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Evaluation and comparison of Genetic Algorithm and Bees Algorithm for location–allocation of earthquake relief centers

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ABSTRACT

One of the important steps in the earthquake disaster management is the establishment of temporary relief centers, to provide the basic helps and support in short time. Finding optimum location for these centers with adequate covering of the urban areas is not a trivial problem. The meta-heuristic algorithms are promising methods, capable of solving such complex optimization problems. The goal of this research was to compare the performance of Genetic Algorithm (GA) and Bees Algorithm (BA) in finding the optimum location of relief centers and in allocating of the parcels to them. In order to limit the search space, GIS was used for selecting a few candidate sites that satisfy the initial conditions and criteria. Then, the two algorithms were used to select nine optimum sites among the candidates and to allocate the parcels to them, while minimizing the sum of all distances between centers and parcels. To calibrate the parameters of the algorithms, a simple simulated data set was used. Having proper values for those parameters, the algorithms were tested on the real data of the study area. The results showed that the convergence of the BA was rather gradual, while the trend for GA was relatively stepwise. Both algorithms showed high levels of repeatability. For both the simulated and real data, GA showed to be faster than BA. Simplicity and repeatability of the algorithm are the main factors from the user's point of view. Therefore, considering these criteria, the GA is more favorable than the BA.

1. Introduction

Based on statistics, the number of natural disasters with strong effects on people's life has increased in recent years [1,2]. Disaster management is divided into four main phases of mitigation, preparedness, response and recovery [2]. Disaster response needs the interaction and coordination of many organizations [3,4]. The response process includes all the measures which are put into action to rescue the human lives and to maintain property, in the moments after the disaster.

Many activities are needed to be planned for the response phase, prior to the disaster [4–8]. This includes the locating and establishing of relief centers and shelters, determination of evacuation routes and planning of transportation, and providing of medical, safety, fire-prevention and food services.

One of the main consequences of earthquake is the massive destruction of buildings. A critical challenge in earthquake response-planning is to find the optimum location of the temporary relief center such that they cover the damaged areas adequately. This is essentially a location allocation (LA) problem. The goal of such an LA process can be to assure the timely emergency relief as well as to reduce the deployment costs [9].

LA problems are usually considered as complex and multi criteria decision problems with multiple and sometimes contradictory aspects. However, they can often be modeled by optimization techniques. Although optimization is an imprecise answer to a multifaceted allocation problem, it often provides the decision-maker with quick and reliable solutions of the problem [10].

Different sources of complexity for LA problems are reported by researchers [11,12]. This includes the inconsistency of objectives, the large number of possible solutions, the complexity of objective functions and constraints, and the volume and uncertainty of the data. Usually, LA problems with such complexities cannot be easily solved using classic methods [12].

To overcome such complexities many nature-inspired meta-heuristic methods/algorithms, including evolutionary algorithms (EAs) and swarm intelligence, are developed and used for LA problems [12–15].

In this paper, the Genetic Algorithm (GA) and Bees Algorithm (BA) along with Geographic Information System (GIS) are used for site selection of earthquake relief centers and for allocation of parcels to these centers, in district 1 of Tehran city. The main goal

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of the research is to evaluate and compare the adequacy of these two algorithms for the presumed LA problem.

To achieve the above goal, first, the candidate parcels that satisfy the conditions required for the establishment of relief centers are chosen, using spatial analyses capabilities of GIS. Then, the GA and BA meta-heuristic algorithms are used for the selection of final centers among candidate centers and for the allocation of parcels to them.

The parameters of the two algorithms are calibrated using a simple simulated data set. Afterwards, the two algorithms with calibrated parameters are evaluated and compared using the real data set of the study area.

In the next section, we review the literature related to the use of meta-heuristics for disaster management and LA. Section 3 is a brief introduction to GA and BA. A solution for relief centers location and allocation problem is presented in Section 4. Data preparation and initial selection of the relief centers are presented in Section 5. Results are discussed in Section 6. The conclusion and recommendation section includes a discussion of practical application and conceptual limitations of the method along with ideas for future research.

2. Previous works

Cooper [16] formulated the location–allocation problem for the first time. He discussed the main complications regarding the presence of local optimum solutions and non-convex objective function [14].

Much research is available on the use of optimization for emergency management and resource distribution. Yi and Kumar [17] developed a model for disaster relief operation, in which the network flow is optimized using ACO algorithm. They divided the problem into two decision phases of constructing the paths and distribution of the relief materials. Zhang et al. [18] used linear programming and network optimization to minimize the total time needed for dispatching emergency resources. Chuan-feng and Chao [19] used GA to solve problems in emergency management effectively and efficiently. Zhang et al. [20] used GA to optimize emergency resources distribution and compared it with Dijkstra algorithm. Kondaveti and Ganz [3] introduced a decision support framework on the basis of on rapid information collection and resource tracking functionalities. Tzeng et al. [8] used fuzzy multi-objective programming to create an emergency relief distribution model for the reference of decision makers. In [12] an integrated model based on cooperative optimization method is proposed for emergency transportation planning.

Similarly, considerable amount of research is carried out on facility location related to disaster response. Balcik and Beamon [21] developed a model for facility location related to relief chain, in which the number, distribution and resource needs of facility centers are considered, and the maximum covering of the people is provided. In a research by Yang et al. [22], the GA, multi-objective programming and fuzzy logic are used to optimize the locations of fire stations. Liu et al. [23] used GIS and ACO algorithm to find the optimal locations for fire stations considering multiple objectives.

Arnaout [14] worked on Euclidean location–allocation problem with unknown number of facilities, in which, the goal was to minimize the transportation cost. In that study, a three-stage ACO algorithm was proposed and compared with the Genetic Algorithm. The results showed the superiority of the ACO algorithm for the assumed problem.

Many algorithms and methods are also used or developed for the resource allocation and location-allocation problems related to disaster management. Bakuli and Smith [24] used state-dependent queueing network models for resource allocation. Wex et al. [25] introduced two methods for allocating resources in emergency response, by minimizing the total weighted completion times of a number of emergencies. Lin et al. [6] proposed a two-phase heuristic approach for site selection of temporary depots and allocation of disaster-affected points. Jing et al. [9] proposed a method for multi-level emergency resource location and allocation. In that research, a bi-level programming model along with an effective PSO-based algorithm is proposed. Fiedrich et al. [26] used simulated annealing (SA) and tabu search (TS) algorithms to optimize resource allocation in earthquake disasters. The results of these algorithms were better than linear programming and hill-climbing.

As mentioned, much research has been carried out on LA, in general, and on the usage of meta-heuristic algorithms for LA, in particular. In the present research, like many others, two meta-heuristic algorithms are used and compared for a disaster respond location allocation problem. In most of other studies, urban regions or zones are allocated to the resources. In this study, parcels, as the smallest spatial and population units, are allocated to the relief centers. Therefore, the simple goal of this research is to optimize the general accessibility of the parcels to the relief centers.

The allocation of parcels, instead of zones, to the relief centers increases the consistency and reliability of the results. The reason is that for different parts of a zone or block, the closest relief centers are not necessarily the same. For example, assuming a big zone with two relief centers in its different sides, some parts of the zone are closer to the first center, while other parts might be closer to the second center. Therefore, in the distressful condition of a disaster, allocation of the entire zone to any of those centers would not be a fair decision for the population of the zone. Use of parcels, instead of the blocks or zones, will basically resolve this problem. On the other hand, the number of parcels is much more than the zones, which increases the complexity of the allocation dramatically. Such a complexity can be easily overcome by the use of meta-heuristic algorithms such as GA and BA.

Many studies, such as [19,20,22,27–31], have used either GA or BA for different engineering and management issues including disaster management. They reported on the advantages of these algorithms. In some other studies such as [22,32–39] the capabilities of either GA or BA are studied for the LA problems. In none of the listed literature, the two algorithms are compared. The comparison of the two algorithms is done only in [40] for the allocation of manpower, which is far different from the application of the present article. In fact, comparison of the capabilities of these two algorithms for the location–allocation of the relief centers is not covered in the previous researchers' work. Therefore, this comparison, as a new research topic, became the main focus of the present study. Another source of curiosity about this comparison is that these two algorithms are conceptually and essentially similar and comparable. The concept of exploration is implemented by mutation operator in GA and by scout bees in BA, which are similar. In addition, they both use the concept of elitism: In GA, the elites have higher chance of being selected as parents; similarly, the neighborhoods of the elites are searched with more follower bees in BA.

In few studies such as [31,40–44] the performance of BA and GA are compared for various applications. The results are sometimes different and even contradictory. For example, [42] reported on the superiority of GA over BA, which is in contrast to the results of [43], even for the same criteria. On the other hand, none of these studies are related to location–allocation or disaster management. In fact no research was found related to the comparison of BA and GA for location–allocation.