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A chaotic coverage path planner for the mobile robot based on the Chebyshev map for special missions

Key words: Mobile robot; Chebyshev map; Chaotic; Affine transormation; Coverage path planning

Corresponding author: Cai-hong LI
E-mail: lich@sdut.edu.cn
ORCID: http://orcid.org/0000-0003-0255-9249

Motivation

- For some special missions, high unpredictability for the robot trajectories as well as fast scanning of the workplace area are strongly required, especially for military applications, such as the surveillance of terrains (Martins-Filho and Macau, 2007), terrain exploration for searching (Sooraksa and Klomkarn, 2010), demining (Prado and Marques, 2014), and patrolling (Hwang *et al.*, 2011).
- The coverage results produced by differently designed chaotic path planner can demonstrate various statistical characteristics with regard to the coverage rate and the evenness.
- The improved Chebychev map by arcsine or arccosine transformation can access better chaotic and statistical characteristics readily.

Main idea

- The performance of the time sequences which are generated by the designed planner can be improved by arcsine or arccosine transformation to enhance the chaotic characteristics and uniform distribution. Then the coverage rate and randomness for achieving the special missions of the robot are enhanced.
- The chaotic Chebychev system can be mapped into the feasible region of the robot workplace by the affine transformation. Then the universal algorithm of coverage path planning are designed for the environments with obstacles and without obstacles.

Method

1. A two-dimensional chaotic path planner is designed by two one-dimensional Chebychev maps.
2. The performance of the time sequences which are generated by the planner is improved by arcsine transformation , and the chaotic characteristics and uniform distribution are tested.

Method(Cont'd)

3. In the environment without obstacles, the chaotic Chebychev map is mapped into the feasible region of the robot workplace by the affine transformation, and link the adjacent sub-goals to be as the running trajectories for the robot tracking to achieve the coverage path planning task.
4. In the environments with obstacles, the algorithm includes:
   (1) Environment modeling;
   (2) Designing of the coverage path planning
5. Verification of the proposed algorithm.

Major results

- The performance of the time sequences which are generated by the chaotic path planner has been improved by arcsine transformation, with regard to the chaotic characteristics and uniform distribution.

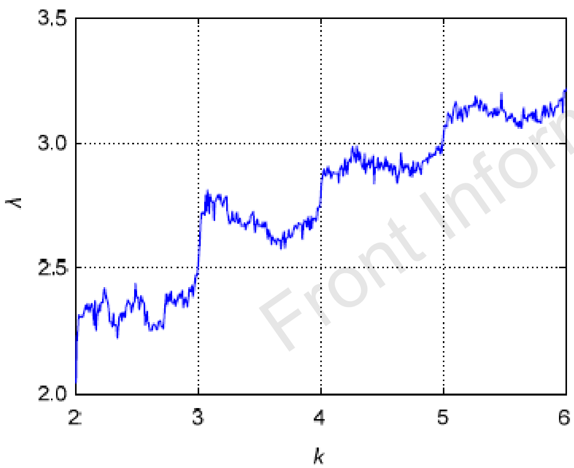

Fig. 5 Lyapunov exponent spectrum after arcsine transformation

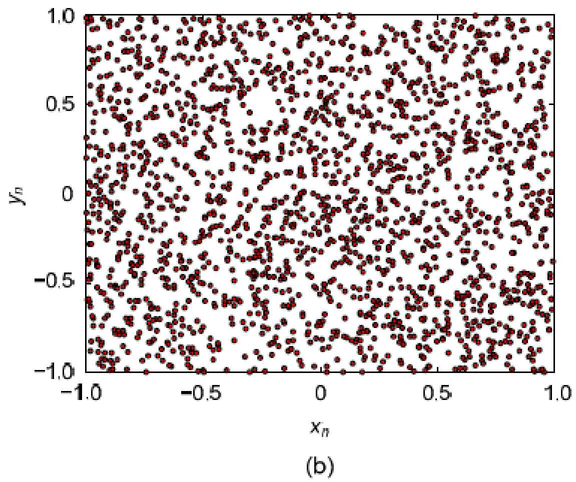

Fig. 7 Trajectories of the chaotic path planner of the robot after arcsine transformation: (b) n=2000

Major results(Cont'd)

- In the environment without obstacles, the coverage trajectories are produced by mapping the Chebychev map into the workspace directly.
- The designed coverage trajectories have the same characteristics as the improved Chebychev map.

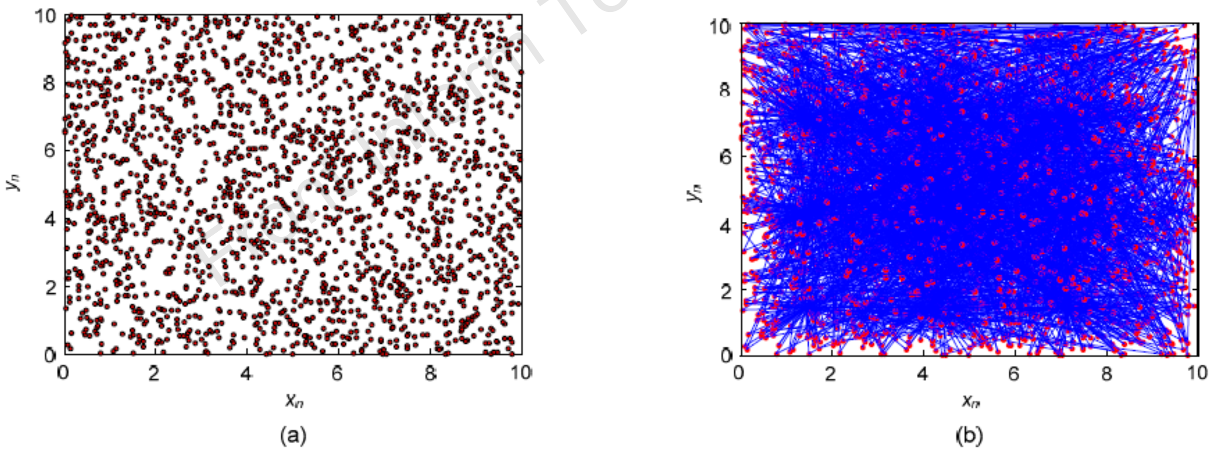

Fig. 8 Trajectories of the robot in the running range [0 10 0 10], at *n*=2000: (a) sub-goals of the trajectories; (b) trajectories

Major results (Cont’d)

- In the environments with one obstacle, the simulation results by the designed coverage algorithm.
- The designed coverage trajectories have almost the same characteristics as the improved Chebychev map, and can avoid the obstacles without specially designing the obstacles' aovidance method.

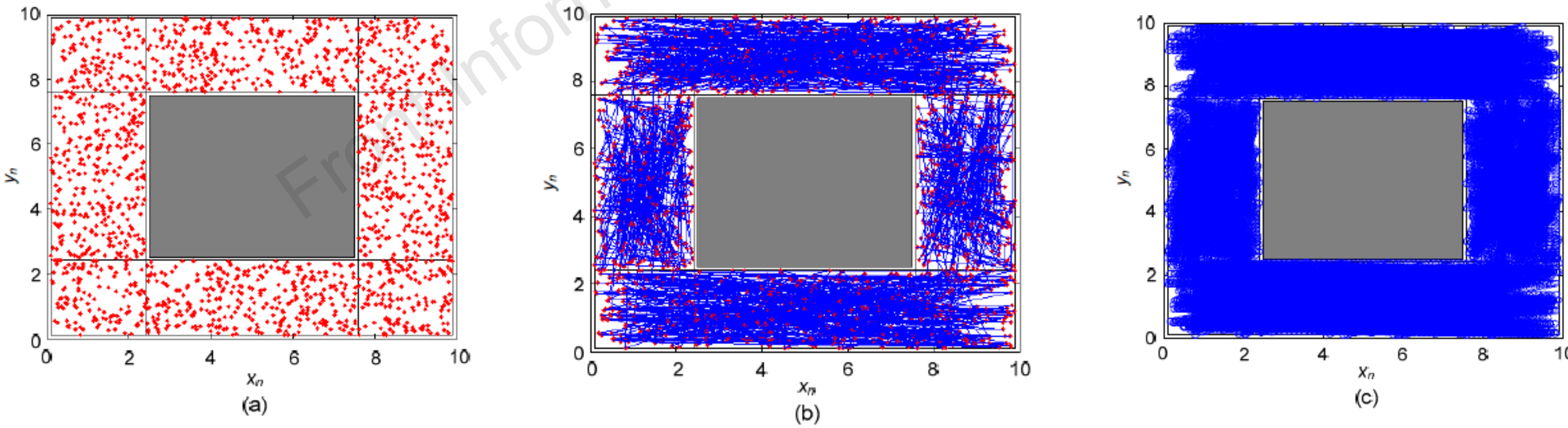

Fig. 14 Simulation results of the designed algorithm for ten big loops : (a) planned sub-goals; (b) planned trajectories; (c) real trajectories, for case 1

Major results (Cont'd)

- In the environments with two obstacles, the simulation results by the designed coverage algorithm.
- The designed coverage trajectories have almost the same characteristics as the improved Chebychev map, and can avoid the obstacles without specially designing the obstacles' aovidance method.

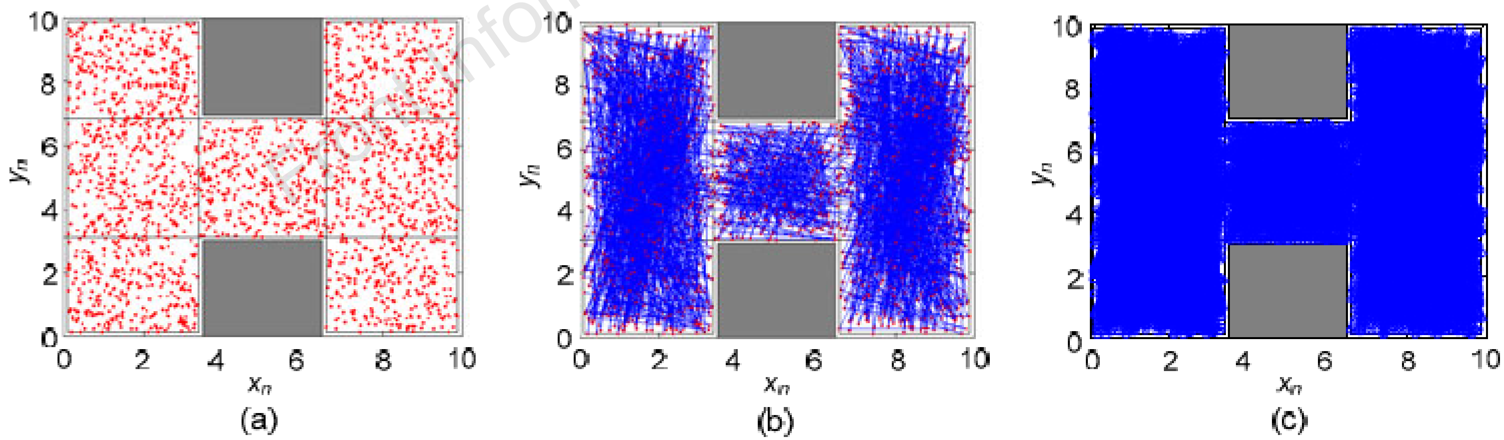

Fig. 17 Simulation results of the designed algorithm for case 2: (a) planned sub-goals; (b) planned trajectories; (c) real trajectories

Conclusions

- The simulation results of the two cases demonstrate that the robot can fulfill the coverage task safely and uniformly in the environment with obstacles.
- By affine transformation, the path planner executes chaotic iterations in each feasible coverage area. Designing of the algorithm has little influences on the Chebychev map, so it can still satisfy the requirements for the special missions.
- Because the chaotic path planner is an attractor, it only iterates in the feasible coverage areas. Thus, no detection of boundaries of workplace and obstacles is needed.

Conclusions(Cont'd)

- The simulation results show that the arcsine or arccosine transformation of the Chebychev map is effective to improve the evenness of the workplace, so the coverage rate and efficiency have been improved.
- By an interpolation and edge expansion method, the planning trajectories can be passed to the real robot to track in the real environment.
- This designed strategy of the chaotic coverage path planning can also be extended to other one-dimensional and two-dimensional chaotic systems.