INS 10926
30 June 2014
ARTICLE IN PRESS
No. of Pages 9, Model 3G
Information Sciences xxx (2014) xxx–xxx
Contents lists available at ScienceDirect
Information Sciences
journal homepage: www.elsevier.com/locate/ins

A hybrid Firefly-Genetic Algorithm for the capacitated facility location problem

Q1 A. Rahmani, S.A. MirHassani *

Faculty of Mathematics and Computer Science, Amirkabir University of Technology, Tehran, Iran

A R T I C L E I N F O

Article history:
Received 17 January 2011
Received in revised form 3 May 2014
Accepted 1 June 2014
Available online xxxx

Keywords:
Firefly algorithm
Q3 Genetic algorithm
Capacitated facility location problem
Meta-heuristic

A B S T R A C T

Capacitated facility location problem (CFLP) is a well-known combinatorial optimization problem with applications in distribution and production planning that is classified as an NP-Hard problem. The aim is to determine where to locate facilities and how to move commodities such that the customers' demands are satisfied and the total cost minimized. In this paper, a new hybrid optimization method called Hybrid Evolutionary Firefly-Genetic Algorithm is proposed, which is inspired by social behavior of fireflies and the phenomenon of bioluminescent communication. The method combines the discrete Firefly Algorithm (FA) with the standard Genetic Algorithm (GA). It is devoted to the detailed description of the problem, and an adaption of the algorithm. Computational results on random generated problems consisting of 2000 locations and 2000 customers are reported.

1. Introduction

The capacitated facility location problem (CFLP) is a well-known combinatorial optimization problem. It consists of deciding which facilities to open from a given set of potential facility locations and how to assign customers to those facilities. The aim is to minimize total fixed and shipping costs subject to satisfying customer's demand and make use of facilities up to their capacity. The applications of the CFLP including location and distribution planning, lot sizing in production planning (see [33]), and telecommunication network design is reported in Kochmann et al. [23], Mirzaian [31], Boffey [6], Ivan et al. [19] and Chardaire [8]. For a detailed review of the field, see Francisco [17], Eiselt [15], Owen et al. [32], ReVelle et al. [35] and Daskin [12].

There are three major areas based on the solution space in which the problems are modeled: (1) continuous problems, (2) network problems and (3) discrete problems. When a set of demand locations and a set of candidate facility locations are given, the problem is usually concerned with the decisions on where to locate facilities in order to minimize the total cost for constructing facilities and satisfying demands subject to a set of constraints.

Different methods including exact algorithms, heuristics, and meta-heuristics are employed to obtain a good solution to the problem. Exact solution methods based on branch-and-cut and branch-and-price are considered by Klose et al. [22], Lorena et al. [26], Senne et al. [37] and Margaret et al. [29]. The Lagrangean relaxation is proposed by Wu et al. [40], Zhanguo et al. [43] and Cortinhal et al. [10] and the Benders' decomposition algorithm are reported in Wentges [39] and Magnanti et al. [28]. Heuristic solution methods as well as approximation algorithms were proposed by Domschke et al. [14], Mateus et al. [30], Shmoys et al. [38] and Korupolu et al. [24]. Neighborhood based methods for the related p-median

Q2 * Corresponding author. Tel.: +98 9121732421.
E-mail address: A_MirHassani@aut.ac.ir (S.A. MirHassani).

http://dx.doi.org/10.1016/j.ins.2014.06.002

problem and the CFLP with single sourcing were developed by Rolland et al. [36] and Delmaire et al. [13]. Evolutionary methods for the competitive facility location problem were suggested by Qiang et al. [34].

In class of heuristic algorithms, the Firefly Algorithm is a novel and interesting population based heuristic. It is based on fireflies' behavior and was developed by Yang [42], for solving continuous optimization problems. A mechanism of firefly communication via luminescent flashes and their synchronization has been imitated effectively in various techniques of wireless networks design, dynamic market pricing and mobile robotics Lukasik et al. [27] by the simulation of the social behavior of fireflies. The swarm intelligence optimization technique is based on this assumption that a solution of an optimization problem can be perceived as agent (firefly) which glows proportionally to its quality in a considered problem setting. Consequently each brighter firefly attracts its partners (regardless of their sex), which makes the search space being explored more efficient. Based on Yang, [41], this algorithm is very efficient in finding the global optima with high success rates. Our computational results show that the algorithm is superior to PSO in terms of efficiency and success rate. The firefly algorithm for continuous optimization tasks has been proposed in Lukasik et al. [27]. Their experimental evaluation demonstrates efficiency of the algorithm.The applications of Firefly Algorithm are reported in areas of image processing [44], queuing systems [25], Non-Linear Optimization Problems [7,2], economics [43,18,3], Scheduling [20], and multimodal optimization [41]. One of the overall motivations for this work was efficiency of the firefly algorithm in optimizing continuous problems reported by researchers. So it is predictable that this algorithm would be impressive to solve discrete optimization problems. The contribution of this paper is to introduce the basic steps of the discrete Firefly algorithm in order to solve CFLP; in fact the present work emphasizes on the implementation aspects of combining the Genetic algorithm [16] and Firefly algorithm to evolve as a new hybrid Firefly-Genetic Algorithm which explores the search space for optimal solution more precisely.

The remainder of the paper is organized as follows. In section 2, the problem is formulated as a mixed-integer program. Section 3 describes the proposed solution procedure and Section 4 gives computational results that have been obtained for a set of problem instances with up to 2000 potential facility locations and 2000 customers and then a comparison between the proposed methods and some heuristic and metha heuristic are also delivered.

2. Problem formulation

A network is considered with one layer of facilities in which locations of facilities have to be decided. Thus there are a set of potential sites and a set of customers; customer's demands are known and each facility has a capacity. Also, the fixed cost of building a new facility and the unit transportation cost of commodity among facilities and customers are known.

The CFLP is usually stated as the following linear mixed-integer problem:

$$
\begin{aligned}
P_1:\min\quad & \sum_{i\in N} f_i y_i + \sum_{i\in N}\sum_{j\in M} c_{ij} d_j x_{ij}, && \\
\text{s.t.}\quad & \sum_{i\in N} x_{ij} = 1, \quad j\in M, && (1)\\
& \sum_{j\in M} d_j x_{ij} \leqslant s_i y_i, \quad i\in N, && (2)\\
& x_{ij} \leqslant y_i, i\in N, \quad j\in M, && (3)\\
& x_{ij} \geqslant 0, i\in N, \quad j\in M, && \\
& y_i \in \{0,1\}, \quad i\in N, &&
\end{aligned}
$$

where N is the set of potential facility sites and M is the set of customers; c_{ij} is the cost of supplying one unit of customer's demand j from facility i and d_j is the total demand of customer j. Furthermore,f_i is the fixed cost of operating facility i and s_i is its production capacity. The binary variable y_i is equal to one if facility i is open and 0 otherwise. Finally, variable x_{ij} denotes the fraction of customer's demand j met by facility i. The objective function minimizes the total cost caused by transporting commodities from open facilities to customers and the cost of building facilities. Constraints (1) require that all customers' demands be met and constraints (2) ensure that total flows moving out from each open facility do not exceed its capacity. Variable upper bound, (3) ensures that no customer can be supplied from closed facility.

3. Discrete firefly algorithm

There are about two thousand firefly species, and most fireflies produce short and rhythmic flashes. The pattern of flashes is often unique for a particular species. The flashing light is produced by a process of bioluminescence, and the true functions of such signaling systems are still debated. However, two fundamental functions of such flashes are to attract mating partners (communication), and to attract potential prey. In addition, flashing may also serve as a protective warning mechanism. The rhythmic flash, the rate of flashing and the amount of time form part of the signal system that brings both sexes together. Females respond to a male's unique pattern of flashing in the same species, while in some species female fireflies can mimic the mating flashing pattern of other species so as to lure and eat the male fireflies who may mistake the flashes as a potential suitable mate. We know that the light intensity at a particular distance D from the light source obeys the inverse