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A Algorithm for Location in Wireless Sensor Networks Based on Local Demand Level

Hui Yang[1, a], Zhengsheng Ding[2, b]

[1]College of Science, Xi'an University of Science and Technology, Xi'an 710054, China

[2]College of Geology and Environment, Xi'an University of Science and Technology, Xi'an 710054, China

[a]yangh816@aliyun.com, [b]dingzs@xust.edu.cn

Abstract: A Critical problem in wireless sensor networks is localization which determine the geographical locations of sensors. Most existing localization algorithms were designed to work well either in networks of static sensors or networks in which all sensors are mobile. In a wireless sensor network where most sensors are without an effective self-positioning functionality, the geographic location problem of nodes was researched. In this paper, a novel algorithm for location problem in the optimization of Wireless sensor networks (WSNs) was proposed. With the considering of requirements, emergency response time and total system cost, a distribution of the dispatch points can be obtained by the algorithm. Using the Gaussian convolution, the local demands level can be obtained and the distribution based on covers and sorted demands is more efficient. Numerical examples show that the proposed algorithm can solve the location problem in the optimization of emergency systems.

Keywords: Wireless sensor networks, localization, square scaling, soft constraint, Gaussian convolution

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1. INTRODUCTION

With the development of technology, Wireless sensor network has attracted a lot of interest in industry, agriculture and military filed due to the diversity of applications. It consists of countless low cost sensor nodes that are capable of data gathering, data processing and radio communication. Sensor nodes integrated with embedded computation are randomly deployed pervasively for collecting information we are interested in, such as temperature, humidity, light and so on [1]. Then the collected message is transmitted to internet through radio communications. Data that is beyond the defined limit will trigger the alarm system, so as to remind people to take measures appropriate as soon as possible. Localization information is helpful for target tracking. So the accuracy of localization is essential for WSN environments, for localization algorithms that have a low level of accuracy provide useless information.

We consider deploying the sensor networks to finish the function of Urban Emergency Systems. The economy and the convenience are both important and should be considered together in the design process. Many methods and models have been applied to these scenarios [1, 2, 3]. Similar to the publication facilities, the location of emergency facilities requires well design. These facilities will be used to meet the demands when the emergencies happened. The losses of people's lives and property can be reduced. In response to the process of emergencies, timely supply of emergency facilities/resources is the key to improving the efficiency of emergency service. Urban emergency systems must meet the emergency requirements in a limited time, space and resource in order to maximize the time efficiency and minimize the losses. Therefore, the optimization of the emergency systems is help to improve the efficiency and effectiveness of emergency service.

Location-Allocation Problems (LAP) of emergency systems are crucial problem in the optimization of emergency systems [4, 5, 6, 7]. In fact, it is related with the path problems and they affected each other and depended on each other. With the opinion of system optimization, it is necessary to research the Location-Routing Problem (LRP). Currently, many approaches have been conducted on LAP or LPN of general logistics Systems [8, 9] while very few has been conducted on LAP or LPN of emergency response systems. [10] studied the coordinate optimization problem of materials distribution and injured transportation in emergency rescue of natural disasters. The location of temporary medical points, assignment of medical staffs, distribution of emergency supply and decision-making of vehicle transport route are considered. Then a determined mixed integer network flow model of multi-species material has been established and solved by some application software.

This paper discusses the requirement of emergency service, emergency service time and total system cost on each demand point based on the wireless sensor networks (WSNs), and then introduces the Gaussian convolution of urgent demands. A cover algorithm is discussed for the location problem. Based on it, a more efficient distribution of dispatching nodes can be obtained with the considering of sorted demands.

The rest of the paper is organized as follows: In Section 2, we first give the location problem of emergency systems and a general optimization problem is given with a fixed condition. The Gaussian convolution is introduced in Section 3 and an unsorted cover algorithm with fixed radius is given in emergency systems. In Section 4, with the considering of local demand level, a sorted cover algorithm is proposed for the location problem and several numerical examples are presented. The conclusions are given in the last section.

2. RELATED WORKS

The existing research which is known about localization in mobile sensor networks is relatively less and the research in situations where the sensors may be static or mobile is much more less.

We survey some relevant papers in this section, and refer the user to the surveys by Bachrach and Taylor [1] and by Savvides et al. [2] for more comprehensive literature reviews. [4] used received signal strength (RSS) to estimate distances. Ward et al. [7] presented a range-based algorithm relied on the Monte Carlo approach. Range-free localization: He et al. [12] proposed a range -free algorithm called APIT in which all possible riangles of the seeds are constructed. The location of a node is the center of intersection region of all triangles. Sextant [11] proposed a distributed algorithm that uses Beziercurves for estimating the possible locations of the nodes. The nodes estimate their locations by using the location information of their neighbors. Bergamo and Mazzimi [3] presented a range-based algorithm for mobile sensor networks which uses only two static seeds that are located at a specific location in the network and their radio ranges cover the whole network. Recently, we proposed a range-free localization algorithm [6] that works in both static and mobile networks. The primary problem associated with the algorithm in [6] is that it cannot estimate locations well when the radio ranges of sensors are not perfect circles. Tilak et al. studied how often a localization algorithm should be applied in a mobile sensor network. This involves a balance between energy and accuracy – localizing usually wastes energy and localizing occasionally results in having fusty locations at most of the time.

3. LOCATION PROBLEM

After the occurrence of emergency service requirements, the urban should quickly make the appropriate response and it can reflect the urban's emergency management capabilities. Management capacity is determined by the amount of available emergency facilities and maximum effectiveness of these facilities [11]. Emergency management is reflected in early warning, evacuation, public safety and protection such as [12]. Therefore, effective emergency management capabilities by managing the quality and scope of facilities and the effective ability play the most effective use of limited facilities. Emergency facilities should be prepared in some selected dispatching points, and if emergencies service requirements (such as extinguish a fire, ask for a doctor, and so on) occur, managers must quickly select a emergency dispatch point, and transport limited emergency facilities to demand points in a limited time as shown in Figure 9. Proper location of emergency dispatch points will greatly reduce transport costs, improve efficiency of emergency facilities utilization and reduce the losses, called Location Problem (LP) of emergency system.

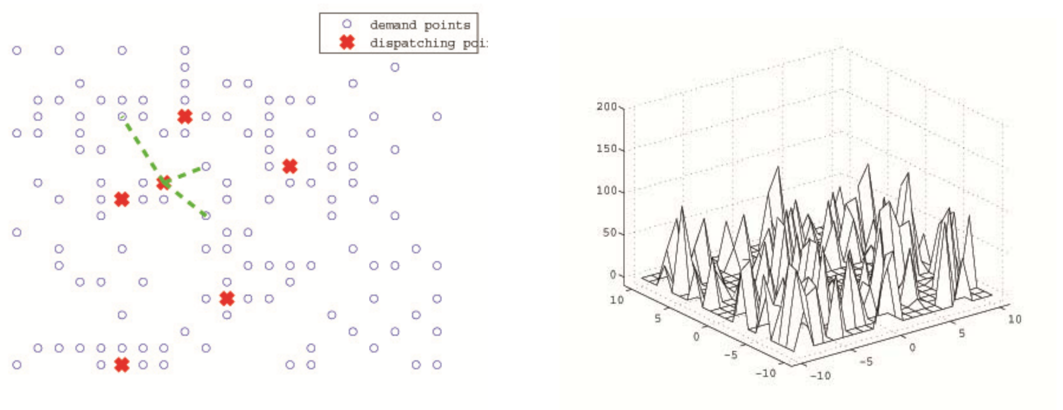
Assumed that there are many service requirements occurred in the past time. The demands distributes on the points $P_i(x_i, y_i)(i = 1,2,\ldots n)$ in the urban. The demand amount on the points are Q_i $(i = 1,2,\ldots n)$. Then the amount and the positions of the distributed points should be determined.

Obviously, the design should satisfy the future requirements. In terms of the past requirements, we can suppose that future distribution be the same as past. If the number of emergency deploying nodes is fixed, it is convenient to establish and solve the programming model. Suppose the number of required deploying nodes for the k, a total of m candidate Emergency Dispatch Point $N_j(x_j, y_j)(j=1,2,\ldots m)$. The cost of unit facility is transferred from dispatching nodes to required ones which is defined by C_{ij} . The cost of unit facility to be prepared on distributed nodes are set to be D_j (j 1 2 ... m) . With the constraint condition of service cost T on each requisite node, then a relative optimization issue can be built as following.

$$\min S(I,X,V)=\sum_{j=1}^{m}\sum_{i=1}^{n}(C_{ij}\cdot I_j\cdot V_{ij})+\sum_{j=1}^{m}(D_j\cdot X_j\cdot I_j) \tag{1}$$

$$\begin{aligned} s.t.\quad & I_j\in\{0,1\} \\ & \sum_{j=1}^{m}(I_j\cdot X_j)=\sum_{j=1}^{m}Q_i \\ & \sum_{j=1}^{m}(I_j\cdot C_{ij})=I_j\cdot X_j,\ j=1,2\cdots m \\ & I_j\cdot C_{ij}\le T, i=1,2\cdots n,\ j=1,2\cdots m. \end{aligned}$$

Where I_j denotes point whether to adopt the dispatching point N_j , X_j denotes the quantity of facilities on dispatching point N_j , V_{ij} is the amount of facilities derived from dispatch point N_j to demand point P_i .



(a) Points random topology (b) Requirement distribution

Figure 1. Points random topology and original demand distribution.

Above problem (1) can be solved if the number k of emergency dispatching points is cohere with supply time T . Otherwise there will be no solution. To avoid this unexpected situation, the number of dispatching points should not be fixed and there are two common solutions. The first one is pre-establishes an additional optimization problem to determine the number of scheduling points, and then solved the above problem (1).The corresponding dynamic programming model will be constructed. The first one consider reasonably about the additional model as the second one will enhance the difficulty of solving problem. Sequentially, it is urgent to obtain a more reasonable solution. As shown in Figure. 1.

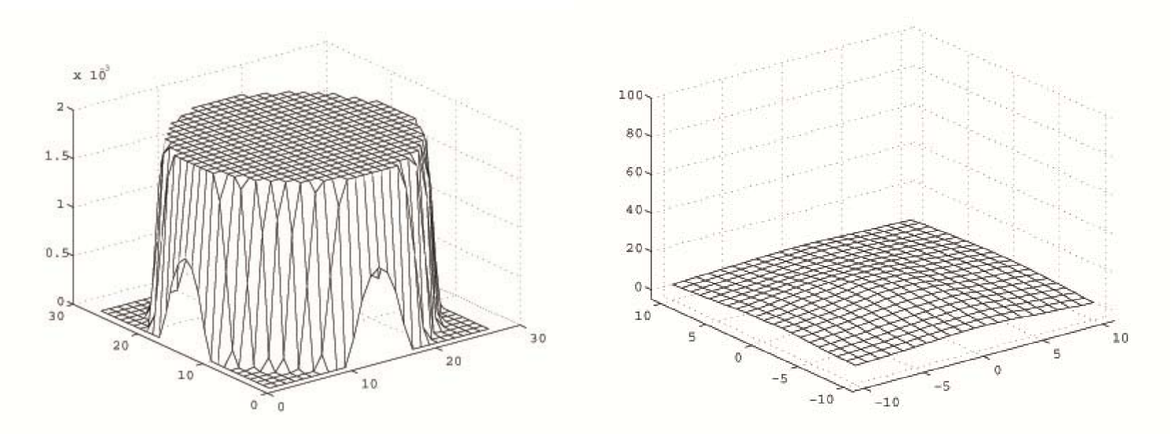
4. GAUSSIAN CONVOLUTION AND LOCAL DEMAND LEVEL

In order to determine the number and location of dispatching points, the Gaussian convolution and local demand level was introduced. Convolution $f*g$ of function f and g can be denoted as following

$$[f*g](x)=\int_{-\infty}^{+\infty} f(t)\cdot g(t-x)dt.$$

Where the function g denote the kernel of convolution to function f . The convolution can be used to construct a more smooth function. The result holds better properties and it has been applied to various practical fields such as signal processing, image processing, information theory, and so on. The original distribution of requirements are disorder and rough, it can tell us few information about the demand intensity. So a new distribution of requirements is expected and it should tell us more about the demand intensity or other important information which are advantageous to solve the problem. For determining the positions of dispatching points, it is a common considering that to obtain the local average demand intensity. And it is sure that there should be more dispatching points in the region where holds higher demand intensity. With this view, the convolution is introduced to get local average intensity of original distribution of requirements.

For a certain original distribution of demands, different kernels lead to different convolution results, For example, the disk kernel and its convolution result was shown in Figure 2.



(a) Disk kernel (b) Convolution result

Figure 2. Disk kernel and the convolution result

5. LOCATION ALGORITHM BASED ON LOCAL DEMAND LEVEL

In this section, we will first proposed a cover algorithm according to the local demand level. A set of circles with the radius d is composed to a cover of the demand region. Efficiency and applicability of algorithm are illustrated by several numerical results. The algorithm is set as following:

Step1. Compute the local demand level through calculating the convolution of original demands $f(x)$ and Gaussian kernel $k(x)$;

Step2. Sorted the demand points according the local demand level by descending;

Step3. Set a proper radius d according to the constraint condition of supply time;

Step4. Generate a set of circles covering the demand region Ω as following procedure according the sorted points.

DO

For the first point P in the sorted point set $PSET$

if it is not in anyone of the circles

then generate a new circle with the center P and erase it from $PSET$

WHILE $PSET$ is not null

6. CONCLUSION

In this paper, we have proposed a cover algorithm for location problem in urban emergency systems. We first discusses the requirement of emergency facilities, service supply time and total system cost in the system, and then introduces the Gaussian convolution of emergency demand distributions. At last a sorted set of circles with radius d is generated to cover the demand region/urban. Numerical results show that the proposed method and algorithm can solve the location problem for optimizing the urban emergency system.

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