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Point Sweep Coverage in Wireless Sensor Networks Using Convex Hull Algorithm

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Abstract— There are lots of applications where only periodic monitoring (sweep coverage) is sufficient instead of continuous monitoring. The main goal of sweep coverage problem is to minimize the number of mobile sensor nodes moving with uniform velocity required to guarantee coverage as per given sweep time. Sweep coverage problems are broadly categorized in three types depending on applications viz point sweep coverage, area sweep coverage and boundary sweep coverage. In this paper we have solved the problem of point sweep coverage, where a set of densely spaced points in the given region are periodically monitored using convex hull algorithm.

Keywords— Sweep coverage problem; Area sweep coverage; Point sweep coverage; convex hull algorithm; Tessellation.

I. INTRODUCTION

Coverage where only periodic patrol inspections are used is called sweep coverage [1,2,3,4,11,13,15]. In the sweep coverage scenario deployment of static sensor nodes may partially solve the purpose but it suffers from poor efficiency and unnecessary extra overhead. Moreover, static sensor network suffers from static sink neighborhood problem in which the sensors which lie near to the sink node die as they have to relay the data of other nodes which consumes more energy due to which the sink disconnects from rest of the network. Sweep coverage problems are broadly categorized in three types depending on applications, point sweep coverage, area sweep coverage and boundary sweep coverage. This paper is about the point sweep coverage problem where set of discrete points are to be periodically covered. In papers [1,2,3,4] given points are globally point sweep covered by the mobile sensor node in given sweep period of time. This paper introduced a new approach for solving point sweep coverage i.e. convex hull approach. The main goal of sweep coverage problem is to minimize the number of mobile sensor nodes moving with uniform velocity required to guarantee sweep coverage as per given sweep time.

Rest of the paper is structured as follows: In section II, our contribution for point sweep coverage is presented. The conclusion and Future work are presented in section III.

II. OUR CONTRIBUTION

A. *POINT SWEEP COVERAGE*

We have considered point sweep coverage problem [1,2,3,4] where a given set of discrete points are monitored by set of mobile sensor node at least once in given velocity and time period. The problem definition of point sweep coverage problem is to find the optimal (minimum) number of mobile sensors to guarantee sweep coverage for all given points. In papers [1,3] the definition of point coverage is given as below:

Definition 1 :

Let u={u1,u2,.......,un} be a set of discrete POI(points of interest) on a two dimensional plane and S={s1,s2,.......,sn} be a set of mobile sensor node. A point ui is said to be ti point sweep covered if and only if at least one mobile sensor node visits ui within every ti time period. The set u is said to be globally point sweep covered by the mobile sensor node of S if all u ui are ti sweep covered. The time period ti is said to be the sweep period of the point ui.

Let us consider a set of POI on a two dimensional plane containing n points. Let G=(V,E) be the complete graph with each point as a vertex and the line joining two points i and j on the plane as edge. The Euclidean distance d(i,j) is the weight w(i,j).let v be the uniform velocity of all mobile sensor nodes and t be the common sweep period for the set of n points in V.

Gorian in paper [2,4] proved the above point sweep coverage problem is equivalent to finding minimum TSP tour of G. Using 'Metric TSP-factor 2'approximation algorithm shown in following figure.

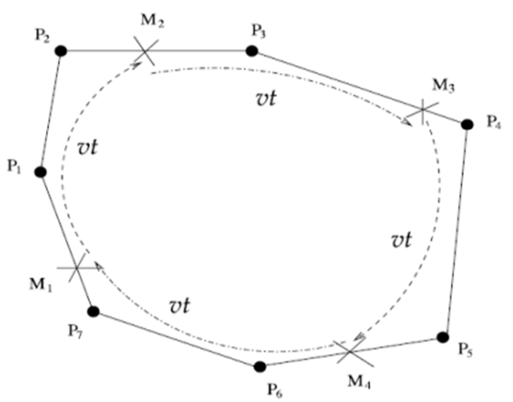

Fig. 1: The figure showing TSP tour for the POI, P1,P2,.........,P7, and initial position of the mobile sensor nodes M1,M2,M3,M4 for sweep coverage of the POI.

Algorithm 1: Point sweep coverage

1. Find a TSP tour L of G by the method of finding Euler tour from a MST of G by 'Metric TSP-factor 2' approximation algorithm.
2. Partition L into parts and deploy mobile sensor nodes at all partition points, one for each.
3. Each mobile sensor node then starts moving at the same time along L in same direction.

B. CONTRIBUTION

In this paper our contribution is on sweep coverage to solve the problem of point sweep coverage. The problem of point sweep coverage can also be solved using convex hull algorithm [6,15,18,19,20,21,22]. The convex hull of a set of planar points is the smallest convex polygon containing all of the points. If we are having densely spaced points then we can make a convex polygon of those points by applying convex hull algorithm and then divide the area of convex polygon using the concept of tilling. The convex hull is the smallest convex polygon in which each point is either on the boundary of polygon or in its interior as shown in fig.2.

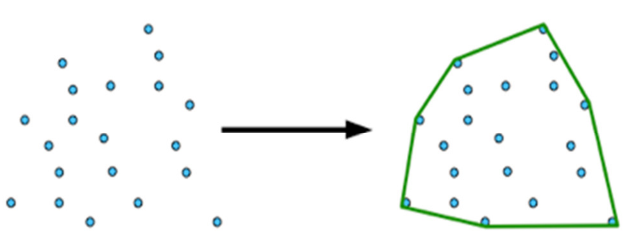

Fig.2: Convex polygon

Algorithm 2: Convex hull algorithm

1. Initialize p as leftmost point.
2. Do the following while we don't come back to the first (or leftmost) point……a) The next point q is the point such that the triplet (p, q, r) is counterclockwise for any other point r……b) next[p] = q (Store q as next of p in the output convex hull)……c) p = q (Set p as q for next iteration).

The idea of Algorithm is simple, we start from the leftmost point (or point with minimum x coordinate value) and we keep wrapping points in counter clockwise direction. The big question is, given a point p as current point, how to find the next point in output? The idea is to use orientation () here. Next point is selected as the point that beats all other points at counterclockwise orientation, i.e., next point is q if for any other point r, we have "orientation(p, r, q) = counterclockwise".
In paper [5] convex hull problem for two dimensional sets of points can be defined as follow:

Definition 2 (Convex hull): The convex hull of set of Q points is the smallest convex polygon P for which each point in Q is either on the boundary of P or in its interior. We denote the convex hull of Q by CH(Q). This algorithm output the vertex in counter clockwise order.
As can be seen in fig 4, every vertex of CH(Q) is a the point in Q. This algorithm explicit this property, deciding which vertices in Q to keep as the vertices of convex hull and which vertices in Q to throw out. This algorithm runs in O(n log n) time.

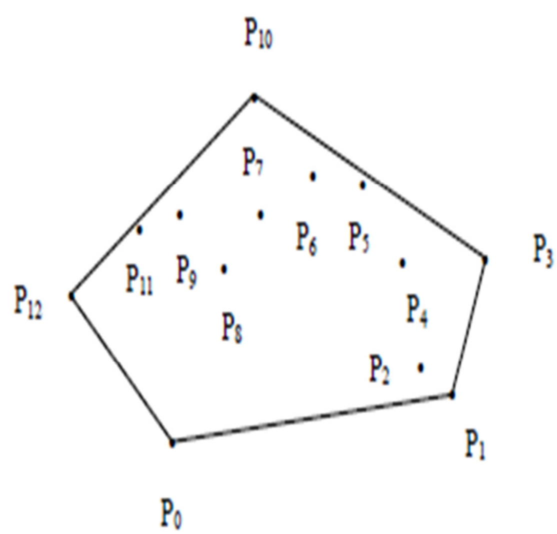

Fig 3: A set point of Q= (P1, P2, P3, ...,P12) with its convex hull CH(Q) in gray.

Algorithm 3: Proposed algorithm for point sweep coverage

1. Make a convex polygon of given points using convex hull algorithm (***Algorithm2***).
2. Apply area sweep coverage (***Algorithm 4***) to compute the number of mobile sensors required for sweep coverage for P.

As given in fig 4 here we take set of discrete points. To apply our proposed algorithm for sweep coverage we will have to make a convex polygon on these given set of points as shown below

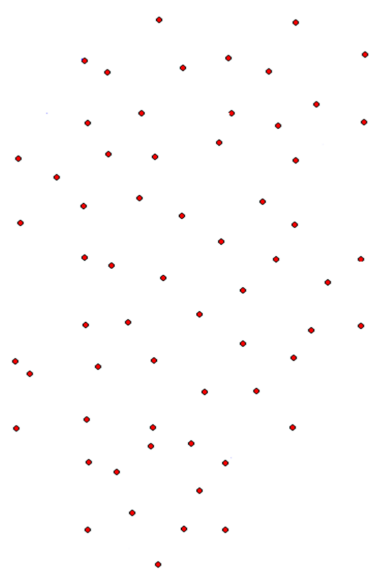

Fig.4: Set of discrete points

To make a convex polygon of given set of points we will use algorithm 2. To divide the region of this convex polygon we use the concept of tessellation [9]. We can tessellate the given area using any one of the three regular tessellations viz square, hexagon and triangular. In paper [9] concept of tiling is described. Gorain et al. in [2] have solved the problem of Area Sweep coverage by considering the area as square region and assuming that the side of the square is divisible by D and tilling it with the square of edge length D. To divide the region of above convex polygon hexagonal tiling is used.

In paper [2] the definition of area sweep coverage is given below.

Definition 3 (Area sweep coverage): The area sweep coverage problem is to find the optimal (minimum) number of mobile sensors such that for a given time period t, each point of a given area A is t-sweep covered.

Algorithm 4: Area Sweep coverage

1: Divide the area using the concept of tessellations (tilling)
2: Let P is the set of center points of each tile.
3: Apply (***Algorithm 1***) to compute the number of mobile sensors required for sweep coverage for P.

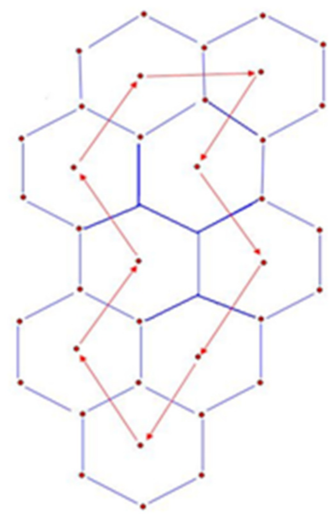

Fig. 5: Sweep covering the given divided region using area sweep coverage algorithm

We use area sweep coverage algorithm to compute the number of mobile sensors required for sweep coverage for points. In area sweep coverage all the points of a bounded region must be covered at least once in a certain time period. Same strategy like point sweep coverage cannot be applied to solve the area sweep coverage since there are uncountable number of points in any bounded region. Here we are considering homogeneous mobile sensors with sensing range D shown in fig 5. The mobile sensors can be considered as sensing disks with radius D, centering at it

III. CONCLUSION AND FUTURE WORK

In this paper we have discussed point sweep coverage problems in wireless sensor networks and we have solved the problem of point sweep coverage using the concept of convex hull. From the above discussion it is clear that the main goal of sweep coverage problem is to minimize the number of mobile sensor nodes moving with uniform speed required to guarantee sweep coverage as per given sweep time. As speed of mobile sensor nodes and sweep time is fixed therefore number of mobile sensor required for sweep coverage depends only on L (length of closed path).

Sweep coverage is a purely new concept for sensor network monitoring. There are still many interesting problems not discussed. The problem of area sweep coverage is studied by Gorain et al. in paper[2] and they proved that the problem is NP complete and 2 -approximation algorithm is proposed in order to solve the problem for a square region using square tilling.

One significant extension of this problem is that the given region is any general Polygon and we need to do the Sweep Coverage for Area of the region. Other extension of this problem is that the given region is any general Polygon and we need to do the Sweep coverage for its boundary. In my future work, I plan to study these problems and obtain useful results.

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