \end{pmatrix} \quad (4)$$

Eq. (3) is similar to two wheel mobile robot equation (5).

$$\begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{pmatrix} = \begin{pmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} v \\ \omega \end{pmatrix} \quad (5)$$

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

2.2 Arnold equation

We define the Arnold equation as follows:

$$\begin{aligned} \dot{x}_1 &= A \sin x_3 + C \cos x_2 \\ \dot{x}_2 &= B \sin x_1 + A \cos x_3 \\ \dot{x}_3 &= C \sin x_2 + B \cos x_1 \end{aligned} \quad (6)$$

where A, B, C are constants.

2.3 Chua' s equation

We define the Chua's equation as follows:

$$\begin{aligned} \dot{x}_1 &= \alpha (x_2 - g(x_1)) \\ \dot{x}_2 &= x_1 - x_2 + x_3 \\ \dot{x}_3 &= -\beta x_2 \end{aligned} \quad (7)$$

where

$$g(x) = m_{2n-1}x + \frac{1}{2}\sum_{k=1}^{2n-1}(m_{k-1} - m_k)(|x + c_k| - |x - c_k|)$$

2.4. Embedding of Chaos circuit in the UAV

In order to embed the chaos equation into the UAV, we define and use the Arnold equation and Chua' s circuit equation as follows.

1) Arnold equation

We define and use the following state variables:

$$\begin{aligned} \dot{x}_1 &= D \dot{y} + C \cos x_2 \\ \dot{x}_2 &= D \dot{x} + B \sin x_1 \\ \dot{x}_3 &= \theta \end{aligned} \quad (8)$$

where B, C, and D are constant.

Substituting (4) into (8), we obtain a state equation on $\dot{x}_1$, $\dot{x}_2$, and $\dot{x}_3$ as follows:

$$\begin{aligned} \dot{x}_1 &= Dv + C \cos x_2 \\ \dot{x}_2 &= Dv + B \sin x_1 \\ \dot{x}_3 &= \omega \end{aligned} \quad (10)$$

We now design the inputs as follows [10]:

$$\begin{aligned} v &= A / D \\ \omega &= C \sin x_2 + B \cos x_1 \end{aligned} \quad (11)$$

Finally, we can get the state equation of the UAV as follows:

$$\begin{aligned} \dot{x}_1 &= A \sin x_3 + C \cos x_2 \\ \dot{x}_2 &= B \sin x_1 + A \cos x_3 \\ \dot{x}_3 &= C \sin x_2 + B \cos x_1 \\ \dot{x} &= V \cos x_3 \\ \dot{y} &= V \sin x_3 \end{aligned} \quad (12)$$

Equation (12) includes the Arnold equation.

2) Chua' s equation

Using the methods explained in equations (8)-(12), we can obtain equation (13) with Chua' s equation embedded in the UAV.

$$\begin{aligned} \dot{x}_1 &= \alpha (x_2 - g(x_1)) \\ \dot{x}_2 &= x_1 - x_2 + x_3 \\ \dot{x}_3 &= -\beta x_2 \\ \dot{x} &= V \cos x_3 \\ \dot{y} &= V \sin x_3 \end{aligned} \quad (13)$$

Using equation (13), we obtain the embedding UAV trajectories with Chua' s equation.

2.5 Mirror Mapping

Basically, equation (5) is assumed that the mobile robot moves in a smooth state space without boundary. However, real robot movies in space with boundary like walls or surfaces of obstacles. To avoid a boundary or obstacle, we consider mirror mapping when the robot approach walls or obstacles using the Eq. (14) and (15). Whenever the robot approaches a wall or obstacle, we calculated the robot new position

$$A = \begin{pmatrix} \cos\theta & \sin\theta \\ \sin\theta & -\cos\theta \end{pmatrix} \qquad (14)$$

$$A = 1/1+m \begin{pmatrix} 1-m^2 & 2m \\ 2m & -1+m^2 \end{pmatrix} \qquad (15)$$

We can use equation (14) when slope is infinitive such as $\theta = 90$ and also use equation (15) when slope is not infinitive.

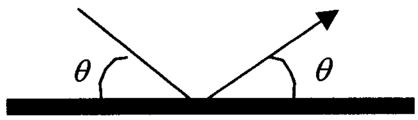

Fig. 1 Mirror mapping

2.6 Van der Pol equation as obstacle.

In this section, we will discuss the UAV' s avoidance of Van der Pol(VDP) equation obstacles. We assume the obstacle has a VDP equation with a stable limit cycle, because in this condition, the UAV can not move close to the obstacle and the obstacle is avoided.

In order to represent an obstacle of the UAV, we employ the VDP, which is written as follows:

$$\begin{aligned} \dot{x} &= y \\ \dot{y} &= (1 - y^2)y - x \end{aligned} \qquad (16)$$

From equation (16), we can get the following limit cycle as shown in Fig. 2.

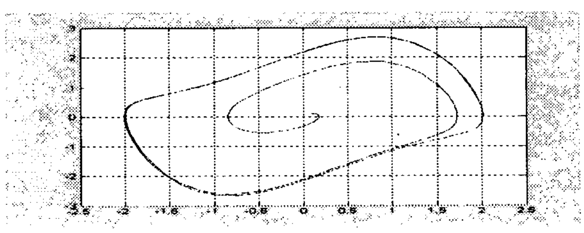

Fig. 2 Limit cycle of VDP

3. The Target searching in the UAV

In this section, we proposed a target searching method with Arnold equation, and Chua' s equation in the any surface. We designed target searching method which if the UAV has been find the target, the UAV defined any radius around target and then the UAV has been a concentrated search within the defined radius.

3.1 Arnold equation

In Fig. 3, we can see the UAV trajectories of target searching result with fix and hidden obstacle and target in the Arnold chaos UAV.

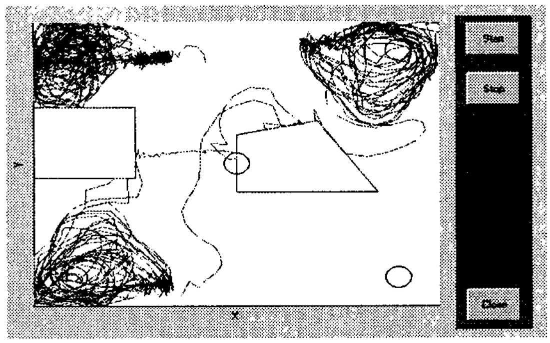

Fig. 3 The trajectory of target concentric search in the chaos UAV with fix and hidden obstacles and target in the Arnold chaos UAVs .

3.2 Chua's equation

In Fig. 4, we can see the UAV trajectories of target searching result with fix and hidden obstacle and target in the Chua' s chaos UAV

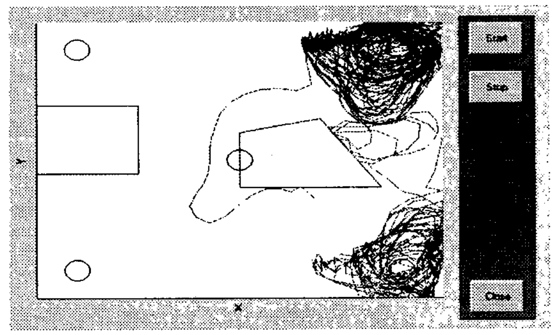

Fig.4 The trajectory of target concentric search in the chaos UAV with fix and hidden obstacles and targets in the Chua's chaos UAVs.

Fig. 3 and 4 shows the trajectory of chaos UAV can avoid obstacles to which mirror-mapping is applied by Eq (14) and (15).

4. Conclusion

In this paper, we proposed a chaotic UAV, which employs a UAV with Arnold equation and Chua' s equation trajectories, and also proposed a target searching method in which we assume that the obstacle and target has a Van der Pol equation with an stable limit cycle.

We designed UAV trajectories such that the total dynamics of the UAV was characterized by an Arnold equation and

Chua' s equation and we also designed the UAVs trajectories to include an obstacle avoidance method and target searching method. By the numerical analysis, it was illustrated that obstacle avoidance methods and target searching methods with a Van der Pol equation that has an unstable limit cycle gave the best performance.

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