Solving Health Care Facility Location Problems with New Heuristic Algorithm Method

Mohammad Taghi Valipour, Arman Nedjati, and Reza Kazemi

Abstract—In recent years, there has been much conservation about the issue healthcare location problem. In this paper we focus on emergency aspect of healthcare that related to allocate facilities. The best locations for some health care facilities are allocated according to different covering distances. We present IPSO (Improved Particle swarm optimization), as a powerful heuristic algorithm to maximizes the population assigned to a facility within the coverage distance. The proposed method was compared with the results of the LINGO software, GA. The results of this comparison show that IPSO can achieve better results for the solution in a faster time.

Index Terms—Maximum covering model, healthcare location, IPSO.

I. INTRODUCTION

Facility location studies are generally devoted to the location of a set of resources or service facilities to optimally serve a given set of existing customer or demand facilities.

The location of facilities is critical in both industry and health care. In industry, poorly located facilities or the use of too many or too few facilities will result in increased expenses and/or degraded customer service [1]. In healthcare system decision, any erratic decision may lead to death and disease. Any unsuitable location decision will result in undesired situations such as increased cost, capital costs, and degraded patient service. Similarly the demand allocation to these facilities has a direct impact on the whole system's efficiency. This location-allocation model plays a significant role in health service planning, as it provides a framework for investigating accessibility problems, comparing the quality (in terms of efficiency) of previous location decisions, and providing alternative solutions to change and improve the existing system[2]. In this case some models are suggested for healthcare location models; set covering model, maximal covering and model p-median model. All three models are in the class of discrete facility location models, in these models assume that there is a finite set of candidate locations or nodes at which facilities can be sited. Thus, we might represent a city by several hundred or even several thousand points or nodes.

Maximal Covering Location Problem (MCLP) first proposed by Church and Revelle [3] is one of the most common models employed in public healthcare planning due

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to limited budget as it maximizes population to be covered given a limited number of fixed facilities. In a standard MCLP, one seeks location of a number of facilities on a network in such a way that the covered population is maximized. A population is covered if at least one facility is located within a pre-defined distance of it. This pre-defined distance is often called coverage radius. The choice of this distance has a vital role and affects the optimal solution of the problem to a great extent. Numerous approaches have been developed over years to solve the Maximal Covering Location Problem which can be mainly classified into exact approaches, Data analysis, Simulation, Muticriteria decision analysis, e) Heuristics, Meta-heuristics, Hybrid approaches or combinations of the above. The exact approaches or the mathematical programming approaches involve the use of techniques such as linear programming, integer programming, multi-objective optimization etc. to arrive at optimal solutions. [4] Used linear program to solve plant location. A Metaheuristic is an approach used for optimization by iteration in the neighborhood of solution space. Examples of Metaheuristics are simulated annealing, Tabu search, genetic algorithms etc. In past decade several heuristics have been designed for the capacitated maximum covering problem. Resende [5] studied the performance of GRASP in solving the maximal covering problem. De Assis Correa, Lorena, and Ribeiro [6] analyzed the probabilistic version of MCLP in which there is one server per center. They used a combination of column generation and covering graph approaches in order to solve this problem. Berman and Krass [7] considered partial coverage of customers for a general class of MCLP. Batanovic, Petrovic, and Petrovic [8] suggested maximal covering location problems in networks with uncertainty. Murray and Church [3] apply simulated annealing for location allocation problem. Tabu search for location allocation problems was investigated by Ohlemüller, Chan and Kumar [9] apply multi ant colony optimiza-tion approach for customer's allocation.

Genetic algorithm was widely applied to solve the problem because of its' unique self-organization and auto-adapted. Genetic algorithm can extremely effectively solve the multi-objectives NP complete question. Owen and Daskin [1] have used GAs to solve a complex model in strategic facility location. Shavandi and Mahlooji [10] presented a fuzzy location–allocation model for congested systems and called it fuzzy queuing maximal covering location–allocation. In this paper a new hybrid method based on particle swarm optimization to solve MCLP is proposed. The remainder of the paper is organized as follows. In Section II, we give a mathematical programming formulation for. In Section III new optimization algorithm used to solve the described. A detailed computational comparison between proposed

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algorithm and other optimization methods is discussed in Section IV. Section V contains some conclusions and summarizing.

II. FORMULATION OF THE PROBLEM

The following formulation, adapted from Pirkul and Schilling (1991) is used to model the problem:

$$\begin{aligned} \max \sum_{i \in I} \sum_{j \in J} c_{ij} a_i x_{ij} \\ \sum_{j \in J} Y_j &\leq P \end{aligned}$$

$$\begin{aligned} \sum_{j \in J} x_{ij} &= 1 \qquad i \in I \\ \sum_{j \in J} a_i x_{ij} &\leq Y_j K_j \qquad j \in J \end{aligned}$$

$$\begin{aligned} x_{ij}, y_j &= \{0, 1\} \qquad i \in I , j \in J \end{aligned}$$

where

I is the index set of all demand nodes,

J is the index set of all facility sites

ai is the demand volume at node i,

Kj is the workload capacity for a facility at site j, *p* is the number of facilities to be sited, *S* is the maximum service distance,

dij is the travel distance from demand node i to facility j,

$$x_{ijk} = \begin{cases} 1 & \text{if } d_{ij} \le s \\ 0 & Otherwise \end{cases}$$

$$x_{ijk} = \begin{cases} 1 & \text{if demand node i is served by facility j} \\ 0 & Otherwise \end{cases}$$

$$x_{ijk} = \begin{cases} 1 & \text{if a facility is sited at j} \\ 0 & 0 \text{therwise} \end{cases}$$

The objective function maximizes the population assigned to a facility within the coverage distance S, such that cij is equal to 1 ifd_{ij} \leq s.

III. IMPROVED PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) is an evolutionary computation technique, introduced by Kennedy and Eberhart [11]. The main idea is based in the way birds travel when trying to find sources of food, or similarly the way a fish school will behave. The way this behavior is modeled, is that the "particles" inside the "swarm" (or population) are treated as solutions to a given problem. The solution space for that problem is where the particles will be moving or traveling through, searching for the best solutions to the problem. The particles will travel following two points in the space; a leader in the swarm, which is chosen according to the global best solution found so far', and its memory. Every particle has a memory, which is the best solution visited by that specific particle [12]. According to [13] Some experimental results show that PSO has greater "global search" ability, but the "local search" ability around the optimum is not very good. In order to enhance "local search" ability of PSO, an improved particle swarm optimization was introduced in this paper, which was PSO with Mut the flowchart of the method is given in Fig. 1.



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IV. COMPUTATIONAL RESULTS

In order to evaluate the proposed hybrid IPSO, two numerical examples are applied. The presented model is solved by the Lingo 8 software and the proposed IPSO algorithm. The proposed algorithm is coded in MATLAB in a windows XP environment. The related results are compared with the results of Lingo and GA. Note that as to our knowledge there is no recent benchmark problems with the same parameter values (S and capacity values) are available for comparison. The network consists of 20 nodes and all the nodes in the network were considered to be candidates for facility location as well as demand nodes.

TABLE I: COMPARISON OF TYPICAL RESULTS BETWEEN IPSO, GA, AND LINDO (BASED ON OBJECTIVE FUNCTION VALUES).

S	Utiliz	ation	LINDO		
	MA	MIN	IPSO	GA	OPTIMAL
100	Х				SOLUTION
	120	0	300,900,216	303,930,220	302,950,400
	160	0	329,943,812	329,973,812	329,973,800
	200	0	314,766,348	334,781,428	334,781,400
	120	0	320,349,882	320,349,882	320,349,900
125	160	0	357,336,233	347,376,253	347,376,300
	200	0	338,150,008	352,184,001	352,184,000
	120	0	346,138,633	346,164,655	346,168,200
150	160	0	358,183,326	370,183,343	370,183,300
	200	0	377,391,822	377,391,822	390,594,500
175	120	0	337,975,380	380,990,395	380,990,500
	160	0	387,574,444	390,594,424	390,594,400
	200	0	400,400,000	404,400,000	404,400,000

S	Utiliz	zatio	n	LINDO	Locations	
	М	Μ	IPSO	GA	OPTIMAL	Locations
	AX	Ι			SOLUTIO	
10		Ν			Ν	
0	12	0		2,3,5,10,13		2,3,5,10,1
	0	0	2,3,5,10,13,	,15	2,3,5,10,13,	3,15
	16	0	14	2,3,5,10,13	15	2,3,5,10,1
	0		2,3,5,10,13,	,15	2,3,5,10,13,	3,15
	20		14	2,3,5,10,13	15	2,3,5,10,1
	0		2,3,5,10,13,	,15	2,3,5,10,13,	3,15
			14		16	
	12	0	2,3,5,6,13,1	2,3,5,6,13,	2,3,5,6,13,1	2,3,5,6,13,
12	0	0	9	19	5	19
5	16	0	2,3,5,6,13,1	2,3,5,6,13,	2,3,5,6,13,1	2,3,5,6,13,
	0		9	19	5	19
	20		2,3,5,6,13,1		2,3,5,6,13,1	2,3,5,6,13,
	0		5	2,3,5,6,13,	5	15
				15		
	12	0	3 4 6 10 13	3 4 5 10 13	3 5 0 11 13	3 5 9 10 1
15	0	0	19	19	19	3,5,9,10,1
0	16	0	3461013	3451013	2451013	345101
0	0	0	19	.19	19	3.19
	20		3 5 10 13 1	3 5 10 13 1	3 5 10 12 1	3 5 10 12
	0		6.18	6.20	3.19	13.19
			.,	.,=~	- , - ,	-,
	12	0	1,2,7,9,12,1	1,2,7,9,12,	1,2,7,9,12,1	1,5,7,9,12,
17	0	0	3	13	3	13
5	16	0			3,5,8,12,14,	2,4,8,12,1
	0		2,4,8,11,14,	2,4,8,12,13	18	3,19
	20		19	,19	2,7,9,12,14,	2,6,9,13,1
	0			2,4,10,12,1	18	8,19
			2,4,9,11,18,	8,19		
			19			

TABLE II: COMPARISON OF TYPICAL RESULTS BETWEEN IPSO, GA, AND LINDO (BASED ON FACILITY LOCATIONS).

V. CONCLUSION

In this study which was a healthcare location problem, the emergency phase of healthcare has been focused. Allocating healthcare facilities for coverage of most of distances was main goal of this study. We identified that Improved Particle Swarm Optimization is a powerful algorithm for maximizing this coverage. Also the problem was tested with Lingo and Genetic Algorithm, so the result shows the excellence of IPSO for this kind of problems.

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