Computers and Electrical Engineering 71 (2018) 237–250

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

Multi-objective competitive location problem with distance-based attractiveness for two facilities☆

Sheng-Chuan Wang[a,b,*], Chun-Cheng Lin[b], Ta-Cheng Chen[c,d], Han C.W. Hsiao[e]

[a] Department of Finance, Asia University, Wufeng, Taichung 41354, Taiwan
[b] Department of Industrial Engineering and Management, National Chiao Tung University, East District, Hsinchu 30010, Taiwan
[c] Department of M-Commerce and Multimedia Applications, Asia University, Wufeng, Taichung 41354, Taiwan
[d] Department of Information Management, National Formosa University, Huwei, Yunlin 63201, Taiwan
[e] Sino-US College, Beijing Institute of Technology, Zhuhai, Zhuhai 519085, China

ARTICLE INFO

Keywords:
Multi-objective competitive location problem with distance-based attractiveness for two facilities (MOCLP-2 facilities)
Facility attractiveness
Coverage
Non-dominated range (N.d. range)
Facility selection

ABSTRACT

The multi-objective competitive location problem with distance-based attractiveness for two facilities (MOCLP-2 facilities) is introduced in this paper. A demand point is covered by two facilities, and the preferred facility satisfies the criteria of maximum attractiveness and minimum distance to the demand point. Facility attractiveness is defined as a distance-based coverage of the facility that can be full coverage, no coverage, or partial coverage of the demand point, depending on the within maximum full coverage radius, outside partial coverage radius between those two radii, respectively. The problem is formulated as a multi-objective optimization model to find a facility with maximum attractiveness and minimum distance. The contributions of this paper is that the problem can be tractably decided by the introduced non-dominated range (N.d. range) with less computation. Furthermore, extensive examples for facility selection and sensitivity analysis demonstrate its effectiveness and efficiency by the developed N.d. range.

1. Introduction

Competitive location problem is commonly seen and can be applied to many fields, like wireless sensor networks (WSN). Hotelling [1] introduced the competitive location problem considering two competitors' strategies in the linear market. Fernández et al. [2] noted that the competitive location problem is to open new facilities to compete with existing ones for the given customers. Aboolian et al. [3] suggested that competitive location model with facility attractiveness should be considered. Traditionally, the competitive location model assumes that consumers seek the closest facilities, where each facility can serve as larger area as possible. Nevertheless, the nearest facility may not guarantee the greatest attractiveness. Zhang [4] and Aboolian et al. [3] then suggested that facility attractiveness and distance should be considered together. However, the tradeoff between facility attractiveness and distance were seldom discussed. Accordingly, the multi-objective competitive location problem considering both maximum attractiveness and minimum distance is introduced in this paper.

Facility attractiveness can be represented as a function of distance or other types. For example, Drezner [5] investigated facility attractiveness as a market size. Fernández et al. [2] indicated that facility attraction can be expressed by different functions of

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Guest Editor Dr. J-S Sheu.

* Corresponding author at: Department of Finance, Asia University, Wufeng, Taichung 41354, Taiwan.
E-mail addresses: tony_w@asia.edu.tw (S.-C. Wang), cclin321@nctu.edu.tw (C.-C. Lin), tchen@asia.edu.tw (T.-C. Chen), feliron@gmail.com (H.C.W. Hsiao).

https://doi.org/10.1016/j.compeleceng.2018.07.013
Received 15 September 2017; Received in revised form 13 June 2018; Accepted 24 July 2018

distance between facility and customer. Zhang [4] presented a model for solving the optimal location decided by the location site and product price, where attractiveness in this model is a strictly decreasing function of distance. Aboolian et al. [3] showed that attractiveness can be the factors of size, appearance, accessibility, layout, and product variety of a facility to be expressed as a function of travel distance to customer. Facility attractiveness can also be represented as the coverage of a facility. For example, Zhang and Rushton [6] proposed a model using a utility function with defined coverage. Facility coverage can be a function of radius as well. Berman et al. [7] defined the cost of constructing a facility as a function of its coverage radius (attractiveness). In this paper, facility attractiveness is presented as a distance-based coverage of a facility.

Berman et al. [8] surveyed the covering location models, such as gradual cover, variable radius and cooperative cover models. There are different kinds of coverage distances (or radii) represented as facility coverage. The binary type of facility coverage that is denoted as one inside a specific distance and zero outside the range can be found in Location Set Covering Problem (LSCP) [9], Maximal Covering Location Problem (MCLP) [10], and Maximal Expected Coverage Location Problem (MEXCLP) [11]. Facility coverage can be divided as well into three categories: *full coverage* within the maximum full coverage radius; *no coverage* outside the maximum partial coverage radius; and *partial coverage* within these two coverage radii. Also, partial coverage can have a variety of forms. For example, Infante-Macias and Muñoz-Perez [12] discussed the competitive location of one new facility with constant partial coverage of 0.5. Church and Roberts [13] proposed a generalized coverage model, where its partial coverage is a decreasing function of distance. Berman and Krass [14] introduced the Generalized Maximal Covering Location Problem (GMCLP), where the partial coverage is a decreasing step function of the distance between the facility and demand point. Partial coverage as a decreasing linear function of the distance included in the "quality of service" function has discussed by Araz et al. [15]. Additionally, the "gradual covering problem" [16], the gradual coverage decay model [17], cooperative covering problems [18], and the maximal covering location model in the presence of partial coverage (MCLP-P) [19] have reported that the demand point is partially covered by the facility with gradual coverage decreasing from the shortest to longest coverage radii.

The various coverages mentioned previously have applied to WSN. The sensing model in WSNs represents the probability of target detection for the sensor (Abdollahzadeh and Navimipour [20], Mohamed et al. [21]). It can be classified as deterministic and probabilistic sensing models, respectively. In deterministic sensing model, the probability to the target is 1 within the sensing range and 0 otherwise. In probabilistic sensing model, the probability to the target is 1 within the inner sensing range, 0 outside the outer sensing range, and vary as a function of distance between both ranges. Vatankhah and Babaie [22] proposed optimized bidding-based coverage improvement algorithm to decrease the overlapping area of the hybrid wireless sensor networks and minimize the number of moved nodes. They also effectively adjusted sensing radius of nodes based on the Delaunay triangulation. Some practical applications have implemented in the literatures. Berman et al. [23] propose the cooperative cover model to locate sirens in North Orange County, California, where the aggregated signals can be regarded as a function of distance. Erdemir et al. [24] worked on the case study using motor vehicle crash data and emergency hospital data for the state of New Mexico with the developed set cover with backup model (SCBM) and maximal cover for a give budget model (MCGBM). Hence, facility coverage utilized in this paper is represented as a full coverage within the maximum full coverage radius, no coverage outside the maximum partial radius, and partial coverage, as a decreasing distance function between both radii.

The proposed problem is extended by multi-objective competitive location problem with distance-based attractiveness (MOCLP) presented by Wang and Chen [25], and defined as "multi-objective competitive location problem with distance-based attractiveness for two facilities" (MOCLP-2 facilities). The difference between these two problems is that MOCLP-2 facilities reduces MOCLP to one demand point and two competitive facilities. Assume that there are two competitive facilities (for example: wireless stations) and one demand point (for example: mobile phone) on the same plane. The attractiveness of the facility can be represented by the distance-based coverage. The full coverage provided by the facility is within the maximum full coverage radius, no coverage outside the maximum partial coverage radius, and partial coverage between full and partial coverage radii, respectively. In order to reduce the complexities of the problem, two competitive facilities with full and/or partial coverage regions overlapped are assumed to provide in the market with same prices, products/services and setup costs. The demand point locates between two competitive facilities. The purpose of this paper is to find one of two competitive facilities to cover (serve) a demand point, where the selected facility can provide the greatest attractiveness (coverage) and least distance between them, simultaneously. Since the selected facility cannot guarantee the largest attractiveness associated with the shortest distance to demand point, the tradeoff of maximum attractiveness and minimum distance can be formulated as a multi-objective optimization model. The presented model is to find two pairs of solutions, which are dominated or non-dominated. In case that two pairs of solutions are non-dominated, the selected facility is not better than the other unselected one. The non-dominated range (N.d. range) is developed to facilitate the facility selection where demand point locates between two competitive facilities.

This paper is organized as follows. In Section 2, the distance-based facility coverage is formulated and the multi-objective distance-based attractiveness competitive location problem with two facilities is presented. Section 3 introduces the mathematical formulation of the problem and the criteria for facility selection with respect to the developed non-dominated range of two competitive facilities. Some instances of the numerical experiments with decreasing linear function of distance for partial coverage and sensitivity analysis for demand point among two competitive facilities are demonstrated in Section 4. Finally, some conclusions and further works are described in Section 5.

2. Problem description

Facility attractiveness is represented as the coverage of the facility and presented as the full coverage of a facility within the maximum full coverage distance (radius), no coverage outside the maximum partial coverage radius, and partial coverage between