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Complete coverage path planning for an Arnold system based mobile robot to perform specific types of missions

Key words: Chaotic mobile robot; Arnold dynamical system; Contraction transformation; Complete coverage path planning; Candidate set

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Motivation

- For some special missions, the characteristics of completeness, and randomness or unpredictability for the mobile robot trajectories are strongly required, especially for military applications, such as patrolling and surveillance.
- The main features of chaotic systems, namely topological transitivity and their sensitive dependence on the initial conditions, happen to meet the requirements of complete coverage path planning for the mobile robot to perform specific types of missions.
- The traditional method for constructing the chaotic mobile robot can destroy the chaotic characteristics of the planned path, and has low coverage rates.

Main idea

- Due to the feature of sensitive dependence on the initial conditions of the chaotic system, the constructed mobile robot can produce many different trajectories around an initial point, where paths with high coverage rates must exist.
- When the robot is located at a certain point in the workplace, if it selects the path with a high coverage rate near the point every time, a complete coverage trajectory with a high coverage rate can be formed in the workplace.

Method

- We construct a chaotic mobile robot by combining the Arnold dynamic system and the kinematic equation of the robot.
- We construct the candidate sets including the initial points with a relatively high coverage rate of the constructed mobile robot.
- The trajectory is contracted to the current position of the robot based on the designed contraction transformation strategy, to form a continuous complete coverage trajectory to perform the specific types of missions.

Major results

- Construction of the chaotic mobile robot

$$\begin{cases} \dot{x} = \sin z + 0.5\cos y, \\ \dot{y} = 0.5\sin x + \cos z, \\ \dot{z} = 0.5\sin y + 0.5\cos x, \\ \dot{x}_{\mathrm{r}} = v(t)\cdot\cos z, \\ \dot{y}_{\mathrm{r}} = v(t)\cdot\sin z, \\ \dot{\theta} = \omega(t), \end{cases} \tag{4}$$

$$\begin{cases} v(t) = \dfrac{1}{2}\left(v_{\mathrm{r}}(t) + v_{\mathrm{l}}(t)\right), \\ \omega(t) = \dfrac{1}{L}\left(v_{\mathrm{r}}(t) - v_{\mathrm{l}}(t)\right), \end{cases} \tag{5}$$

Major results (Cont'd)

- Construction of the candidate set

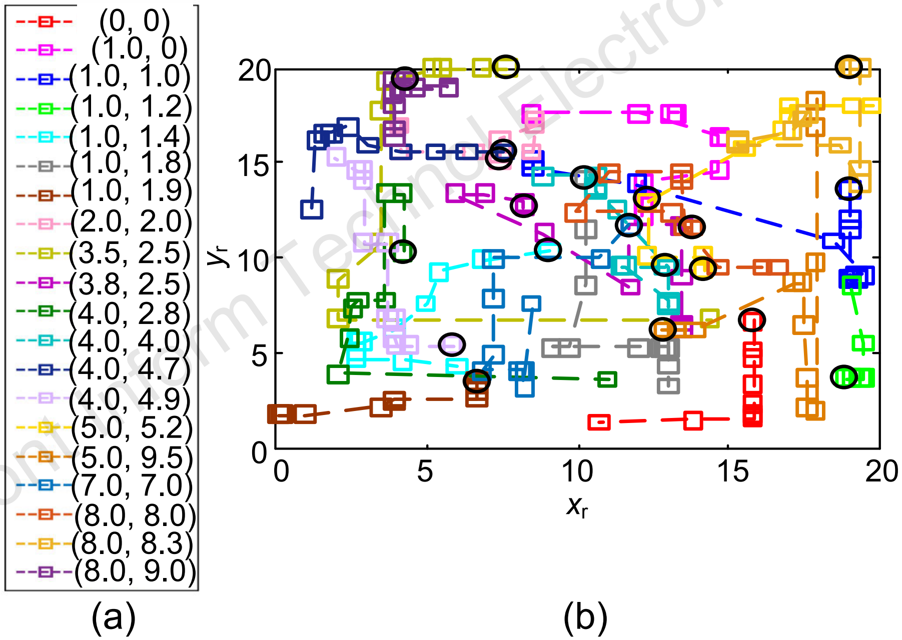

Fig. 11 The selected start points in Set($x_{r.0}$, $y_{r.0}$) (a) and the corresponding start point group in Set($x'_{r.0}$, $y'_{r.0}$) (b)

Major results (Cont’d)

- Design of the contraction transformation algorithm

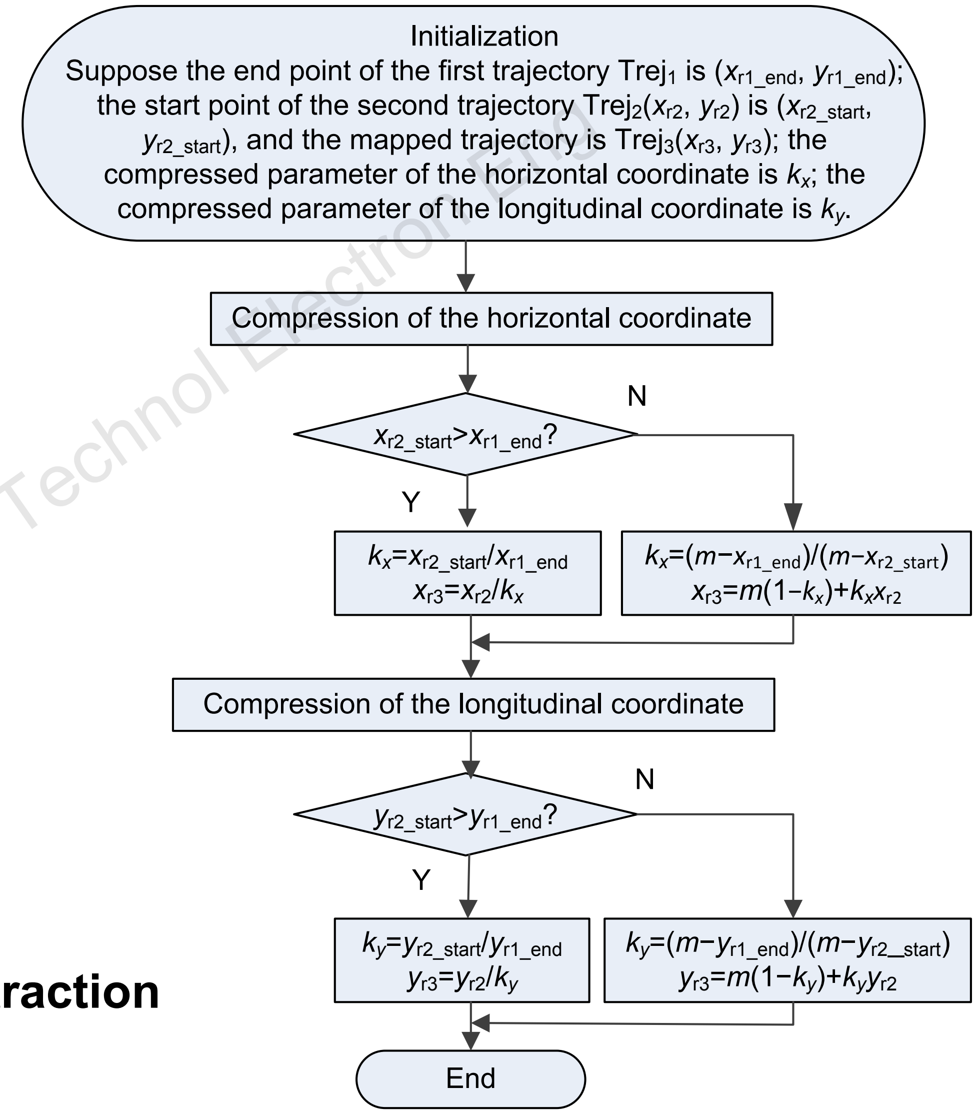

Fig. 12 Flowchart of the contraction transformation algorithm

Major results (Cont'd)

- Implementation of the designed method:

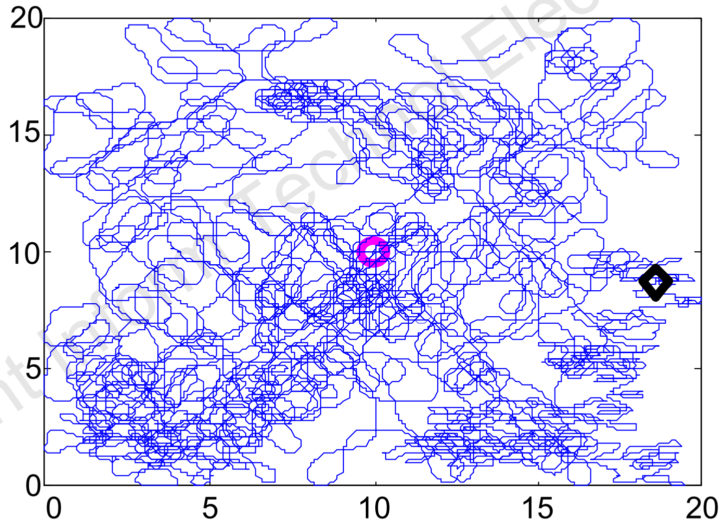

Fig. 14 The planned coverage trajectory produced by the designed algorithm

Conclusions

- In a given workplace, the trajectory produced can be contracted to any start point in it and form a continuous trajectory with a high coverage rate based on the construction of the candidate set and the design of the contraction transformation strategy.
- No obstacle avoidance is needed to avoid collisions of the workplace boundaries. The produced trajectory is bounded in the workplace, and the coverage rate and efficiency are improved.
- All the coverage trajectories are produced by the designed chaotic mobile robot and possess the chaotic characteristics, namely completeness, and randomness or unpredictability, to meet the requirements of specific types of tasks.