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REVIEW ON CITY-WIDE COLLABORATIVE GEOFENCE SITES FOR RENTING AND RETURNING DOCK-LESS SHARED BIKES

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Abstract- The dock-less shared bike systems provide a convenient transportation mode for users to find, ride, or return a bike anywhere via GPS-based smartphone apps, with the bike position turmoil arises as side effects. To solve this problem, the geofence technology has been explored and then equipped in the ride-sharing service. However, the inadequate utilization and unreasonable distribution of the geographical resource impact the effectiveness of the geofence sites seriously. In this paper, we propose a collaborative geofence site selection (CGSS), which first picks up the hotspots based on a density-based and collaboration- inspired method, and then allocate the geofence sites in the top-ranking hotspots. The CGSS aims to optimize the distribution location and the occupied area for each geofence in the city, so as to maximize the satisfactory degree of customers for both coverage ratio and capacity, with the total supplied geographical area for building geofence sites. The experimental results show that the CGSS method distributes geofence sites with a highly satisfactory degree and utilization rate.

Key Words: Geofencing, Collaborative Geofence Site Selection(CGSS), Global Positioning System (GPS)

I. INTRODUCTION

Bike-sharing systems are widely deployed in many major cities, e.g New York, Paris and Beijing , which offer an environment-friendly solution for the first-and-last mile connection and help bridge the gap between existing transportation modes such as subways and bus systems. Dock-less shared bike, which emerges from China, has reinvented the bike riding business and provided a more convenient and flexible mode to citizens. Users can find, ride or return a bike anywhere via GPS-based smartphone apps. There is an unprecedented booming of the dock-less bike systems. For example, Shanghai, the largest metropolis in China, currently has over 1.5 million dock-less shared bikes on the streets.

II. PROPOSED ARCHITECTURE AND ALGORITHM

the framework of CGSS. Based on the real-world data sets, the objective is to formulate a model to determine the location of each geofence site and assign the total geographical area to these chosen geofence sites, so as to maximize the satisfactory degree of customers.

The problem of deploying geofence in the city boils down to ensuring a high satisfactory degree of customers, that is high coverage ratio of the geofence sites and sufficient capacity of each geofence site. Designing a geofence at any location incurs charges in land lease, resource deployment, and equipment maintenance. To maximize the satisfactory degree of customers with a given amount of geographical area, it is in best interests of the city managements to select the geofence sites intelligently such that the designated geofence has maximum utilization. Our model enables city managements to find optimal geofence sites and allocate an optimal amount of area for each geofence site in a large metropolitan area.

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2.1 Customer Mapping–

Previous research in user mobility has shown that user request distribution is temporally and behaviorally influenced . For example, user request density is more populated in city centers than sub- urban areas. Such request patterns profoundly affect the utilization of geofence deployments in any region. An effective server deployment algorithm must consider the origin and destination of any shared bike log for optimal utilization. Therefore, before selecting geofence sites, customer map- ping is an important survey for detecting the real demand for shared bikes. Through this, the customer preference and demand density can be reflected visually.

2.2. Hotspot Detection–

This phase focuses on detecting the hotspots in the city. Specifically, the hotspots are detected utilizing a density-based and collaboration-inspired method. Note that the logs of the shared bikes may be biased and cannot reflect the overall demand and supply for each grid at any time period. Therefore, the collaboration factor should be considered for fear of some hotspots being omitted. The collaboration factor between grids can be reflected through the PageRank value, where grid connecting with more popu- lar grids would be assigned with a higher value. Therefore, in this phase, we detect the hotspots based on the density of the shared bike logs initially, and then the collaboration information is integrated into the model to modify the hotspot omission and consummate the hotspot detection.

2.3. Geofence Site Selection-

With the information of the hotspots detected through Phase II, we aim to allo- cate the geofence sites in the selected top-ranking hotspots in Phase III. Given the geographic resource for building geofence sites, we optimize the schedule and designation of the geofence in the city, so that the satisfactory degree of customers is ensured. The satisfactory degree of customers is defined with two categories: 1) the real destinations of customers are within a certain range from the nearby geofence; 2) the designated area of a geofence can afford the number of returned bikes.

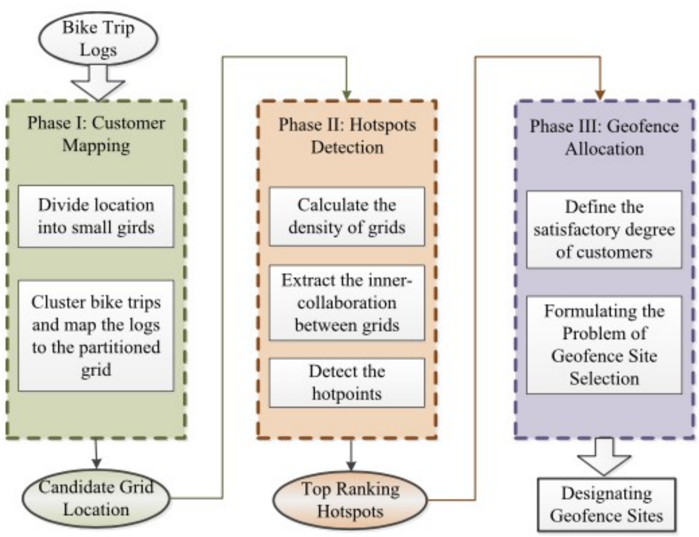


Figure 1. The framework of the CGSS method.

2.3. Algorithm-

To facilitate the understanding of the solution process, we provide a solution algorithm in this subsection. The main solution process is composed of two parts, i.e., hotspots detection and geofence site selection. In terms of hotspots detection, the factor of visiting popularity density and inner- collaboration for each grid can be calculated from the history dataset through Equation. In terms of geofence site selection, we first pick the top H ranked grids to be the geofence sites. The satisfactory degree for the coverage ratio can be calculated from site selection directly. Moreover, the satisfactory degree for the capacity can be determined through Equation. which is a variant of the linear programming problem. For the reason that the number of variables of the system of linear equations is greater than the number of equations, there will be an indefinite number of solutions. In order to reduce the computational complexity, we utilize the Simplex algorithm to find the optimal solution in a limited number of iterations. The specific solution algorithm is represented in Algorithm. 1 as follows.

Algorithm 1 Our Efficient Solution of the CGSS Method

```
for each grid i in N do
    calculate the visiting popularity density factor Vi
    calculate the inner-collaboration factor ICi
    determine the top |H| ranked grids
endfor
calculate the Str based on the geographical location of the top |H|
  ranked grids
find an basic feasible solution for the satisfactory degree
  for capacity as the current best solution CBS
while the CBS does not satisfy the optimality condition do
find another feasible solution through replacing a basis variable
update the CBS and Stc
endwhile
return Str, CBS and Stc
```

Firstly, the factor of visiting popularity density and inner- collaboration for each grid is calculated , with which, the top H ranked grids can be selected to be the geofence sites . Then the satisfactory degree for the coverage ratio can be calculated from site selection directly . Thereafter, to find the geofence site allocation solu- tion with the highest satisfactory degree for capacity, we uti- lize the Simplex algorithm to find the optimal solution in a limited number of iterations. In the end, the optimal solution and the value of satisfactory degree can be gained satisfactorily.

III. Experiment and Result

Comparing the following algorithms:

Random: This approach chooses k grids in Beijing ran- domly to build geofence sites, and the area of each geofence is also randomly designated.

Area-Random: This method focuses on customer request densities. It selects the *top*-$|H|$ hotspots with the density of customer requests. The area of each chosen geofence is designated randomly.

Density-Based: This method also focuses on customer request densities. It selects the *top*-$|H|$ geofence sites in the visiting popularity density. The area of each chosen geofence site is also designated based on the density. The site with a higher customer visiting density would be assigned with more area.

CGSS: This method focuses on both customer request densities and the inner-collaboration between different grids. It selects the *top*-$|H|$ ranked geofence sites. The geographical area for each geofence site is determined with the aim to augment the satisfactory degree of customers.

Rigorous analysis of the above methods using the following performance metrics.

The Satisfactory Degree of Customers: The satisfactory degree refers to the average percentage of customer requests being satisfied by the designated geofence sites. The sat- isfactory degree of customers can be divided into two categories: 1) the satisfactory degree for coverage ratio, where the average percentage of customer requests when the real destinations of customers is within 500m from the nearby geofence; 2) the satisfactory degree for capacity, where the average percentage of customer requests when the designated area of the geofence can afford the amount of rented and returned bikes.

The Utilization Rate of Geographical Area (URGA): Given a number of shared bike logs and the total area for a geofence site, the utilization rate of the geofence sites refers to the max- imum load-carrying capacity. The utilization rate is 1 when the geofence site is always full. The URGA can be derived from.

3.1. The Satisfactory Degree of Customers:

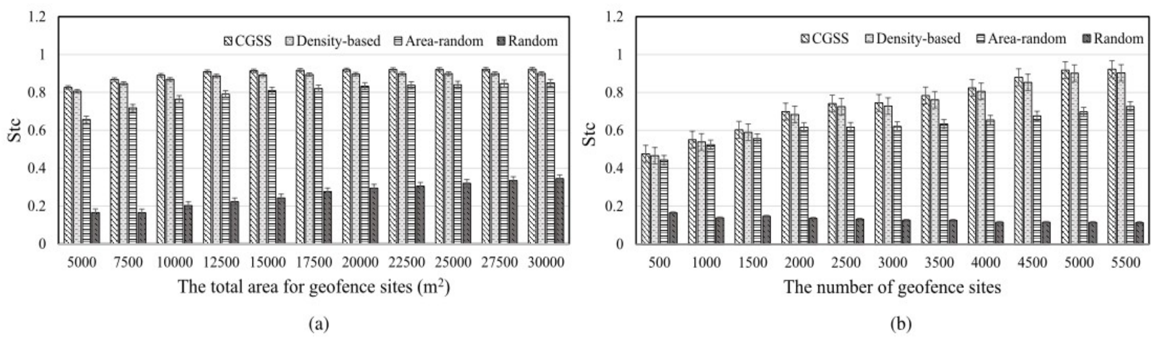


Figure 2: The experimental results of satisfactory degree for capacity. (a) The satisfactory degree for capacity under various amounts of area for geofence sites, when the number of geofence sites is fixed as 4000. (b) The satisfactory degree for capacity under various number of geofence sites, when the area for geofence sites is fixed as 5000 m2

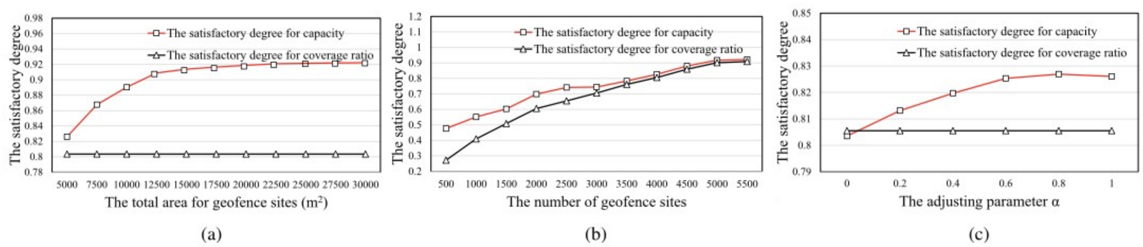
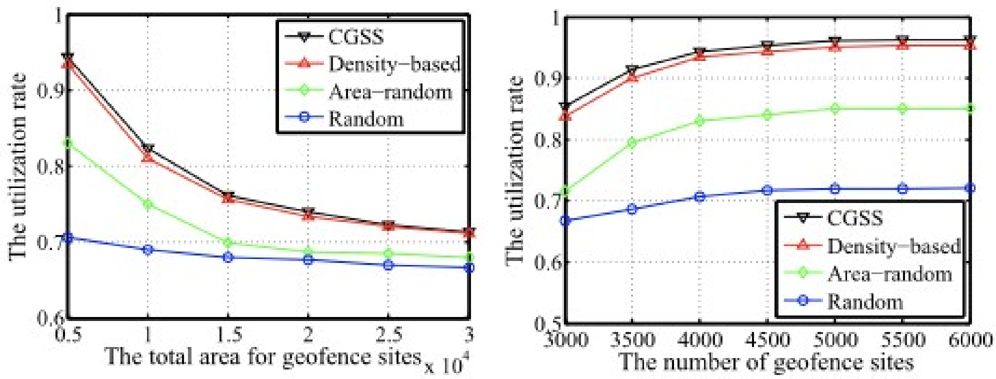


Figure 3: The experimental results of satisfactory degree for coverage ratio and capacity. (a) The satisfactory degree for coverage ratio and capacity under various amounts of total area, when the number of geofence sites is fixed as 4000. (b) The satisfactory degree for coverage ratio and capacity under various number of geofence sites, when the total area is fixed as 5000 m2. (c) The satisfactory degree under various adjusting parameters, when the number of geofence sites is fixed as 4000 and the total area is fixed as 5000 m2.

3.2. The Utilization Rate of Geographical Area (URGA):



(a) (b)

Figure 4: The experimental results of utilization rate. (a) The utilization rate under various amount of total area (the number of geofence sites is fixed as 4000). (b) The utilization rate under various geofence sites (the area for geofence sites is fixed as 5000 m2)

IV.CONCLUSION

We present a novel method called CGSS, which provides an optimal way for city managements to designate geofence sites for dock-less shared bikes in the city. We first detect the hotspots of the dock-less shared bikes in a density- based and collaboration-inspired method. Thereafter, we allocate and designate the geofence sites in the top-ranking grids, aiming at maximizing the satisfactory degree of customers. We mathematically formulate this problem in the form of Linear Programming technology. In the evaluation, we compare our proposed methods with the other three algorithms and find that our method accomplishes the geofence site allocation task with a higher customer satisfactory degree and utilization rate of the geographical area.

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