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# Using Voronoi diagrams to solve a hybrid facility location problem with attentive facilities

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ABSTRACT

In this paper, we introduce a novel class of facility location problems, and propose solutions based on Voronoi diagrams. Our solutions locate a set of facilities on a two dimensional space, with respect to a set of dynamic demand. The information about these demand is gathered through modifications of the overall system, into a central decision unit. This influences our objective of minimizing the total loss function. Considering a continuous space and discrete time, facilities are assigned to meet demands in each time cycle. Two distinct approaches are proposed and thoroughly studied, followed by a case study. We call our main algorithm *R*eactive *A*gent *D*ynamic *V*oronoi Diagram *F*acility *S*pread. We also test our solutions empirically through a set of experiments. Considering $n$ and $p$ to be the number of demand points, and the number of facilities in hand, respectively, the time complexity of the algorithm is $O(c(n^2 + p)logn)$ for a complete run of $c$ cycles.


## 1. Introduction

Facility location problems try to locate a number of facilities in order to serve a pre-determined number of demands. This goal is to optimize a collection of objectives through a process known as demand satisfaction. In this paper, we aim to introduce a novel hybrid class of facility location problems which locate facilities on a two dimensional ($2D$) space. Based on a number of assumptions – which will be described in Section 3 –, we propose two variations of an algorithm which attempts to provide service to a collection of dynamic demands. In our algorithm, wee utilize the idea of reactive agents to better satisfy the demands. We assume the facilities to be both **attentive** and **reactive** agents. These two are properties of a very fundamental class of intelligent agents known as reactive agents.

Consider that this is an extended version of our previous paper [8], in which we first introduced our viewpoint toward this problem. In this paper we try to provide a more thorough study by optimizing the main algorithm and also providing the new set of experiments. The rest of this paper is structured as follows: in order to get familiar with the ideas behind our proposed approach, we will introduce facility location problems, Voronoi diagrams and also reactive agents in Section 2. Section 3 formally states the problem and introduces the assumptions for our approach. Section 4 studies our approach through an algorithm called *R*eactive *A*gent *D*ynamic *V*oronoi Diagram *F*acility *S*pread (RA-DV-FS). Section 5 is a case study to better show the ideas behind our approach. Then in Section 6, we put our algorithm in action through a set of experiments, followed by a discussion and some future works in Section 7. Finally Section 8 concludes this paper.

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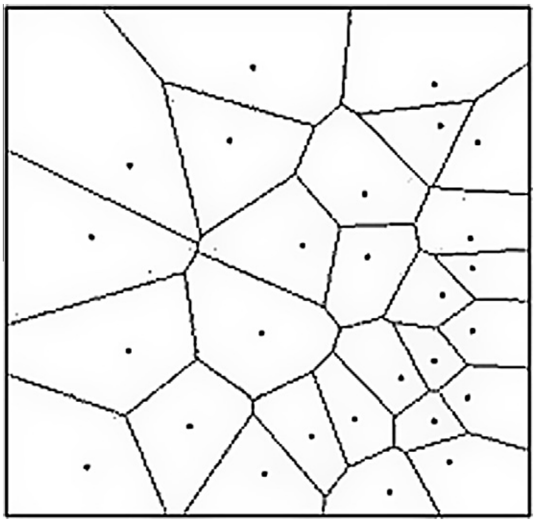

**Fig. 1.** A standard Voronoi diagram for a set of points located on a two dimensional space, depicted inside a bounding box.

## 2. Basic definitions

This section will introduce the basic ideas behind this paper. Three different concepts will be studied in this section.

### 2.1. Facility location problem

The purpose of facility location problems[1] (FLP) is to assign a set of facilities to a collection of demands. The goal is for the facilities to satisfy the demands, either completely or if not possible, optimally. Facility location is an NP-hard problem [16]. Because of the wide range of facility location problems (see [20] for a listing), no generic agreed-upon solution is available. Therefore computer scientists have categorized the variations of this problem and provide specific solutions to cover the defined needs of each category individually. The major categories ([16] modified) are listed below:

- Set Covering (SCFLP) considers to locate the minimum number of facilities required to cover all of the demand nodes.
- Maximum Covering (MCFLP) attempts to locate a pre-determined number of facilities so that the covered demand satisfactory level is maximized, where facilities are not enough to cover all demands.
- p-Median in which we locate $p$ facilities to serve $n$ demand points in a determined space (i.e. the Euclidean space) to minimize the weighted distance between demand points and facilities.
- p-center that utilizes a pre-determined number of facilities to minimize the maximum distance between any demand and its closest facility.
- Dynamic Location problem in which the time dimension is introduced and problem parameters may vary over time.
- Stochastic Location problem where problem parameters are not known with certainty.
- Multi-Objective Location Problem which models the real world considering multiple and even conflicting objectives.

Of all the methods represented for all these categories, two are of most interest to the authors of this paper. These two aspects are the Voronoi diagram viewpoint toward solving FLPs (e.g. [2,10,9]) and the agent viewpoint (see [1,15]). The basic approach for the former is to section the space using Voronoi diagrams, so that different facilities locate in different Voronoi cells. Voronoi diagrams are described in detail in the coming Section 2.2. Of the latter aspect is [16] that looks at the facilities as attentive objects. We consider these objects as reactive agents in this paper. This assumption has precious advantages for us: agents are well suited in dynamic problems and are also good for distributed problems with several evolving/moving entities, cooperating to perform collective and local goals. The key idea here is for agents to be attracted to demands, as like in [16,8].

### 2.2. Voronoi diagrams

Voronoi diagrams are useful and powerful tools that help build rational solutions for several problems [8]. A Voronoi diagram for a set of points (a.k.a. Voronoi sites) is one of the most well studied structures in computational geometry [10]. It can

[1] Also known as the "*Location Analysis Problem*".