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Locating Optimal Places for Emergency Medical Centers Using Artificial Bee Colony Algorithm

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Abstract

The Emergency Medical Centers are very helpful since they reduce the number of death and injuries by getting to the scenes of accidents and dealing with the case immediately. As saving one's life is the prime goal in these centers, any findings and techniques which will improve the services and ease achieving the goal will be highly welcomed. The first and the major factor in giving this kind of service is the time. The place where these centers are located can play an important role to reduce the time so as to offer the service right away and on time. Hence, finding the best places in a big city or cities to set up these centers to be able to give the services urgently will have a crucial importance. The method offered in this paper is to give the service qualitatively while we reduce the number of ambulances. Artificial bee colony (ABC) algorithm is an extended algorithm based on the bees' vigilant behavior that they search for food. This paper uses The ABC algorithm to solve the problem of positioning. The findings and the correlative coefficient of the study show that this Algorithm can be helpful especially in larger cities where it is difficult to locate a proper position to offer the service in an expected time.

Keywords: *Emergency Medical Centers, Finding Optimal Location, Artificial Bee Colony Algorithm*

1. Introduction

Emergency instances are periods if medical emergencies are not done quickly, the health of the damaged or ill person will be in hazard, or they will suffer from body deficiency throughout the life. These Emergencies are: Heart diseases , accidents ,drowning, electric shocks, radiations, and medical emergencies such as: deficiency in alertness, difficulty in breathing, blood pressure, pregnancy emergencies, convulsion, heart failure, swooning with unknown cases, poisoning, addiction, emergencies due to sudden blow on the abdomen and pelvis, spinal cord damage, shock to skeleton of the thorax, sudden stopping of breath that mostly happen in children because of the emergency operations done to new born babies and young children.

The number of death among people suffering from heart attack may decrease before getting to a hospital due to the care given by the medical emergency centers [1].

The major factors are: The time of care before reaching the hospital, recovery done by the personnel, the number of personnel, the length of time taken by an ambulance, and other emergency services offered [2].

Cummins believes that every minutes of delay in offering help to those with heart problems will decrease their chance of being alive up to 7 to 10 percent [3].

Cummins and et al found out if recovery of the person with heart attacks be done in the first five minutes and pressing the breast be done in the first ten minutes, the chance of being rescued up to the time the patient will leave the hospital will be about thirty percent. Otherwise, the chance of being alive will be less than 7 percent [4].

As a result, the time to get to the scene of the accident is very important so that the emergency centers' doctors can start examining the victims to offer the required operation including splinting or CPR. Then taking the victim's overall state of health into attention, they take him/her to the hospital. The managers of such centers face mainly with three difficulties:

a. Finding the best locations for emergency medical centers.

b. Allotting the required service among different hospitals and centers.

c. Re- arrangement of the available ambulances in such centers.

The number of accidents, the distance of accident- prone areas, and the number of the required emergency centers have been used to evaluate the service. Due to the large number of data, evaluating the service, in larger cities, is really time consuming. This time in offering the service is considered very important especially in setting up new centers. The results the Genetic Algorithm give and its speed in comparison to human beings make it crucial to be used.

The present article tries to explain locating of the emergency medical centers first while considering its limitations. Then it introduces the ABC algorithm and finally it explains the problem of finding the proper location for the medical emergency centers using ABC algorithm.

2. The Problem of Locating The Emergency Medical Services:

Different countries all over the world use The Emergency Medical Services or EMS to reduce the number of death in accidents and emergencies. Its task is to get to the scene on time to offer urgent medical services and to take the victims to hospitals immediately. Considering the growth in population, shortage of facilities, and limited number of centers offering the service, make it vital to offer the service despite these shortcomings and to reduce the number of death. The location of EMS has a major role in reducing the time to offer the service. This reduction in time of service is important to save the victims. To find a location for EMS and decide on the number of ambulances in each center, location models have been used. In these models the location of these centers are decided on the basis of the number of calls. The areas where there is a potential need to set up a new base are marked as the potential places for new centers. Using the location model makes it possible to give the service by less number of centers covering the most neighboring areas while using the least number of ambulances.

The amount of time required between the scene of an accident and the emergency medical center which is different in different countries is the second important factor. It is also variable inside and outside the cities.

Another important parameter is having the required confidence on the service being offered in different places in an expected length of time.

The maximum acceptable distance and time between EMS and the scene of an accident is an important parameter. For example in Iran, the Ministry of Health and Medical Education is required to ensure the emergency medical ambulances will get to the scene of accidents in less than eight minutes in 80% of cases.

The model used in the project is the binary linear model which is purposeful, and ready to offer the service with the least possible number of ambulances. To meet the needs with a high degree of certainty here, we have used the frequency according to which ambulances demanded. It is computed as follows: The total estimated time for each point divided by the total number of ambulances at hand on this area. To ensure its precision, the frequency of ambulances requested is not estimated beforehand. But a maximum range is chosen to the ambulances. The model has been designed in a way that that they will ensure the maximum quality of their service with the least number of ambulances. To guarantee the quality and certainty of services, they are considered greater than the expected or at least as equal as to what happens and expected.

Meta-Heuristic algorithm has been used in various papers and studies to find the optimal locations. Several samples of genetic algorithm can be found in reference number [5-10]. Aickelin [11] used a special genetic algorithm to solve the problem. Jia and et.al [12] used the genetic algorithm in another innovative way to solve the proposed model in 2007. Marvin and his co-researchers [13] compared Simulated Annealing with genetic algorithm and Tabu Search in finding the location in 2006.

Atashpaz Gargari introduced a model to find the location of the emergency centers in 1389. Saied Ma'adi , Afshin Shariat Mahini, and Mohsen Babaie used the Imperialist Competitive Algorithm to find the location of the emergency medical centers and got satisfying results than the genetic algorithm.

In this paper we investigate the application of ABC algorithm for finding optimal locations for the emergency medical centers.

3. Artificial Bee Colony Algorithm

In a bee hive, each members of the colony has special and predetermined jobs. These bees with special tasks try their best to increase the nectar in the hive efficiently and in an orderly way. For real optimization, Karaboga proposed The optimization algorithm, Artificial Bee Colony (ABC) algorithm in 2005. This optimization algorithm is a very recent one that simulates the search of a bee colony for nectar [14-15]. A honey bee colony simulated by the ABC algorithm consists of three kinds of bees: worker bees, onlooker bees and scout bees.

Half of the bees in a colony are employed bees, while the other half includes onlooker bees. Employed bees are in charge of exploiting nectar sources being explored. They send information about the quality of food source to the onlooker bees. Scout bees, either randomly search the area to find a new food source or some external or internal clues lead them to the new food sources [16]. Their foraging behavior can be summarized as:

1. At the primary stage of the foraging behavior, the bees begin to explore the environment casually to find a food source .
2. After finding the source, the bee like an employed forager starts to exploit the discovered source. The employed bee returns to the hive with the nectar to unload it. It can either go back to the discovered source site straight or share the information with the other bees, by dancing in an accepted and evident way. If the previous source vanishes gradually, it becomes a scout and starts searching for a new source.
3. The onlooker bees that are waiting in the hive watch the dances and choose a source site based on the frequency of dances.

In the ABC algorithm that Karaboga proposed, the position of food source represents a possible solution to the optimization problem, and the nectar, the amount of a food source is equivalent to the associated solution. Each food source is discovered by only one employed bee. It is clear that the number of employed bees is equal to the number of food sources found around the hive. The employed bee whose food source has been run out becomes a scout bee.

Using the analogy of emergent intelligence in foraging of bees and the ABC algorithm, the units of the basic ABC algorithm can be explained as follows:

3.1 Population initialization

When the search area is not regular to the environment of the hive and the food sites, the algorithm starts with a slow producing food source. It relates to the solutions in the search place .The first food sources will produce randomly within the range of the limited area.

$$x_{ij} = x_j^{min} + rand(0,1)\left(x_j^{max} - x_j^{min}\right)[17] \quad (1)$$

Where i=I…..SN, j-I..D. SN is the food source number and D is the number of parameter optimization. Besides, counters which store the number of the attempts of the solutions are reset to 0 in this form.

Then, the population of the food sources has to repeat the cycles of the search done by the employed bees, the waiting bees and the scout bees. It is clear that termination criteria for the ABC algorithm might reach a maximum cycle number (MCN) or meeting an error tolerance (ϵ).

3.2 The Phases of the employed bees (Sending the employed bees to the source of food)

As it is stated before, each employed bee is eager to produce only one food source. Therefore, the number of food source sites is equal to the number of the employed bees. An employed bee can change the position of the food source. It depends on local information and neighboring food source. Then it evaluates the quality of the source. In ABC, finding neighboring food source is defined using (2)

$$V_{ij} = x_{ij} + \emptyset_{ij} (x_{ij} - x_{kj}). \quad [17] \quad (2)$$

In the formula, neighboring area of every food source site represented by xi, a food source shown by v_i which is determined by changing one parameter of xi. In Eq (2) j is a random integer in the range [I,D] and $k\epsilon\{1,2…SN\}$ is an index chosen randomly which is different from 1. $\emptyset_{ij}$. It uniformly produces real random number in the range [-1,1].

As it is obvious from Eq(2), the difference between the parameters of the $x_{i,j}$ and $x_{k,j}$ lessons the changes on the position of x_{ij}. Thus, when search gets to the optimal solution, the length of the search space will naturally reduce.

If the value produced by this operation is more than its predetermined boundaries, it can be set to a more reasonable value.Here, the value of the parameter is set to its boundaries.If xi > x_i^{max} then $X_i = x_i^{max}$;

if $x_i < x_i^{min}$ then $x_i = x_i^{min}$.

First v_i is produced within the boundaries, then a fitness value for a minimization problem will be added to the solution by (3)

$$\text{Fitness}_i = \begin{cases} 1/(1+f_i) & if \quad f_{i \geq 0} \\ 1 + abc(f_i) & if \quad f_{i<0} \end{cases}, \qquad (3)$$

Where f_i is the cost value of the solution V_i. In problems of maximization, the cost function can be used as a fitness function. A greedy function is used between X_i and V_i; then the better one is selected based on the fitness values that represent the amount of the food source at X_i and V_i. If the source at V_i is better than that of X_i and is more profitable, the employed bee remembers the new position and ignores the old one. If it is not, then the former position is kept in the memory. If X_i cannot be better, the counter taking the number of test times is incremented by 1, otherwise it is reset to 0.

3.3 Calculating Probability Values in the Probabilistic selection

When all employed bees complete their search, they share the information about the nectar amounts and place with the onlooker bees by dancing. Of course this is a complicated interaction feature of the bees of ABC. One of the onlooker bees verifies the information taken from all the employed bees and chooses a food source site having enough nectar amounts. This action depends on the fitness values of the solutions in the bee population.

A suitable selection scheme can be a roulette wheel, ranking based, over all sampling, and another selection scheme. In ABC, roulette wheel selection plan, in which each slice is proportional in size to the fitness value is employed (4):

$$p_i = \frac{fitness_i}{\sum_{i=1}^{sn} fitness_i} \quad [17] \qquad (4)$$

In this testing selection plan, as the nectar amount of food sources(the fitness of solutions) goes up, the number of onlooker bees visiting them increase as well. This is the positive supplied feature of ABC.

3.4 Onlooker bees' food source site selection based on the information supplied by the employed bees

In the ABC algorithm, a random real number in the range [o,1] is given for each source . If the estimated value (pi in Eq.(4)) related to that source is greater than the random number, the onlooker bee produces a modification on the position of the food site by using Eq.(2) as in the case of the employed bee.

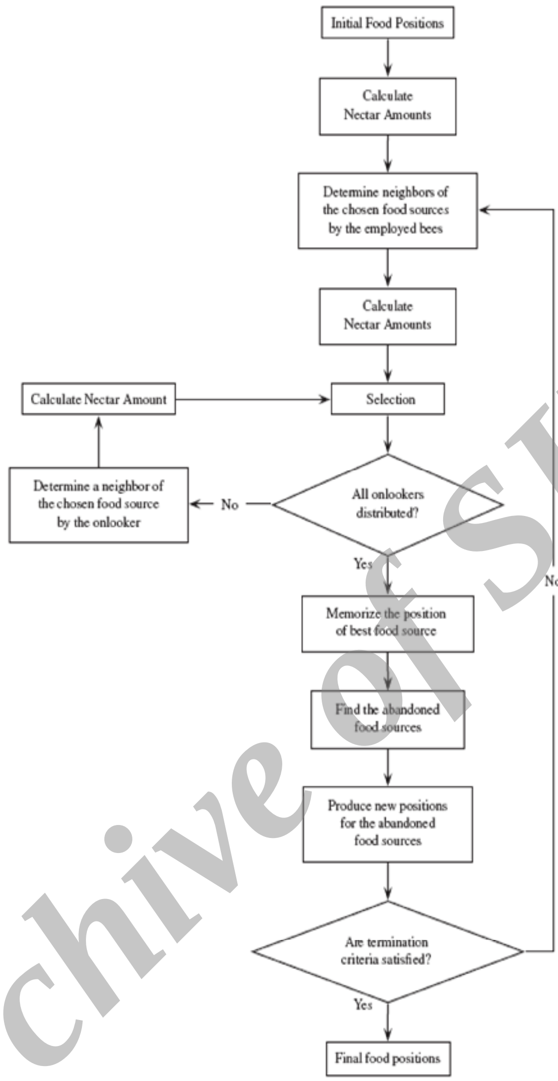

Fig.1. Flowchart of the Artificial Bee Colony algorithm.

When the source is tested, greedy selection is applied and the onlooker bee memorizes the new position and forgets the old one, or keeps the old one. If solution xi cannot be better, the counter holding trials is increased by 1, or if not, the counter is reset to 0. This process is repeated until all onlooker bees are moved to the food source sites.

3.5 Limiting criteria: scout production and Limit

When all employed and onlooker bees complete their search, the algorithm checks to see if there is any unprofitable source to be left. In order to decide to leave the source, the updated counters during the search are used. If the value of the counter is greater than the control parameter of the ABC algorithm known as the "limit", then the source with this counter is thought to be finished and must be left. The food source left by the bees is replaced with a new food source the scout bees found. This represents the negative feedback mechanism and fluctuates property in the ABC organization. This is simulated by finding randomly a site and replacing it with the site abandoned. Suppose that the abandoned source is $x1$, and then the scouts randomly discover a new food source to replace xi. This action can be defined in (1). In basic ABC, it is supposed that only one source at a time can be exhausted in each cycle and one employed bee can be a scout bee. If more than one counter goes farther than the "limit" value, one of the maximum ones should be chosen [17-18]. All these units and interactions between them are shown as a flowchart on Fig.1.

4. The Experimental Results

In this problem, there are several potential locations that emergency centers can be set up there. They are shown in table No.1 (L1 and L2). However due to the shortage in budget we want to have one center. The number of centers which will be built are shown by P.

The main question then is which one should be chosen. The best location will be the one that is nearer to the place which is prone to accidents and will be able to offer its service easier. The accident-prone areas are shown in table1 (D1, D2, D3). The numbers show the distance up to the accident – prone areas.

Table 1. Distance matrix of the dangerous place

	L1	L2
D1	3	5
D2	4	4
D3	2	1

For example, the distance from potential location to set up center number 1 up to accident-prone area is 2 or 3 kilometers. In this diagram, time can replace the distance. Table 2 shows the number of accidents in each accident-prone area. For example, on the average, there have been 40 accidents in the accident-prone area number 3 in a month per year.

Table2. number of danger in dangerous places

	Number of incidents
D1	50
D2	10
D3	40

The maximum expected coverage is shown by *S*. It means that if the distance to the accident-prone area is more than the amount expected, it cannot cover that area. To show this, if the numbers inside table 1 are less than s, we take them as 1 and if they are higher than *s* we consider them as 0. In this example S is equivalent to 3. The results are shown in table3.

Table 3. Distance matrix of the dangerous place

	L1	L2
D1	1	0
D2	0	0
D3	1	1

Table 3 shows that the center number 1 can cover locations number 1and 3. The center number 2 covers only the location number 3. As the size of the example is very small, it can be the best location to set up the center number 1. That will cover 90% and will be shown by z. Its coverage will be 90%. The inputs are p=1 and s=3, and the output is z=90. The total coverage is 90%. This example can be solved using the mathematical methods.

In brief, in this problem the main objective is to reduce the numbers of ambulances to offer the service in an acceptable time and at the same time offering the service with great certainty. At the same time there are three limitations: 1) The frequency of centers being called should be lower than the numbers considered. 2) When a center is set up, there should be at least one ambulance in each center. 3) The least number of ambulances available should not be less than the number required.

Table 4. Results compared ABC algorithm with GA

Input		GA			ABC		
Coverage REDUSE	NUMBER of centers	Fitness	Coverage(%)	Time Execution	Fitness	Coverage(%)	Time Execution
S=1	P=05	7425	11.701	5.7158	14515	22.8741	1.4665
S=1	P=10	13444	21.1863	3.3999	20709	32.6352	2.9251
S=1	P=20	23235	36.6159	4.6743	29248	46.0918	2.8938
S=1	P=30	30966	48.7992	7.9306	35604	56.1082	3.6937
S=1	P=40	36549	57.5974	8.2553	38670	60.9399	3.4942
S=2	P=05	13618	21.4605	2.9209	27126	42.7477	1.8728
S=2	P=10	23712	37.3676	3.2912	37885	59.7028	2.1161
S=2	P=20	38704	60.9934	5.0498	45713	72.0389	2.6758
S=2	P=30	47905	75.4933	6.9016	52104	82.1104	2.8722
S=2	P=40	53566	84.4144	8.1038	55695	87.7695	4.7446
S=3	P=05	19066	30.046	3.098	36439	57.424	1.9945
S=3	P=10	32610	51.3899	3.5443	44421	70.0028	2.3743
S=3	P=20	48438	76.3332	4.9049	53595	84.4601	4.0067
S=3	P=30	56134	88.4613	5.4049	58415	92.0559	3.5127
S=3	P=40	59644	93.9927	6.6528	60432	95.2345	5.0838
S=4	P=05	24433	38.5038	2.9891	39891	62.864	1.7303
S=4	P=10	39113	61.638	4.014	52778	83.1726	3.3288
S=4	P=20	54338	85.631	4.347	58346	91.9472	3.5222
S=4	P=30	60077	94.6751	5.9456	61199	96.4432	5.6827
S=4	P=40	62328	98.2224	8.3354	62497	98.4887	5.7149

Now suppose an example that has 100 potential locations to set up centers and 2500 accident-prone areas. We want to set up 20 centers in the area. This problem can be solved only with Heuristic algorithm not by mathematic rules. Table 4 and Fig.2.

indicate the comparison of the ABC and GA algorithms for solving this problem. Results show that the ABC algorithm is superior to GA.

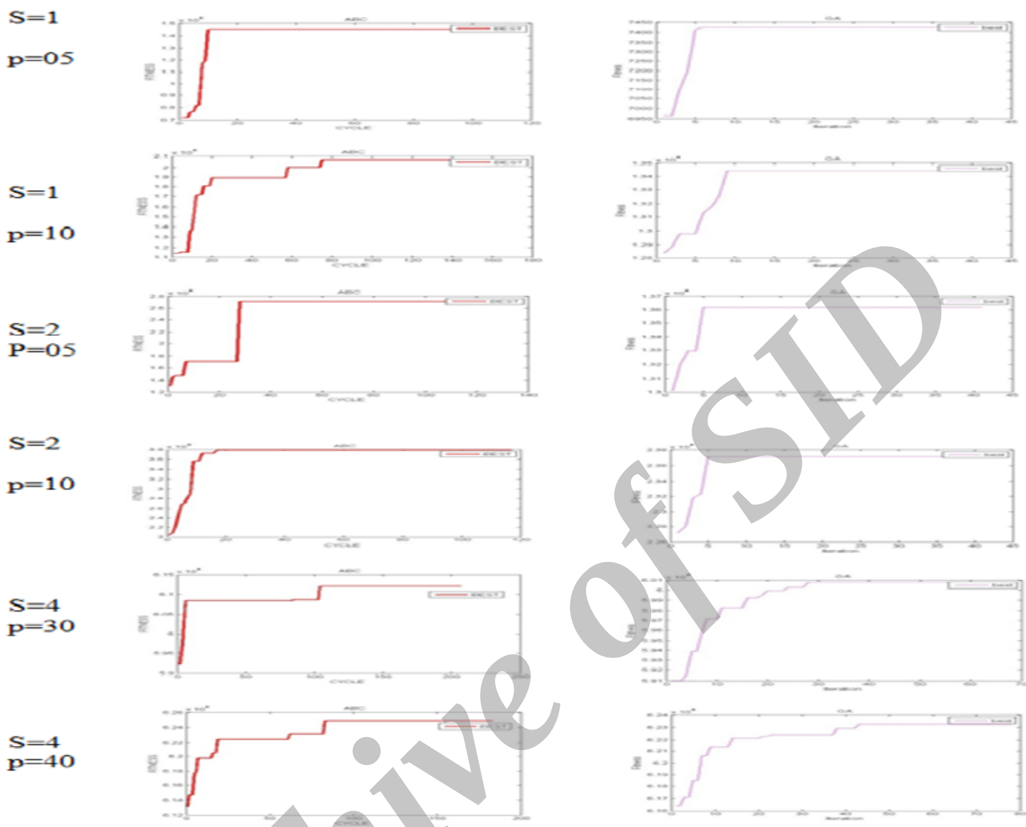

Fig.2. Comparison chart of ABC and GA And how to convergence they

5. Conclusion

In this paper the application of the artificial bee colony algorithm for locating optimal places for the emergency medical centers is investigated. The locations of the emergency medical centers are very important to provide the fast and better services in the emergency situations. Experimental results using several test problems confirm the potential of the ABC algorithm for solving this problem. Moreover, the results comparison showed ABC algorithm proves to be more efficient than genetic algorithm, pso, etc. It can be used to solve problems in more conditions and dimensions.

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