Cluster Based Object Detection in Wireless Sensor Network

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Abstract

Sensing and coverage are the two relevant tasks for a sensor network. Quality of sensor network totally depends upon the sensing ability of sensors. In a certain monitored region success of detecting or sensing an object with the help of sensor network tells that how efficiently the network coverage perform. Here in this paper we have proposed a clustering algorithm for the deployment of sensors and thus calculated the object detection probability. Actually by this work we can easily identify the present network coverage status and accordingly can take action for its improvement.

1. Introduction

Wireless sensor networks are a hastily striking resource to scrutinize the environmental conditions where people wish to implement their thoughts, expertise application etc. Wireless sensor networks are the strategy for many new kinds of applications, and logistics. Wireless sensor networks along with their communication link and applications are still to be designed and deployed for various purposes. Deployment and structuring of a sensor network in a target area can be an incessant practice. Actually deployment establishes an association of sensor nodes with objects, creatures, or places in order to augment them with information-processing capabilities via a number of communication links. Deployment can be as diverse as establishing one-to-one relationships by attaching sensor nodes to specific items to be monitored [1], covering an area with locomotive sensor nodes [2] or throwing nodes from an aircraft into an area of interest [5]. As wireless sensor network is collection of sensors and each sensor has limited amount of capacity so deployment, re-deployment and structuring of them is an important issue on this regard. Now a day for the improvement of the network lots of research is going on this related topic.

Sensing and detecting tasks are the most sophisticated functions for the sensors. Both of these functions have to be performed effectively and inexpensively so that quality of sensor can be increased. This paper proposes a new approach for the clustering the sensors. It also describes how an object can be detect/sense by some cluster border sensor in a monitored region. Here a probabilistic function has been used to determine the efficiency of the sensors.

2. Cluster Formation

Here in this paper a clustering algorithm is used which is based on Delaunay triangulation of the sensor nodes. The key idea of this clustering method has been taken out from the clustering method used for key frame-based video summarization technique [3]. This is an efficient and inexpensive clustering method in comparison to other clustering method. The clustering algorithm here generates clusters from a large number of deployed sensors in a network without any user-defined arguments about the large number of sensor nodes.

2.1 Facilitated Technology of Computational Geometry

In recent years the use of computational and convex geometry for the application of network design has enormously increased. The concept of Voronoi diagram and Delaunay Triangulation are mostly uses in the domain of network. In case of Voronoi diagram the partitioning of a plane with n points into convex polygons such that each polygon contains exactly one generating point and all points inside a given polygon are closest to only one edge [4]. In case of Delaunay triangulation, it is equivalent to the connecting points in the Voronoi diagram whose convex polygon shares a common edge [4].

2.2 Clustering Algorithm:

According to the properties of Delaunay Triangulation [6] each node/point set of triangulation is unique and the circumcirle of each triangle in the triangulation does not contain any other point. After generating a whole sensor network using triangulation intra-cluster edges and inter-cluster edges have to be identified. Generally network discontinuity is identified using the inter-cluster edges and our target is to find all the inter-cluster edges in the network. Thus this clustering method ends by removing the inter-cluster edges and we get some unique clusters which are in turn are unique convex polygon.

Variability of different parameters of edges such as: edge length, local mean length of the edges, and local standard deviation of the edges etc. make the identification of inter-cluster edges easier. One important criterion is that, always inter-cluster edges are larger than the intra-cluster edges.

Algorithm (N)

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1. **for** a given set of nodes $N_i = \{n_1, n_2, \ldots, n_p\}$ in the network where $p \geq 2$,
   Generate Delaunay Triangulated Graph G
2. **for** each node $N_i = \{n_i, n_2, \ldots, n_p\}$ in G
   if $N_i ==$ new node **then**
   for each edge e_j incident to node N_i
   Calculate local mean edge length,
   $$L(N_i) = \frac{1}{d(N_i)} \sum_{j=1}^{d(N)} |e_j|$$
3. **Calculate** the local standard deviation of length of each edges incident to node N_i,
   $$LD(Ni) = \sqrt{\frac{1}{d(N_i)} \sum_{j=1}^{d(N_i)} (L(N_i) - |e_j|)^2}$$
4. **Calculate** the mean of local standard deviation
   $$GD(N) = \frac{1}{p} \sum_{i=1}^{p} LD(N_i)$$
5. $Intra\text{-}Cluster\_Edge(N_i) = \{e_j \mid |e_j| < L(N_i) - GD(N)\}$
6. $Inter\text{-}Cluster\_Edge(N_i) = \{e_j \mid |e_j| > L(N_i) + GD(N)\}$
7. **Remove** all Inter-Cluster edges
8. **Define** the boundary sensor nodes of each cluster.

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3. Object Detection Model:

We have considered a Voronoi diagram, such that it partition the 2-D plane in to a set of convex polygon, where from the higher point of view a cluster inside a polygon are thought to be a point and closest to only one Voronoi edge. Each of these Voronoi edges are common between two clusters and we have derived a probabilistic value for each of them. This probabilistic value in turn will show the efficiency of detecting an object.

3.1 Cluster Sensing Model:

Let s is a boundary sensor of a cluster C and p is an arbitrary point of any incident Voronoi edge. Thus the sensing model can be shown as[4]:

$$S(s, p) = \frac{1}{[d(s_{\min}, p)]^K}$$

Where $d(s_{min}, p)$ is the Euclidian distance of closest sensor of the cluster C to the point p and K is a sensor technology dependent positive constant.

3.2 Common Cluster intensity function:

If we consider a sensor field with several clusters then for a point p over a common Voronoi edge of two clusters then the common cluster intensity function can be defined as:

$$I(C, p) = S(s_{\min}, p)$$

Here s_{min} is the closest sensor to p from each cluster.

3.3 Object Detection Probability:

According to the random sensing schedule all the sensor have the same sensing range. Now if an object moves from left to right of x-axis where we consider that each Voronoi edge has mapped over x-axis. Let the length of the Voronoi edge is L and an object moves from $(-L/2)\ to\ (L/2)$. In figure-1 the total active area can be defined as the rectangle area (shaded) with length L and width of 2R. So the active area: $A = L * 2R$.

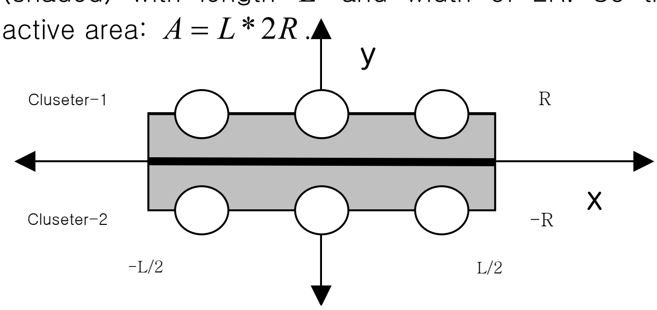

Figure-1: A Simple Scenario for Active Area A

Theorem 1:

Let (x_p, y_p) be the location of an object point p over a Voronoi edge and $\bar{P}$ be the detection probability of a closest sensor s_{min} to the point p. Point p has the intensity $I(C,p)$ due to s_{min}. So,

$$\bar{P} = \frac{1}{A}\int_{-L/2}^{L/2} I(C,p)\,dx \quad \int_{-R}^{R} dy$$

Proof:

To detect any object in a point (x_p, y_p) specifically a sensor should satisfy two conditions: i) the sensor must be in active area and ii) the sensor must be in active mode when the object passes through the edge along its sensing range. The detection probability of the closest sensor to a point is totally depending on the length of the Voronoi edge and the intersection point between the sensors sensing range and the point on the edge. It is certain that each point will intersect the edge. As the Voronoi edge lies along the x-axis and it has length L so the different random value of intersecting points should be in a range of $(-L/2)\ to\ (L/2)$. So, the derivation in the above theorem can easily be justified.

4. Experimental Result:

The clustering algorithm here proposed and used has been implemented in an analytical simulation. According to the simulated result we have found the complexity of the algorithm O (n *log* n) which is computationally less and inexpensive. In case of object detection we have analyzed a variant number of probabilistic value with some specified parameters.

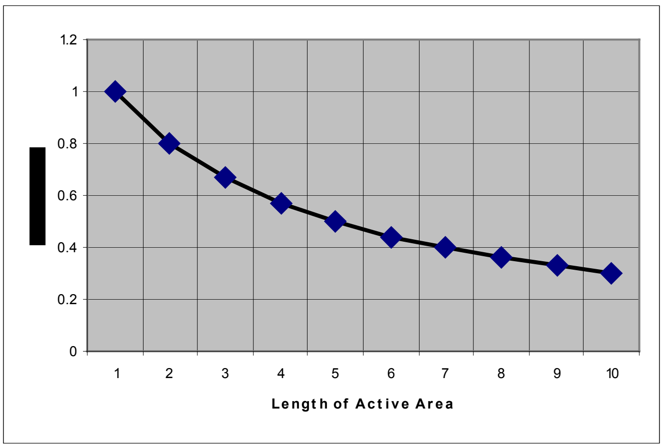

Figure-2: Detection Probability Variation

Figure-2 shows an experimental output from which we can easily understand the probabilistic improvement or degradation of detecting any object over a Voronoi edge. As the active area only active upon the x-axis so it totally depends on the length of a Voronoi edge.

5. Conclusion:

Wireless sensor networks are now a day becomes a key technology for surveillance systems for its flexibility and agility. This paper addresses a general idea regarding the object detection in a monitored region through a sensor network. Here an inexpensive and computationally less clustering algorithm has been proposed so that the task of sensing or detecting an object can become easier for sensors. The experimental results indicate that the probability of detecting any object depends on the length of the monitored Voronoi edge. Our future works is to identify the minimum probabilistic values for each edge so that overall network coverage weakness can be identified for further improvement. Though the coverage problem is a critical issue for wireless sensor network still we hope our further advancement of this paper will contribute enormously.

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