A Route Scheduling Algorithm for the Sweep Coverage Problem

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***Abstract*—In order to decrease the sweep cycle and the number of mobile sensors required, we propose a route scheduling problem in this paper which is the first to consider the effect of sensing range. We prove that the Distance-Sensitive-Route-Scheduling(DSRS) problem is NP-hard, and consider two different scenarios: the single kissing-point case and the general case. For different cases, We propose three corresponding approximation algorithms ROSE, G-ROSE, D-ROSE.**

I. Introduction

All of the previous works [1]–[7] in sweep coverage problem neglected the impact of sensing range and they tried to make the sensors pass all targets in the surveillance area. In fact, it is unnecessary to schedule the sensors pass all targets. We just need to guarantee the distance between the targets and the route of the mobile sensor is no more than the sensing range, then the targets can be detected periodically. Obviously, in this way, we may decrease the route length greatly and improve the performance of sweep coverage, especially when the sensing range is large. Thus considering the sensing range of the mobile sensor is necessary.

In this poster, We are the first to consider the impact of sensing range in sweep coverage. We propose a method, named as kissing-method to visit the targets. We formulate the route scheduling problem in the new model and prove that the problem is NP-complete. We study the route scheduling problem for a single mobile sensor and find the property of the best route. We propose an approximation algorithm ROSE for single kissing-point case. Furthermore we propose another algorithm G-ROSE for general case. We study the route scheduling problem for large scale networks. We propose a distributed algorithm D-ROSE based on dividing-and-conquer technique. We compare our algorithms with the previous works and find that our algorithms outperform the previous works greatly with large sensing range.

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II. Distance Sensitive Route Scheduling Problem in the Sweep Coverage

In this section, we define the DSRS(Distance-Sensitive-Route-Scheduling) problem: the problem is to decide the shortest path on which the mobile sensor can sweep around the targets, such that the distance between each target and the path is less than r_o.

We prove the DSRS problem is NP-hard. We consider a special case when $r = 0$. Obviously, it is a well known Euclidean Traveling-Salesman-Problem (TSP) which is NP-complete. The TSP is a special case of the DSRS problem. Thus the DSRS problem is at least as hard as NP-hard. Many approximation algorithms can be used to find the TSP path. However, we cannot neglect the sensing range and apply the TSP path directly.

To study the DSRS problem, we give the definition of kissing-point. If a point is on the route of sensors and the distance between the point and a target t_i is r_o, the point denoted as $kp(t_i)$ is kissing-point. Obviously, $|kp(t_i)| \geq 1$. To simplify the problem, we firstly consider the single kissing-point case when $|kp(t_i)| = 1$ for each target t_i. Then we generalize from the special case $|kp(t_i)| = 1$ and get a solution for the general case.

III. Route Scheduling Algorithms for a Single Mobile Sensor

Under the single kissing-point case, every target has only one kissing-point. Thus we find the kissing-point of each target and connect the kissing-points in order. Then we get a solution. In the poster, the order of kissing-points is determined by the TSP path of targets. An approximation algorithm, named Efficiently Route Scheduling Algorithm(ROSE), is proposed to find the kissing-points in this section. To decide the positions of the kissing-points, we characterize the kissing-points firstly.

We can get an ellipse from three adjacent kissing-points $kp(t_{i-1}), kp(t_i), kp(t_{i+1})$. The focal points of the ellipse are $kp(t_{i-1}), kp(t_{i+1})$. $kp(t_i)$ is a point on the ellipse curve. Then the ellipse curve is tangent to the detection cycle of t_i. As shown in Fig. 1(a), if the ellipse curve is not tangent to the detection cycle, the route of mobile sensor can be shorter. Then we can prove a theorem: the line l_i, which passes the point t_i and the point $kp(t_i)$, is the bisector of the angle $\angle kp(t_{i+1})kp(t_i)kp(t_{i-1})$. As shown in Fig. 1(b), $\angle\alpha = \angle\beta$.

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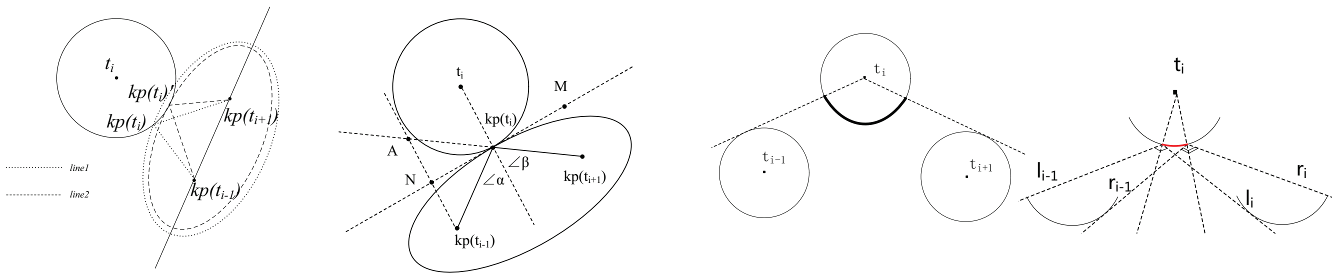


(a). Proof of the Lemma 1 (b). Proof of the Theorem 2 (c). The range of the kissing-point (d). Illustration for narrow process

Fig. 1. The Principle and Design of ROSE

Based on the theorem above, we propose an algorithm, named Efficiently Route Scheduling Algorithm (ROSE) for single kissing-point case. In this algorithm, we gradually narrow the range of kissing-points as shown in Fig. 1(c) and Fig. 1(d). In the Fig. 1(c), $kp(t_i)$ must be somewhere in the arc marked in bold. In the Fig. 1(d), $kp(t_i)$ must be somewhere in the arc marked as red. Besides, we set two threshold, th_{time} and th_{range}. th_{time} give the limit of narrow loops. th_{range} give the limit of the minimum narrow range. When beyond the thresholds, ROSE stops.

For general case, We proposed another algorithm, called as General and Efficiently Route Scheduling Algorithm (G-ROSE). The targets which have more than one kissing-points have no impact on the route of the mobile sensor. We choose the targets which have only one single kissing-point and apply ROSE algorithm to those targets. Then we get the route of the mobile sensor. This is the main idea of G-ROSE.

IV. Distributed Route Scheduling Algorithm for Large Scale Networks

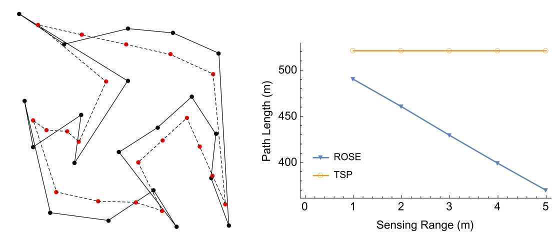
In this section, we propose another algorithm distributed route scheduling algorithm, called as D-ROSE algorithm for large scale networks. The D-ROSE algorithm is divided into two phases.

In the first phase, we divide the surveillance area in two rounds. In the first division, the area of each subregion is $q \times q$. Thus we can we can process each big square girds independently. To know the position of the targets, we have second division in each big square grid. The big square grid is divided into some square grids. The mobile sensors need to travel along the Peano Curve in the square grids and get the positions of all targets in their grids. Then we make communication sensors collect the information about the targets position.

In the second phase, we divide the targets into several groups based on K-means algorithm and assign one mobile sensor to each group. Finally, we can get a solution by G-ROSE algorithm.

V. Performance Evaluation

In this section, we conduct extensive simulation experiments to evaluate our algorithms. We apply ROSE algorithm and TSP algorithm to 20 targets, then we can find two route scheduling solutions as shown in Fig. 2. We also compare G-ROSE algorithm with CSWEEP [1] and ISTP [3]. Experiments show that the proposed algorithm G-ROSE has a better performance than the previous algorithms especially with large sensing range and great density of targets.



(a) An example when $r = 3$ (b) Average route length with different r

Fig. 2. Comparison between ROSE algorithm and TSP algorithm

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