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# STFLS: A Heuristic Method for Static and Transportation Facility Location Allocation in Large Spatial Datasets

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**Abstract.** This paper solves a static and transportation facility location allocation problem defined as follows: given a set of locations  $Loc$  and a set of demand objects  $D$  located in  $Loc$ , the goal is to allocate a set of static facilities  $S$  and a set of transportation facilities  $T$  to the locations in  $Loc$ , which minimizes both the average travelling distance from  $D$  to  $S$  and the maximum transportation travelling distance between  $D$  and  $S$  through  $T$ . The problem is challenging because two types of facilities are involved and cooperate with each other. In this paper, we propose a static and transportation facility location allocation algorithm, called STFLS, to solve the problem. The method uses two steps of searching for static facility and transportation facility locations. Experiments demonstrate the efficiency and practicality of the algorithm.

**Keywords:** Facility location problem, Static facility, Transportation facility

## 1 Introduction

Facility location problem is an important research topic in spatial analysis which solves problems of matching the supply and demand by using sets of objectives and constraints [1]. The objective is to determine a set of locations for the supply so as to minimize the total supply and assignment cost. For instance, city planners may have a question about how to allocate facilities such as hospitals and fire stations for new residence area. The decision will be made based on the local populations and the capability of the limited resources. Various methods for the single type of facility location problem have been proposed for the above applications [1, 2, 3].

In reality, we often face two types of facilities location problem when the number of the single type of facilities within a service area is inefficient. For example, for emergency medical services, we can locate the hospital locations in such a way that it achieves full coverage of a service with the minimum total travelling distance. This usually ends up the hospital locations close to the dense community. However, for the residents in the sparse and remote area, since the number of hospitals is limited, in order to offer fast response time, the ambulance should be located to shorten the time to access medical services. In this application, two types of facilities need to be located in a region, static facilities (e.g. hospitals) and transportation facilities (e.g. ambulances). The service is supplied to the customers by the cooperation of these two

types of facilities. However, none of the current methods can apply to the two types of facilities location problem directly.

In the paper, the average travelling distance and transportation facility travelling distance are defined as follows:

**Definition 1** Given a set of demand objects  $D$  and a set of static facilities  $S$ , the *average travelling distance (ADT)* is defined as:

$$ADT = \frac{\sum_{d_j \in D} dist(d_j, s_i) * d_j.w}{\sum_{d_j \in D} d_j.w}, \text{ where } s_i \in S, d_j \in D \text{ and } s_i \text{ is } d_j\text{'s assigned static}$$

facility.  $d_j.w$  is a positive number representing the demand of the demand object  $d_j$ .

**Definition 2** Given a set of demand objects  $D$ , a set of static facilities  $S$  and a set of transportation facilities  $T$ , the *transportation travelling distance (TTD)* of the demand object  $d_j$  is defined as:

$$TTD(d_j) = dist(d_j, s_i \parallel t_k) + dist(d_j, s_i), \text{ where } s_i \in S, d_j \in D, t_k \in T \text{ and } dist(d_j, s_i \parallel t_k) \text{ is the distance from a location of a demand object } d_j \text{ to its assigned static facility location } s_i \text{ or the closest transportation facility location } t_k, \text{ whichever is shorter.}$$

The main contribution of the paper is that we introduce a new type of facility location problem regarding to static and transportation facilities and propose a novel heuristic algorithm to solve the problem. Instead of only minimizing the average travelling distance between the static facilities and demand objects, the new problem also considers the constraint between the transportation facilities and static facilities and minimizes the maximum travelling distance of transportation facilities.

## 2 STFLS: Static and Transportation Facility Location Searching Algorithm

Static and transportation optimal facility locations problem is a NP-hard problem. In this section, we propose a heuristic method called Static Transportation Facilities Location Searching Algorithm (STFLS). The algorithm contains of two steps (shown in Fig. 1): static facility location searching and transportation facility location searching. In the following, we will give a detail discussion on these two steps.

### STFLS (D, S, T)

**Input:** a set of demand objects  $D$ , a set of static facilities  $S$  with unknown locations, and a set of transportation facilities  $T$  with unknown locations

**Output:** locations of  $S$  and  $T$

```
/* static facilities locations searching step */
1 SearchStaticFacilityLocations (D,S)
/* transportation facilities locations searching step*/
```

```

2 SearchTransportationFacilitiesLocations(D, S, T,
threshold)

```

**Fig. 1.** Pseudo code of STFLS

## 2.1 Static Facility Location Searching

Searching optimal locations for static facilities is a NP-hard problem. Various methods have been proposed [1, 3]. However, most methods are not efficient enough to deal with large spatial datasets. In this step, we propose a heuristic method to find local optimal locations using clustering. Clustering is the process of grouping a set of objects into classes so that objects within a cluster have high similarity to one another, but are dissimilar to objects in other clusters [4]. The clustering process is used to reduce the searching area.

In each iteration, each static facility and the demand objects assigned to it would be seen as a cluster. Then we search every static facility's optimal location in its cluster and only change one static facility's location to its optimal intra-cluster location which can reduce the average distance most.

## 2.2 Transportation Facilities Location Searching

Locations of transportation facilities depend on both locations of demand objects and static facilities. To reduce the computation time, we use a greedy method in this step. The strategy is that it changes a transportation facility to the location whichever reduces the maximal transportation reachability distance most within each loop and stops if the exchange cannot bring the reduction of transportation reachability distance or the iteration time reaches the redefined times.

## 3 Experiments

### 3.1 Experiments on Synthetic Data

Synthetic datasets for demand objects were created in a  $300 \otimes 300$  area. All values in the following experiments are the average of the results which are from running the algorithm six times. Table 1 shows the comparison between STFLS and the optimal solution when allocating 5 static facilities and 10 transportation facilities to 10,000 demand objects.

	STFLS	Optimal solution
Average traveling distance	27.5 km	25.1km
Maximum traveling distance	157.1km	148.1 km

**Table 1.** The comparison between STFLS and the optimal solution

### 3.2 An experiment on Real Data

This section presents a sufficient-capacity experiment with a real data set from South Carolina, which is to locate five hospitals and three ambulances. The data set consists of 867 census tracts (Census2000), with each treated as a demand object. The population of each census tract is considered as the demand weight of each object, which varies from 197 to 16,745. The total population (or demand) is 4,212,012. Capabilities of the hospitals range from 800,000 to 1,400,000.

Table 2 shows the comparison between the result of using STFLS and that of using a capacitated p-median algorithm [5]. STFLS can reduce the average travelling distance from 59.7km to 56.2 km and reduce the maximum transportation travelling distance from 322km to 260km.

	STFLS	Capacitated p-median
Average traveling distance	56.2 km	59.7km
Maximum traveling distance	260km	322 km

**Table 2.** The comparison between STFLS and the capacitated p-median algorithm

## 4 Conclusion and Future Work

In this paper, we introduce a new type of facility location problem with both static and transportation facilities and propose a novel heuristic algorithm STFLS to solve it. STFLS assigns two types of facilities to the local optimal locations based on the spatial distribution of demand objects and the dependency of the facilities. To our knowledge, STFLS is the first algorithm to handle the location allocation problem about two types of facilities. According to the experimental results, STFLS can accurately allocate two types of facilities into an area.

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