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PATH-PLANNING FOR AN AUTONOMOUS MOBILE ROBOT WITH CHAOTIC BEHAVIOUR

Ventseslav Kirilov Shopov and Vanya Dimitrova Markova

Institute of Robotics - Bulgarian Academy of Sciences
e-mail: vkshopov@yahoo.com
Bulgaria

Abstract: This manuscript examines the path planning of an autonomous mobile robot with chaotic behaviour. The main question is what is the coverage of the environment in the autonomous generation of chaotic routes. The main problem with this type of chaotic trajectory is how to determine the control law, which allows to guarantee a good map coverage and at the same time to preserve the chaotic nature of the robot's movement.
Key words: autonomous mobile robot, chaotic robot, path-planning.

1. INTRODUCTION

In recent years, the topic of robotics, and in particular the strategy of motion controllers for autonomous robots, has become a very promising area of research [1, 2]. This happens because there are many dangerous or difficult tasks where it is desirable for humans to be replaced by robots. In principle, performing a task without direct human supervision is a great advantage of autonomous robots [3, 4]. Some of the tasks that autonomous mobile robots can be useful for are: exploring terrain to search for explosives [5], transportation [6], full terrain coverage [7, 8], searching and rescuing humans [9], mapping of buildings [10, 11], fires [12] and surveillance or protection of protected areas [13, 14].

In this work, we examine the specific problem of exploring a particular terrain for surveillance or security purposes. For the first application, the best method is to quickly scan the entire workspace of the robot. For the above applications, several path planning algorithms have been proposed, such as an alternative spiral algorithm [15], as well as some artificial intelligence algorithms such as genetic algorithm [16] and neural networks [17].

For the second task, a high unpredictability of the motion path of the mobile security robot is desirable. In addition, to prevent intrusion into a guarded area, the path of the robot must be very difficult to predict from the intruder. Therefore, unplanned traffic is an interesting solution to this problem.

The chaotic systems provide the necessary framework to achieve the aforementioned tasks because of their sensitivity to the original conditions, their functionality, and topological transitivity [18]. Thanks to the property of topological transitivity, the chaotic mobile robot is able to analyze the whole connected workplace. Sensitivity under initial conditions will lead to a completely different chaotic trajectory and will make impossible the long-term prediction by the intruder. Many dynamic chaotic systems in the literature can be used to generate chaotic motions for a robot such as the Lorentz attractor [19], the Roesler chaotic system [20], and others [21].

The document is organized as follows. The description of the robot model is described in Section 2. The chaotic systems and their main characteristics are presented in Section 3, together with the integration strategy and behaviour of their generated chaotic trajectories. In Section 4, we present the generation of trajectories for robot coverage, and further compare the performance of robot space coverage using two chaotic systems. Finally, the last section outlines the conclusions.

2. METHODS AND MATERIALS

2.1. Lorenz, Roessler and Burke-Shaw attractors

In [10] a non-linear autonomous system of differential equations (dynamical system) was defined as follow:

$$\begin{aligned} \frac{dx}{dt} &= \sigma(y - x) \\ \frac{dy}{dt} &= x(\rho - z) - y \\ \frac{dz}{dt} &= xy - \beta z \end{aligned} \tag{1}$$

Where in (2), are some Lorenz system parameters that leads to chaotic behaviour.

$$\begin{aligned} \sigma &= 10 \\ \rho &= 28 \\ \beta &= \frac{8}{3} \end{aligned} \tag{2}$$

In (3) Is presented Burke-Shaw system, with typical chaotic parameters in (4).

$$\frac{dx}{dt} = -s(x+y)$$
$$\frac{dy}{dt} = -y - s\,x\,z \qquad (3)$$
$$\frac{dz}{dt} = s\,x\,y + v$$

$$s = 10,\ v = 4{,}272 \qquad (4)$$

The Roessler system is described in (5) with its chaotic parameters in (6).

2.2. Model description

The main work on the control of mobile robots is based on the differential motion with two degrees of freedom, consisting of a passive wheel and two active, parallel and independent wheels [22, 23, 24]. Active wheels are controlled by the feel and speed of rotation. Consider wheeled robot configurations according to its position (x, y) and orientation θ in two-dimensional space. According to the non-slip condition, the non-holonomic restriction of the robot is defined as follows:

$$\dot{x}\sin\theta - \dot{y}\cos\theta = 0$$

$$\dot{x}\cos\theta + \dot{y}\sin\theta = r\dot{\phi},$$

Where r is the radius of the wheel and φ is the angle of the measured wheel from the vertical. Assuming that the angular velocity ω = ˙ θ and the linear velocity v = r ˙ φ. The mathematical model of a mobile robot can be described as a differential system consisting of two control parameters, v and ω. The kinematic model, considering these two control variables - the orientation and position of the robot, is defined as the following:

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

Linear velocity produces linear motion at the center point of the wheel axis, while angular velocity provides rotational motion for the mobile robot above the same point. This mobile robot model represents a very interesting trade-off between degrees of freedom and simplicity of control, enabling the mobile robot to meet the demands of mobility [25]. It has been significantly adapted in many studies of mobile robotics [26]. The motion of the robot in a plane is described as shown in fig. 1 where L is the length of the axis.

3. EXPERIMENTS AND RESULTS

To test the effectiveness of the proposed mobile robot control strategy, we use a known degree of coverage (C), which determines the efficiency as the amount of surface covered by the robot executing the algorithm. To calculate the degree of coverage, we use approximate cell digestion. The latter is a representation of the free space, as shown in FIG. All space cells are the same size. We assume that the cell is considered covered after the robot visits it. The coverage of the terrain or degree of coverage (C) is expressed by the following equation:

$$C = \frac{1}{M} \cdot \sum_{i=1}^{M} I(i),$$

where I (i) represents the coverage situation for each cell in which the workspace is separated from the robot. It is obtained as follows:

$$I(i) = \begin{cases} 1 & \text{if the cell } i \text{ is covered,} \\ 0 & \text{if the cell } i \text{ is not covered.} \end{cases}$$

The total number of cells M given as:

$$M = \frac{workspace\ dimension}{Cell\ size}$$

The degree of coverage represents the efficiency, defined as the number of cells covered by the robot relative to the total number of cells. To accurately calculate the coverage percentage, once the cell is covered by the robot, it will not be considered a second visit. In our method, the robot's workspace is defined as a 10 m × 10 m square area. To evaluate the proposed control law and the coverage strategy, we propose the following two parts of the simulation: The first part gives the results of our proposed control law and the second simulation part provides the results of the coverage workspace.

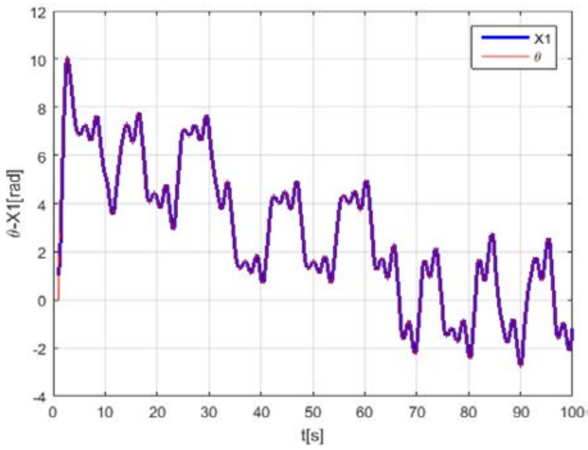

Fig. 1. Tracking error for robot positions using the plane controller.

We create a controller using the chaotic system to generate a reference path. The initial position of the robot is selected as (x r, y r) equal to (0, 0). We note that the initial conditions for the chaotic system are selected as presented in the sections above. We propose to allow workspace coverage using our method based on the law of plane control, chaotic systems, and mirror mapping. In fact, we use the plane control method to realize a chaotic trajectory of workspace coverage (10 m × 10 m). In addition, we ensure that the desired coverage path is accurately traced by the robot. From figure 1 is clear that approximation is accurate.

4. CONCLUSION

The use of the robot would be possible for a variety of civilian and military tasks, such as field exploration for explosives, field observation, search and rescue missions, floor scrubbers, and more. This study shows that the application of the behaviour of non-linear chaotic systems to the solutions to the problems with the control of the trajectory of robots is a very interesting interdisciplinary interface for many researchers in both robotics and scientific fields. This opens up interesting prospects for future research, including experimental implementations.

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