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A BB-BC based Approach for Ambulance Deployment

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Abstract

Background/Objectives: Punjab State's Department of Family Welfare and Health has extended Emergency Response Service (ERS) to all the citizens of the state free of cost at all times since March 2011. Under the service 240 ambulances were positioned across the state. The author intends to cover maximum area with given ambulances. **Methods/Statistical Analysis:** the aim of the paper is to improve the coverage of ERS. To do so, the author surveys the deployment methods found in the literature and proposes a new approach of ambulance deployment based upon Big Bang Big Crunch optimization algorithm. The applied approach was implemented and validated on MATLAB. **Findings:** This technique allows us to cover the entire state of Punjab which is divided into 8 sectors with the fleet of 236 ambulances providing a coverage radius of 8.5 kilometers by an individual ambulance. **Improvements/Applications:** The applied soft- computing technique surpasses the existing techniques.

Keywords: Ambulance –Deployment, Big Bang Big Crunch, ERS, Optimization, Soft-Computing

1. Introduction

Ambulances are the specialized vehicles equipped with life supporting system which caters to the needs of sick and injured people. In geographically remote areas, lots of valuable human lives could not be saved after accidents/ incidents due to non-availability of Emergency Response Service (ERS) in time. It is observed that the ambulances of government/private hospitals are either deployed in front of the premises or in urban areas. In order to take maximum benefits from this service it becomes very essential that these vehicles reach the given destination at the earliest possible.

There are many shortcomings in the existing structure of ERS and have been studied in literature. Significant investment is required for the effective utilization of emergency services. Various approaches are referred for concluding the improved levels of competence and upgraded coordination system between the emergency service providers. There is a need to devise improved logistics. Some factors like coverage of rural areas, ambulance fleet location, dynamic redeployment, effective services, response time, coordination amongst members etc. are discussed in detail. From March, 2011 Punjab State's Department of Family Welfare & Health has extended ERS to all the citizens of the state free of cost at all times. It is a three phase scheme in which 240 ambulances are positioned across the state. The number of ambulances under this scheme are based on the population, with one ambulance covering 0.12 million citizens[1]. The state occupies 50,362 square kilometers of land[2] as shown in Figure 1. In order to provide a better ERS in the State, the positions for ambulance deployment across the state is a major factor which effects the response time. The response time in this scheme is 20 minutes for urban and 30 minutes for rural areas.

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Figure 1. Geographical Map of Punjab.

In[1] discussed about the incoming demands according to the space and time distribution. The role of transport activities and ambulance response time is significant for effective allocation of ambulances. The solution to the problem was developed by making use of modeling and simulation respectively.

In[2] used the facility location algorithm for carrying out study on selection of permanent sites of ambulance in Texas City. A contiguous zone search routine is framed to capitalize on availability of huge data base of zone travel times. This algorithm permits systematic evaluation of system performance directed at improving average response time. This simulation model is combined with heuristic search routine which further permits degree of model realism. The heuristic search routine selects the location desirability for evaluation. A final analysis is done to the set of joint use sites identified in priority order, 12 locations for EMS vehicles needs to be phased in five year period time.

In[3] in 1978 studied EMS. Observations are laid to know how the services to be provided, who will provide and by what equipments and locations. The average response reduced through the service calls have increased and equitable service is rendered to those who need it the most.

In[4] examines for Bangkok City and developed deployment policies for ambulances. A model to screen the possible alternatives for selecting good solutions is used. A detailed simulation analysis is then subjected on each good solution. A new deployment policy is framed providing some existing performance levels but with lesser number of ambulances.

In[5] adapted the problem formulation according to the requirements. A number of sub problems originated from original problems which need an easier solution and proved intelligible to management.

In[6] proposed an algorithm for the purpose of maximizing deployment. It is also used to for ambulance coverage as well as for fire coverage. It included two constraints; one is the number of vehicles and other solutions of both problems. A new integration concept can be framed to allow ambulance stations to be sited. It also concludes budget level. The coverage of ambulances can be increased. Sometimes, there may be a little loss or may be no loss in fire coverage.

In[7] developed Maximal Availability Location

Problem and related it with probabilistic approach. The randomness feature of server availability is introduced in MALP. Queuing theory is related further for relaxing the assumption for getting more realistic emergency model. Formulations and computations are done with time or distance by using queuing model for server availability.

In[8] provide a brief summary and outlined a case study "Report of the inquiry into the London Ambulance Service" was considered for discussion as bridging different contributions.

In[9] proposed a model for double coverage ambulance location problem. A solution was obtained by developing Tabu search heuristic providing computational results using both real data and randomly generated data.

In[10] studied emergency medical system implemented in Brazilian. The main focus is on the response time of emergency medical system. For assessment of system performance, the hypercube model is used. The hypercube model a tool for servicing based on queuing theory. The outcome proved that model is effective for operation decisions.

In response time is an applicable measure to make an Emergency Medical Services (EMS) better. Ambulance travel time is alternate to response time. It is a common practice. An overview is presented for the EMS travel time and travel distance. The purpose of the research is to develop an appropriate model to satisfy the services of ambulance in Island of Penang.

In[11] proposed a technique to deploy or locate the ambulances to fixed location points to achieve the goal of having less response time to emergency calls. Erlang loss based models are used to solve the problem. The experiments performed on the first model give results that how the ambulance allocations can be modified. The second models results are compared with the results of A-hypercube model. These models are used as tools to identify optimal allocations.

In[12] presented Emergency medical service providers to manage the ambulances for minimizing the response time. First approach that assists in decreasing response times is ambulance allocation. It is analyzed that the ADP (Adaptive Dynamic Programming) policies are much better than other static policies. These are better than near-optimal static policies.

In[13] deals with main problem in EMSs management which is the allocation and reallocation of emergency vehicles. This article explicitly considers the redeployment of vehicles, ambulances – based on cyclic changes in service demand (e.g., based on population movements during the day from residential areas to the workplace and vice-versa). A multi-period is introduced to take into account such service demand changes. The vehicle deployment plan is chosen to simultaneously maximize coverage and minimize vehicle relocation between periods. A mathematical model is proposed that allows small to medium instances of the problem to be solved. In order to tackle large instances corresponding to real-life situations, two heuristic approaches are proposed. Finally the performance is evaluated using a set of randomly-generated instances.

2. Ambulance Deployment Problem

The Punjab state's earlier approach of ERS was based upon the population. The new soft computing approach proposes that every Rural and Urban geographical location of state has to be covered with at least one ambulance by optimizing the deployment pattern of these ambulances. The geographical dimensions of the state of Punjab are from 29°32' to 32°32' North and 73°55' to 76°50' East having total area of 50,362 Square Kilometers. This area is divided into 8 sectors[18, 19].

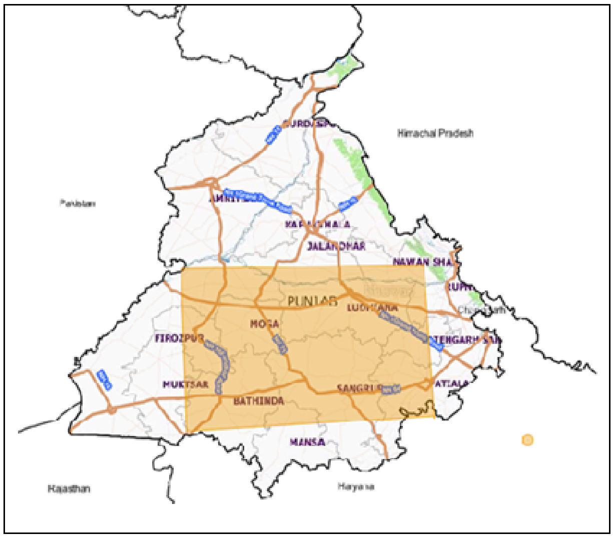

Figure 2. Map of Punjab with Sector I.

Each sector is measured with respect to longitude and latitude. With the reference to Sector I as shown in Figure 2, the longitude and latitude is shown below in Table 1.

Table 1. Longitude and Latitude of Sector I

Sector No.	Area (km2)	Longitude	Latitude
One	22134.71	74.66	31.06
		76.36	31.06
		76.44	29.99
		74.66	29.99

The problem is to determine the optimal positions of the deployment of ambulances in various sectors across the state.

3. Soft Computing Algorithms

3.1 Proposed Solution

The total area of the state is assumed into two dimensional grid of 210 kilometer X 240 kilometer. In this two-dimensional grid G,, n set of ambulances such as S = {S_1, S_2…………..,S_n} is to be deployed at n different positions having coordinates (x_i, y_i) where i=1,2,3,….., n so that each and every geographical location of the state is in the coverage of at least one ambulance. To compute the position coordinates of ambulances in every sector, soft computing technique is proposed[15-17].

3.2 Pseudo Code of BBBC Algorithm14, 15

Begin

/* Start (Big Bang Phase) */

Generate a random set of *NC* candidates (population)

/* End of Big Bang Phase */

While not *TC* /* *TC* is a termination criterion */
Calculate the fitness of all the candidates;
Sort the population in increasing order on the basis of fitness;
/* Start (Big Crunch Phase) */
Calculate value of X_c (center of mass) using following Equation;

$$X_c = \frac{\sum_{i=1}^{NC} \frac{1}{f^i} X_i}{\sum_{i=1}^{NC} \frac{1}{f^i}} \quad (1)$$

Where X_c is the location center of mass; X_i is location of candidate *i*; f^i= fitness of candidate i;

/* End of Big Crunch Phase */

Calculate new positions of candidates by using Equation ;

$$X^{new} = X^c + l\,(rand)\,/\,k \quad (2)$$

Where X_c is center of mass, *rand* stands for random value and k is the k^{th} number iteration of the algorithm. Then new position of candidate is upper bounded and lower bounded.

End while
End

4. Proposed Work

4.1 Mathematical Model

In this model, for a two-dimensional physical space, each ambulance range is considered as circle and is placed at the centre say *(x, y)* where x and y are coordinates of centre. The radius *r* of the circle is the coverage range of ambulance. Thus, the coverage area is πr^2. In this two-dimensional grid G, heaving area of 50,362 kilometer^2, n set of ambulances such as S = {S_1, S_2…………..,S_n} is to be deployed at n different positions having coordinates (x_i, y_i) where i=1,2,3,….., n.

The area of overlapping between coverage of two ambulances *i* and *j* is represented by A_{ij} and is calculated by

$$A_{ij} = 2r^2\cos^{-1}\left(\frac{d_{ij}}{2r}\right) - \left(\frac{d_{ij}}{2}\right)\left(\sqrt{4r^2 - \left(d_{ij^2}\right)}\right) \quad (3)$$

Where, d_{ij} is the distance between the ambulance i and ambulance j and is calculated by

$$d_{ij} = \sqrt{\left(m_j - m_i\right)^2 + \left(n_j - n_i\right)^2} \quad (4)$$

$$\text{Total Overlapping of Deployment} = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} A_{ij} \quad (5)$$

The area of overlapping of every ambulance with the other *(n-1)* ambulances is represented in the form of square matrix of order *n* called the Area Matrix as shown as below:

$$\text{Area Matrix (AM)} = \begin{bmatrix} A_{11} & A_{12} & A_{13}\ldots A_{1n} \\ A_{21} & A_{22} & A_{23} & A_{2n} \\ A_{31} & A_{32} & A_{33} & A_{3n} \\ & \vdots & & \\ A_{n1} & A_{n2} & A_{n3} & A_{nn} \end{bmatrix} \quad (6)$$

Table 2. Physical parameters of 8 Sectors

Sector No.	Area (km2)	Longitude	Latitude	Dimensions	No. of Ambulances
I	22134.71	74.66	31.06	184.95	87
		76.36	31.06	117.86	
II	14586.94	74.56	31.83	175.25	57
		74.56	31.12	80.11	
III	5740.367	76.24	31.31	45.79	22
		76.24	30.13	135.59	
IV	5465.588	73.84	30.45	95.23	21
		74.70	29.99	57.38	
V	4517.74	74.93	30.05	143.44	17
		76.19	30.05	32.96	
VI	3984.017	74.62	32.13	147.92	15
		75.91	32.13	30.52	
VII	2095.586	74.21	30.98	45.92	8
		74.61	30.98	48.36	
VIII	2379.816	76.61	30.78	35.48	9
		76.61	30.33	78.8	

5. Simulation Results

We implemented the proposed approach using MATLAB[16, 17]. The total area was divided into 8 sectors in which coverage radius for each ambulance was 8.5 kilometers. BBBC algorithm was run with 500, 1000 and 10,000 iterations with a population size of 20. The plot of coverage area vs iteration of proposed approach is shown in Figure 3. Physical parameter values used in simulation and optimal coverage are listed below in Table 2.

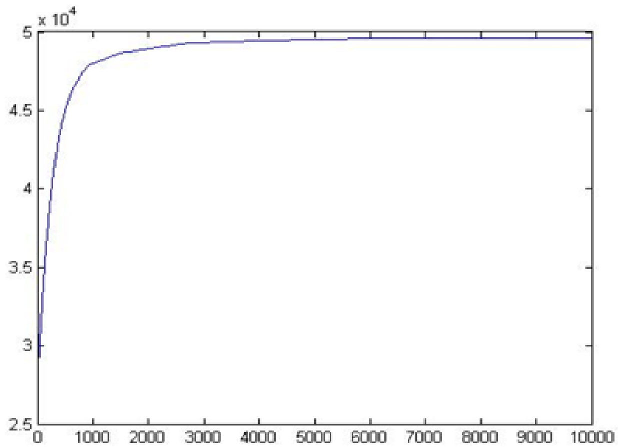

Figure 3. Coverage Area of the deployment vs 10000.

6. Conclusions

The paper proposes a new soft computing based approach for ambulance deployment. This technique allows us to cover the entire state of Punjab which is divided into 8 sectors with the fleet of 236 ambulances providing a coverage radius of 8.5 kilometers by an individual ambulance. The proposed BB-BC (Big Bang Big Crunch) optimization technique is based on the concept that each and every location of the state lies in the coverage of a single ambulance. The approach has been verified and tested on MATLAB.

7. References

1. Berlin GN, Liebman JC. Mathematical analysis of emergency ambulance location. Original Research Article, Socio-Economic Planning Sciences. 1974 Dec; 8(6): 323–28.
2. Fitzsimmons JA, Srikar BN. Emergency ambulance location using the contiguous zone search routine. Original Research Article Journal of Operations Management.1982; 2(4):225–37.
3. Eaton DJ, Daskin MS, Simmons D, Bulloch B, Jansma G. Determining Emergency Medical Service Vehicle Deployment in Austin. Texas. 1985 Jan; 15(1): 96 –108.
4. Fujiwara O, Makjamroen T, Gupta KK. Ambulance deployment analysis: a case study of Bangkok. European Journal of Operational Research Elsevier. 1987 Jul.; 31(1): 9–18.
5. McAleer WE, Naqvi IA. The relocation of ambulance stations: A successful case study. Original Research Article, European Journal of Operational Research. 1994 Jun.; 75(3): 582–88.
6. Charle R, Stephanie S. Integrated fire and ambulance siting: A deterministic model. Socio-Economic Planning Sciences Elsevier. 1995 Dec.; 29(4): 261–71.

7. Marianov V, Re Velle C. The Queueing Maximal availability location problem: A model for the siting of emergency vehicles. Original Research Article, European Journal of Operational Research. 1996 Aug.; 93(1): 110–20,
8. Finkelstein A, Dowell J. A comedy of errors: the London Ambulance Service case study. Proceedings of the 8th International Workshop on Software Specification and Design; U K. 1996 Mar. p. 2.
9. Gendreau M, Laporte G, Semet F. Solving an ambulance location model by tabu search. Elsevier Science Limited. 1997 Aug.; 5(2): 75–88
10. Mendonça FC, Morabito R. Analyzing emergency medical service ambulance deployment on a Brazilian highway using hypercube queuing model. Journal of the Operational Research Society. 2001; 52(3): 261–70.
11. Restrepo M, Henderson SG, Topaloglu H. Erlang loss models for the static deployment of ambulances. Health Care Manag Sci Published online: 27 July 2008. Springer Science and Business Media, LLC 2008. 2009 Mar.; 12(1):67–79.
12. Maxwell MS, Henderson SG, Topaloglu H. Ambulance Redeployment: An Approximate Dynamic Programming Approach. Ithaca: NY. 2009 Dec. p. 1850–60.
13. Boctor FF, Carpentier G, Ruiz A. Dynamic Management of an Emergency Vehicle Fleet: Deployment and Redeployment of Ambulances. 2011 Aug.
14. Manoharan S, Sathappan S. A Comparison and Analysis of Soft Computing Techniques for Content based Image Retrieval System. International Journal of Computer Applications. 2012 Dec.; 59(13):13–18.
15. Sharma S, Kumar S, Singh B. Hybrid Intelligent Routing in Wireless Mesh Networks: Soft Computing Based Approaches. IJISA. 2014; 6(1): 45–57. DOI: 10.5815/ijisa.2014.01.06.
16. Suresh R, et al. Real Power Loss Minimization uses Big Bang Big Crunch Algorithm. International Journal of Computer Applications. 2013; 65(17):28–33.
17. Punjab geography and history. Available at: http://www.mapsofindia.com/punjab/geography-and-history, [Accessed: 10- Jun- 2015].
18. Operationalization of Emergency Response Services {Ers} In the State of Punjab. Available: http://www.pbnrhm.org/docs/ers.pdf. [Accessed: 10- Jun- 2015].
19. Indian Geo-Platform of ISRO. Available at: http://bhuvan.nrsc.gov.in/bhuvan_links.php [Accessed: 10- Jun- 2015].