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# A descent method for the Dubins traveling salesman problem with neighborhoods

**Key words:** Dubins vehicle; Descent method; Dubins traveling salesman problem

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# Motivation

1. The Dubins traveling salesman problem with neighborhoods (DTSPN) is a core problem for mission planning of unmanned aerial vehicles (UAVs) to visit multiple regions.

2. The existing algorithms for DTSPN either are computationally demanding or generate low-quality solutions.

3. To achieve a better trade-off between solution quality and computational cost, an efficient gradient-free descent method is designed.

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# Main idea

1. The Dubins traveling salesman problem is decomposed into a series of subproblems.

2. Each subproblem consists of finding the minimum-length path of a Dubins vehicle from a configuration to another configuration via an intermediate circular region.

3. Analyzing the geometric properties of the subproblems allows employing the simple bisection method to solve each subproblem efficiently.

4. The DTSPN is addressed by successively solving a series of subproblems.

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# Method

A real-valued function is established so that the zero of the function determines the solution path of the subproblem. As a result, the simple bisection method is employed to address the subproblem.

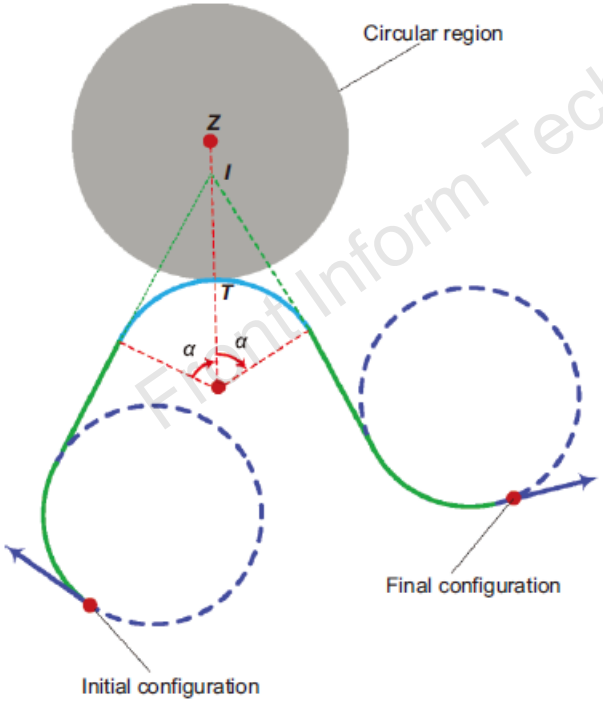



Fig. 2 Geometry of the solution path of the subproblem

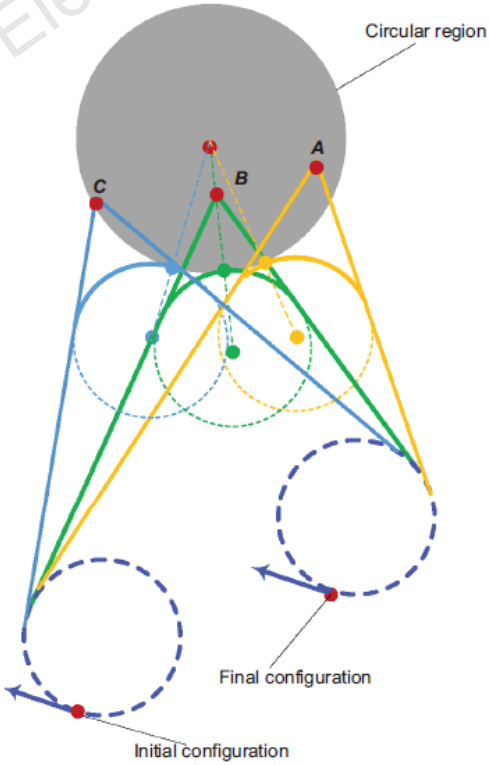
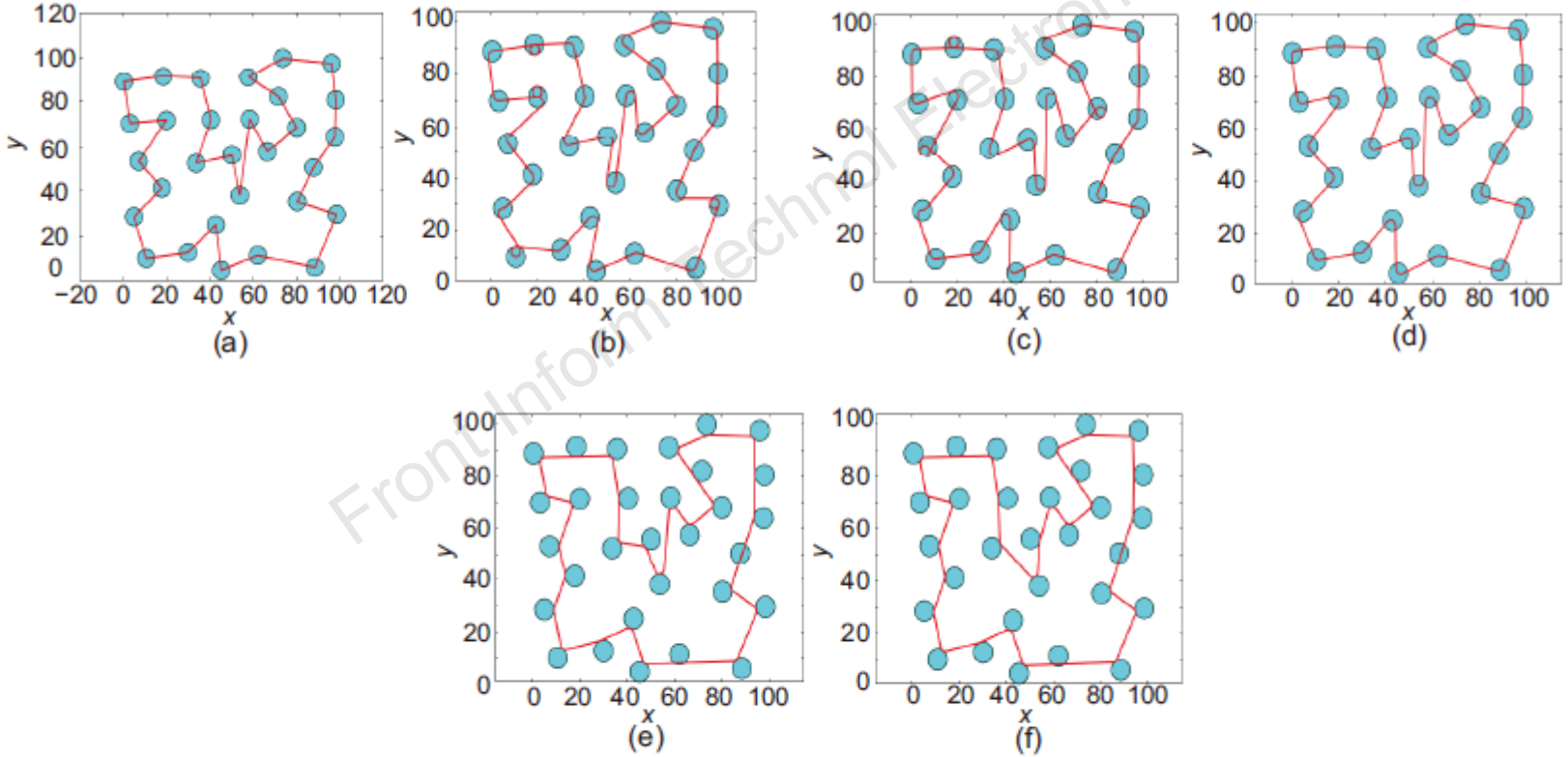



Fig. 3 Geometry of the Dubins paths

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# Major results

The solution paths for UAV to visit 30 regions generated by the proposed method and existing methods:




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**Fig. 5 Paths of DTSPN generated by ETSP (a), AA (b), SVA (c), LAA (d), DA (e), and DA with a reordered sequence (f)**

# Major results

Comparison of the solutions obtained by the proposed method and existing methods:

**Table 1 Lengths of DTSPN's solution paths generated by AA, SVA, LAA, and DA**

| Algorithm | Length |
|---|---|
| AA | 665.45 |
| SVA | 621.12 |
| LAA | 590.76 |
| DA* | 458.2 |
| DA# | 454.99 |

* indicates that the order of sequence is not optimized.
# indicates that the order of sequence is optimized

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# Conclusions

1. A gradient-free descent algorithm has been proposed for DTSPN, decomposing DTSPN into a series of simple subproblems.

2. Considering that the computational cost of the descent algorithm is determined mainly by the time to solve each subproblem, a simple bisection method has been established to efficiently and accurately address the subproblems.

3. Due to the descent property of the proposed algorithm, any approximate solution obtained by existing methods can be further improved by the proposed algorithm.

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Zheng CHEN received his MS and BS degrees in aerospace engineering from Northwestern Polytechnical University in 2013 and 2010, respectively, and his PhD degree in applied mathematics from the University Paris-Saclay in 2016. He is currently a researcher with the School of Aeronautics and Astronautics at Zhejiang University. His current research interests revolve around guidance and control in aerospace engineering.



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