Clustering Approach Using Artificial Bee Colony Algorithm for Healthcare Waste Disposal Facility Location Problem

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ABSTRACT

In this study, an Artificial Bee Colony (ABC) based clustering algorithm is proposed for solving continuous multiple facility location problems. Unlike the original version applied to multivariate data clustering, the ABC based clustering here solves the two-dimensional clustering. On the other hand, the multiple facility location problem the proposed clustering algorithm deals with is aimed to find site locations for healthcare wastes. After applying ABC based clustering algorithm on test data, a real-world facility location problem is solved for identifying healthcare waste disposal facility locations for Istanbul Municipality. Geographical coordinates and healthcare waste amounts of Istanbul hospitals are used to decide the locations of sterilization facilities to be established for reducing the medical waste generated. ABC based clustering is performed for different number of clusters predefined by Istanbul Metropolitan Municipality, and the total cost—the amount of healthcare waste produced by a hospital, multiplied by its distance to the sterilization facility—is calculated to decide the number of facilities to be opened. Benchmark results with four algorithms for test data and with two algorithms for real world problem reveal the superior performance of the proposed methodology.

KEYWORDS

Artificial Bee Colony, Clustering Algorithms, Healthcare Waste Disposal Facility Location, Real World Problem

INTRODUCTION

Facility Location Problem (FLP) is defined by Tavakkoli and Shayan (1998) as “locating \( n \) facility to \( m \) locations \( (n<m) \) to minimize the transportation costs”. These problems consider identifying the places of the facilities to satisfy customers’ demand and, assigning every customer to a specific facility location under defined constraints. These constraints define the specific characteristic of the FLP (Daskin, 1995):

- Whether the facility locations are selected from a finite/infinite set of possible locations; continuous/discrete problems;
- Whether the facility capacities are limited; capacitated/uncapacitated problems;

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• Whether the facilities to be opened are singular or plural; multi-facility problems;
• Whether the facility demands are static or dynamic; problems with time periods;
• Whether the facility demands are stable or subject to change; deterministic/probabilistic problems;
• Whether the product is singular or plural; multi-product problems;
• Whether the problem has one/more objectives; multi-objective problems;
• Whether the problem is hierarchic; multi-stage problems.

The use of clustering methods, that aim to separate and group elements in a data space depending on similarity, is seen for location selection problems in literature due to the four components that characterize the location problems (ReVelle & Eiselt, 2005); (1) customers located on points, (2) facilities to be located, (3) a metric that indicated distances between customers and facilities, and (4) a space in which customers and facilities are located. The facilities that are to be located are assumed to be desirable in the sense that the closer they are to the customers, the better the value of the objective function. Yet the location of healthcare waste disposal facilities may have different conditions based on the treatment system that are thermal processes, chemical processes, biological processes, mechanical processes, and irradiation technologies respectively. The choice of treatment system involves various factors such as, waste characteristics, quantity of wastes for treatment and disposal, technology capabilities, environmental and safety factors, public acceptability, regulatory requirements and costs – many of which depend on local conditions and consequent decisions (World Health Organization, 2014). The most established waste treatment technologies focus on disinfection that is realized with thermal processing in autoclaves. Autoclaves have the advantage of being designed in various capacities that are suitable to fit every area preferred, and every source generating medical waste can sterilize its own load. On the other hand, since the handling of large amounts of medical waste require special precautions, in big cities municipalities manage the collection and treatment of healthcare waste, and local healthcare waste disposal facility locations are identified and facilities with required capacities are established for treatment.

In this study, Artificial Bee Colony (ABC) clustering algorithm is exploited for an uncapacitated continuous multiple facility location problem for a healthcare waste disposal facility. The contributions of our paper are as follows. In this paper, Artificial Bee Colony (ABC) based clustering algorithm is used for solving continuous multiple facility location problems for the first time. This is the first contribution. Second contribution is that the proposed algorithm is applied for medical waste disposal facility location. According to our knowledge this is the first study in the healthcare management literature.

The paper is organized as follows; in Section 2 the mathematical definition of the uncapacitated continuous multiple facility location problem (MFLP) subject to this study is given. Literature review on the application of clustering algorithms for FLP is given in Section 3. Section 4 describes the general information about the ABC algorithm and its application for clustering. In Section 5, initially the results of the benchmark tests applied with library data to evaluate the performance of ABC clustering are reported. This section then covers the case study for a real-world problem; alternative healthcare waste disposal facility locations are evaluated for Istanbul and the results are explained and summarized with tables. The experimental results are both giving the performance of clustering method using ABC algorithm, and the alternatives of sterilization facility location and capacities for the company of Istanbul Municipality that is responsible for healthcare waste collection and disposal. Four benchmark algorithms are also applied to the real-world data. Finally, the last section is for concluding the findings of the research.

PROBLEM DEFINITION

In this research a continuous uncapacitated multiple facility location problem (MFLP) is studied. Continuous MFLPs are concerned with determining the location or coordinates of c facilities in a
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