DEPLOYMENT OF DIVERSE MOVING SENSORS AT STABLE LOCATION IN AREA OF INTEREST

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ABSTRACT

By considering traditional quandary in uniform placement has difficult to place diverse sensors at Area of Interest. We discussed uniform network failed when used in various changing operation.

Unluckily, device uniformity & network is an unlikely assumption in most practical deployments. In order to deal with realistic scenarios, we discussed combination of Voronoi approach with Laguerre geometry. We notionally show the appropriateness of our approach to the managing the diverse networks. In addition we demonstrated that VorLag can be extended to deal with dynamically generated events or uneven energy depletion due to communications.

Furthermore, our idea regarding to VorLag provides a very constant sensor behavior, speedy and guaranteed termination and sensible energy utilization. Our discussion on VorLag has better performance to other methods based on virtual forces.

***Keywords**: Device diverse, Self-deployment, Voronoi-Loguerre.*

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I. INTRODUCTION

The deployment of mobile sensors is attractive in many scenarios. Mobile sensors may be used for environmental monitoring to track the dispersion of pollutants, gas plumes or fires. They may also be used for public safety, for example to monitor the release of harmful agents as a result of an accident. In such scenarios it is difficult to achieve an exact sensor placement through manual means. Instead, sensors may be deployed somewhat randomly from a distance, and then reposition themselves to provide.

The potential of such applications has inspired a great deal of work on algorithms for deploying mobile sensors. Most of this work has addressed the deployment of homogeneous sensors to achieve a consistent coverage of a certain density in a specific Area of Interest (AoI).

We address two more practical and challenging problems: (i) the deployment of Diverse sensors to achieve full coverage, and ii) the deployment of sensors to achieve coverage of varying density within an AoI. The first application accommodates sensors that may have different sensing ranges due to design or operating conditions, for example depleted battery supplies or damage to a transducer. The second application addresses the need for a higher density of sensing resources at a particular site where perhaps an event has been detected and requires more analysis.

We studied an algorithm which is based on a generalization of the Voronoi approach presented in [1]. We find that the original algorithm does not solve the problems of deployment with diverse sensors or varying density over a field. We discover that in these scenarios, sensors do not move to cover the required area entirely, but instead stop moving when they wrongly recognize that they have covered their maximum area. To solve this problem we introduce the idea of Laguerre distance into the Voronoi algorithm, and with some other modifications show that the resulting algorithm, which we call VorLag, is able to solve both deployment problems effectively. The primary additions to the original Voronoi algorithm are the use of the Laguerre distance and the redefinition of several algorithm parameters to ensure algorithm termination and improve convergence time. We compared VorLag with another class of well accepted deployment algorithms based on virtual forces. We modify one particular virtual force algorithm so that it may operate in scenarios requiring the use of heterogeneous sensors or deployment of varying density. We realize that VorLag has better performance and characteristics than the virtual force algorithm. For the reason that the virtual force algorithm balances the distance between sensors, and does not specifically target sensor heterogeneity or a specific coverage density, it takes longer to converge, and due to some difficulty is not guaranteed to converge at all. A prior knowledge of the density of deployed sensors is required for the proper tuning of these parameters which makes the algorithm impractical.

In summary, our contributions are:

- We discover the limitations and their root causes when using Voronoi-based algorithms with heterogeneous sensors and when deploying sensors with varying density.
- We generalize a previously proposed Voronoi based algorithm with the notion of Laguerre distance to solve the problem of deploying diverse mobile sensors.
- We extend the new algorithm to execute in environments in which a varying coverage density is required.
- We expand previous algorithm to accommodate diverse sensors and proved precious properties.

We distinguish the performance of the VorLag and virtual force algorithm and determine the fundamental causes behind the limitations of the virtual force algorithm. The VorLag algorithm is practically provides very stable sensor behavior, with quick and guaranteed termination and moderate energy consumption. It does not require manual alteration or perfect knowledge of the operating conditions, and works properly if the sensor positioning is imprecise. The algorithm only requires loose synchronization and local communication. Because it converges quickly and does not require a priori knowledge of the deployment environment suitable for dynamic environments in which the sensing density requirements change over time.

II. LITERATURE REVIEW

Various approaches have been proposed to self-deploy mobile sensors. The virtual force approach (VFA) models the interactions among sensors as a combination of attractive and repulsive forces. An outcome of these antagonist forces, the sensors spread throughout the environment. An algorithm based on VFA was studied. Shortcomings of VFA include complex required altered parameters and an oscillatory behavior of sensors. Possible improvements include introduction of dissipative forces studied [1], [2] or the definition of arbitrary thresholds as stopping conditions [6], [8]. Altered thresholds are laborious and rely on an off-line configuration.

The virtual force model is also at the basis of several other proposals [5]. Of these proposals we focus on the one presented in [5] under which a dynamically calculated constraint on the length of sensor movements prevents oscillations. This algorithm is studied. Deployment problem in voronoi is solved by technique or Delaunay triangulation. In movement assistance deployment, each sensor iteratively calculates its Voronoi polygon, determines the survival of coverage holes and moves to a superior position if necessary. This advance inspired our proposal and it could be obtained as an instance of our general approach, when sensor capabilities are identical. A dual approach use Delaunay triangulation. Oscillation could be avoided by proper setting of threshold parameter. Other approaches introduced techniques for sensor deployment in a different operative setting. Ultimately, an approach based on the construction of a regular triangular lattice is proposed in [7]. We also studied about focus on static sensor deployment with variable density in order to moderate the effects of the uneven energy depletion due to communication with a sink [6]. Adaption of density to the proximity of events of interest introduced a unified solution for sensor deployment and relocation. The work identified the problem of sensor heterogeneity specially, but assumptions on the network topology that are very restricted. We close this section by pointing out that the idea of using generalized Voronoi diagrams is familiar to sensor networks. Nevertheless, to the most excellent of our knowledge, none of the previous work uses the approach proposed here to address the problem of heterogeneous mobile sensor deployment or deployment of varying density[9].

III. MOTIVATION AND PRELIMINARY

We showed the limits of existing Voronoi based approaches to guide sensor movements and give the basics of our new algorithm.

A Traditional Voronoi approach

We memorize that given N generating point in the plane, C_i =(xi, yi) with i=1,..,N, the voronoi polygon Vv_{or} (C_i)

A Voronoi diagram partitions the AoI into smaller polygonal regions so that each polygon is better covered by the sensor to which it belongs, rather than by any other one. The Voronoi algorithm is designed for homogeneous sensors. Each sensor calculates its Voronoi polygon, and move towards its vertices if they are opened. Each edge of the diagram lies on a line which partitions the AoI in two half planes, each one covered better by either one or the other of the two generating sensors. This property of the Voronoi diagram no longer holds in the case of heterogeneous sensors, but it is a necessary property for the diagram to guide sensor movements towards coverage holes, according to the Voronoi algorithm.

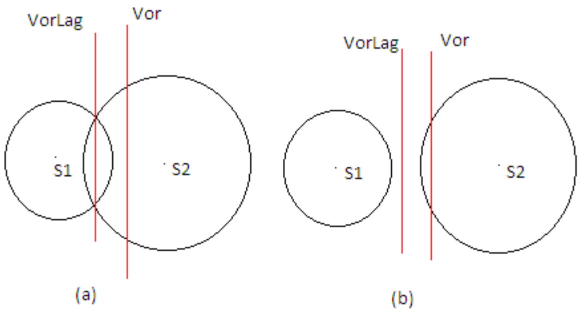

Fig – Different position of lines are same to s1and s2 in case of (a) Intersecting (b) Non-Intersecting

Figure 1(a) shows an example in which the line "Vor" is halfway from the points s1 and s2. It is easy to see that since this line does not cross the intersection between the two circles, it does not partition the plane as required. Instead, the line labeled "VorLag" is drawn so as to assign each sensor to the half plane that it can cover best. We are going to show this line is also halfway from the points s1 and s2 but it is so in the Laguerre geometry.

Figure 1(b) shows the Voronoi axis does not properly partition the AoI as it is done by the VorLag axis.

So as to show what kind of troubles may occur when using the Voronoi algorithm in the case of heterogeneous sensors, we have an the example in which sensors are deployed over a rectangular AoI, where the left zone is enclosed redundantly and the right zone is largely uncovered. The use of this algorithm produces no movements in such a configuration.

The sensors with a small sensing circle (sensors 10-14) are fixed, as their sensing range is completely included by their Voronoi polygon. The sensors with larger sensing circles (sensors 0-9), do not move either, because they already cover their own polygon completely. We can conclude that Figure c represents a critical configuration for the Voronoi algorithm for which the bad bisector placement leads to a barrier effect. This effect is one of the reasons of VorLag.

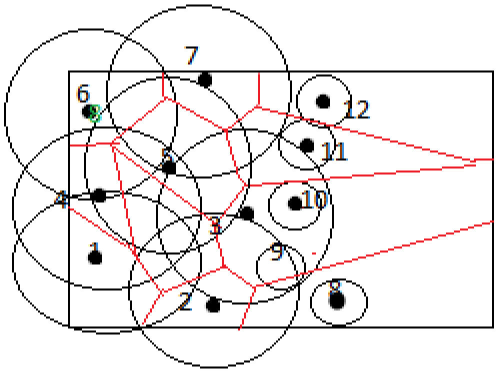

Fig (c) Configuration for traditional Voronoi Algorithm

B. Voronoi Diagrams in the Laguerre Geometry

One of the most interesting generalizations of Voronoi diagrams relates to the idea of distance. The notion of Euclidean distance can be replaced by a variety of different formulations, among which we chose to use the one by Laguerre [3]. This choice is attractive as it keeps the property of generating straight edges, instead of complex curves, that is required for the Voronoi algorithm to work. The Laguerre-Voronoi diagrams are constituted by portions of straight lines which are perpendicular to the line segments connecting the centers of the associated generating points.

Given a circle P with center P = (xP ; yP) and radius r_P , and a point of the plane S = (xS ; yS) £ R^2, the Laguerre distance d_L(P ; S) between the circle C and the point S is defined in terms of the Euclidean distance d_E (P; S) between points P and S: d^2_L (P; S) = d^2_E (P; S) - r^2_c

It should be noted that this metric is not a distance in the mathematical sense. Actually d^2_L (P , S) can be negative. The sign of d^2_L (P, S) depends on the position of S with respect to the circle P . It is negative or positive if S lies inside or outside circle P respectively.

Lemma1.Given two circles P 1 and P 2 with non coincident centers P1 and P2, and radii r1 and r2, respectively, the locus of the points equally distant, in the Laguerre geometry, from Fig. 3. Example of

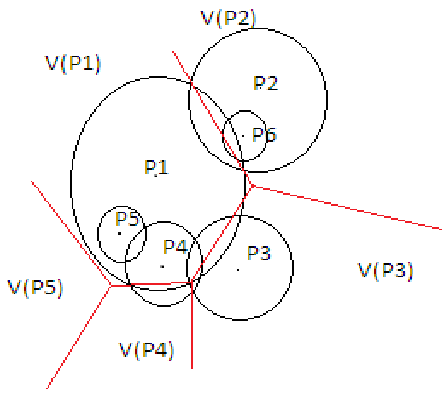

Fig 3- Example of voronoi Laguerre diagram with null polygon

Voronoi-Laguerre diagram with empty and null polygons the two circles is a straight line, called the radical axis of P1 and P2.

The radical axis is perpendicular to the segment connecting the centers P1 and P2 of the two circles. This axis is located at distance k from P1, with

$k= [d_E (P1, P2) /2]+[(r_1^2 – r_2^{2)}/2 2d_E (P1, P2)]$

The proof of Lemma 1

An application of the Laguerre notion of distance, and it is omitted due to space limitations. We now define the Voronoi-Laguerre diagram of n circles as follows. Given n circles in the plane Pi with centers Pi = (xi; yi) and radii ri ,the Voronoi-Laguerre polygon V (Pi) for circle PI is defined as V (P I) = P 2 <2 d^2_L(Pi, P) $d_L{}^2$ (Pj, P) . Obviously, if $r_i = r_j$ for all i=j=1.., 2, the Voronoi-Laguerre diagram reduces to the ordinary Voronoi diagram.We highlight that the polygon V (P_i) may not contain any point of the plane. In this case, the Voronoi-Laguerre polygon V (P_i) is called a null polygon. We also note that the point P_i, that is the center of Pi, may not lay inside V (P_i), even if this polygon is not null. A non-null Voronoi-Laguerre polygon V (C_i) that does not contain the center of its generating circle is called an empty polygon. Figure 3 shows an example of Voronoi-Laguerre diagram that contains both null and empty polygons. Namely, the Voronoi-Laguerre polygon of the circle P6 is null, and the polygons of the circles P4 and P5 are empty. On the contrary the polygons of the circles P1, P2 and P3 are non-empty and consequently non-null.

Theorem1. Given n circles Pi with centers Pi = (xi, yi) and radii ri , i = 1; : : : ; n, consider the Voronoi-Laguerre polygon V (Pi) for circle Pi.. The intersection of V(Pi) with all circles Pj , with i 6= j, is contained in Pi. In other words, it does not exist any point in V (Pi) contained in some Pj, j 6= I that is not also contained in Pi.

Proof: By contradiction, assume there exists a point P2 V(Pi) contained in Pj for some j 6= i but not contained in Pi. In view of the definition of Voronoi-Laguerre polygon, it must be d_L(Pi, P) < d_L(Pj, P) that is, equivalently, $d_E{}^2$(Pi, P) r_i^2 < $d_E{}^2$(Pj, P) r_j^2: On the other hand, If P is contained in P_j but not in P_i then d_E(Pj, P)rj and d_E(Pi, P)> ri. Substituting these inequalities in Equation 1 we get 0 < 0, which is a contradiction.

IV. A VORONOI-LAGUERRE APPROACH FOR DIVERSE SENSOR DEPLOYMENT

A. statement

1) The sensing and communication radii of sensor s_j are rj and r_i^{tx} , respectively, with i=1,..,N

2) The communication and the sensing radii of any two sensors are such that $r_i + r_j < \min_i r_i^{tx}$,that is any two sensors are able to talk while their circles are contacting

3) Each sensor enquires the coordinates of the AoI and can determine its own location (e.g. using low cost GPS, notice that the algorithm is not particularly sensitive to inexact location).

4) The sensors are loosely synchronized.

5) Sensors move at possibly different speeds $v_{i.}$

B. The Thought

Placing algorithm, called VorLag, determined by the sensor locations over the AoI and their related sensing radii. Such a diagram devides the AoI into disjoint polygons; each has only one generating sensor. If a sensor cannot detect a phenomenon in its polygon, no other sensor can detect it. Hence each sensor uses the information related to its Voronoi-Laguerre polygon to determine the presence of coverage holes and to decide future movements. Sensor deployment protocol runs iteratively. The sensors broadcast their locations and construct their home Voronoi-Laguerre polygons on the basis of the information received from neighbors.

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LAY OUT OF VORLAG ALGORITHM EACH ROUND
Perform neighbor discovery
Compute the Voronoi-Laguerre polygon V(S_j)
if V(Sj) is null
    Do nothing
Else
    if a coverage hole exists
    Compute  Om(Sj)
        Compute locqal coverage
         if (| V_i, Om(s_j)| > Dmax_j )
      Minimize  |  V_i, Om(s_j)| to be  Dmax_j
if (a movement according to V_i, Om(s_j)
      increase the local coverage )
      move according to V_i, Om(s_j)
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V. ON THE USE OF THE VORONOI LAGUERRE ALGORITHM FOR DENSITY DRIVEN DEPLOYMENT

To enlarge our algorithm to contain deployments at varying density we introduce two modications:1) we intro-duce the concept of position dependent sensing radius, 2) we introduce a new limitation to the maximum distance that each sensor can traverse at each round.

VI. USE OF THE VIRTUAL FORCE APPROACH FOR THE DEPLOYMENT OF MOBILE HETEROGENEOUS SENSORS

Among the deployment algorithm proposed for mobile in the sensors in the literature, very few specially for address the problem of sensor heterogeneity, and none are suitable for context due to the many assumption they introduce. We compare it with an algorithm based on virtual forces called Parallel and Distributed Network Dynamics (PDND). In PDND the force exerted by s_i to sensor s_j is modelled as a piecewise linear function. Therefore it is repulsive when the distance between s_i and s_j

VII. INVESTIGATIONAL OUTCOME

We ran three sets of experiments. In the first set we study the deployment of diverse sensors. In the second we consider varying density requirements within the AoI. In the last set, we consider time-varying density requirements due to dynamic missions.

A. Diverse Sensors

In this numbers of sensors complete with VorLag and PDND both require amount of time to reach end coverage when we have less time.

B. Density driven deployment

In the second set of experiments we consider the problem of cover an AoI with varying density. In these experiments, we assume that all sensors are homogeneous, i.e. have the same sensing radius r_s of 5m. We show the average traversed distance In the deployment phase. VorLag shows the best behavior among three algorithms, allowing sensors to complete by traversing less distances with respect to PDND.

C. Dynamic mission arrival

A mission is seen as change in the coverage requirement over the AoI. Center density high around same center have better detection on event. The density is around a mission is set to 0.1. Fig show the final deployment has gotten by VorLag & PDND.

VIII. CONCLUSIONS

Major modifications to the Voronoi based approach to the problem of deploying mobile sensors over an AoI. Sensor deployment at AoI.

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