Using Biogeography -Based Optimization to Solve the Extremity Automobile Directing Problem with Relief Goods in unexpected Disasters

Master of Science
In
Mathematics
By

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CERTIFICATE

This is to Certify that ***Ms. Anjali Singh*** has carried out her project work entitled ***”Using Biogeography-Based Optimization to solve Extremity Automobile Directing Problem with relief goods in unexpected disasters”*** under my supervision. This work is fit for submission for the award of Master Degree in Mathematics.

The final project MSCM9999 is completed satisfactorily towards fulfilling the requirements for submission of final project in the IV$^{\text{th}}$ Semester, 2020. The results obtained, in this project report have not been submitted in part or full, to any other university or institution for degree or diploma.

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CANDIDATE DECLARATION

I hereby declare that the dissertation entitled ***"Using Biogeography –Based Optimization to Solve the Extremity Automobile Directing Problem with Relief goods in unexpected Disasters"*** submitted by me in partial fulfillment for the degree of M.Sc. in Mathematics to the Division of Mathematics, School of Basic and Applied Science, Galgotias University, Greater Noida, Uttar Pradesh, India , is my original work. It has not been submitted in part or full to this University or any other Universities for the award of Diploma or Degree.

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Anjali Singh

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Using Biogeography -Based Optimization to Solve the Extremity
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ABSTRACT

The act of obtaining best results under the given circumstances is known as Optimization. Optimization techniques based on linearity of objective function or constraints, can be categorized in two parts: Linear Programming Problem and Non-linear Programming Problem. Based on constraints present in the optimization problems, these can be subdivided into constrained and unconstrained optimization problems. Despite numerous literature present for solving optimization problems, they have limitation for continuous and differential optimization functions. Non-traditional methods i.e. nature inspired optimization techniques do not require any limitation. Thus nature inspired optimization are applicable to real world problem. Present study is an attempt to understand the philosophy of various nature inspired optimization techniques and further an attempt is made to solve a real life optimization problem using a recently developed nature inspired optimization technique.

INTRODUCTION TO OPERATIONS RESEARCH

Operations Research (O.R.) is relatively a new professional discipline and still without fixed content and boundaries, and, thus, a formal definition of the term Operations.
Research (or Operational Research) is somewhat difficult. In normal circumstances, we can predict the decisions and proficiency without making use of any complex calculation. Yet, the administrative are worried with more difficult situations, bear a heavy responsibility for their decisions (such as appropriate product mix giving a maximum profit, planning public transportation network in a town, etc.), Though such decisions may well be taken intuitively from knowledge and simple logic, the decisions would be more thoughtful and acceptable if supported by analytical (mathematical) reasoning. The objective of Operations Research is to conduct inaugural calculations (escaping extended and expensive study) with the goal of minimizing/maximizing the use of time, labors, and capitals while escaping the errors.
Operations Research begins with the use of some mathematical and quantitative techniques to support the decision being taken.
Operations Research may be regarded as the use of logical techniques and methods to decision-making problems and devoted to understanding, describing, and predicting the behavior of man-machine-material systems.

OPTIMIZATION TECHNIQUES

Optimization:- The act of obtaining best results under the given circumstances is known as Optimization. In other words, Optimization is the process of getting optimal solution under the given inputs under given circumstances.

***Mathematical model of optimization* consists of:**

1. variables: the unknowns that require to be found as a result to the problem;

2. constraints: a system of linear equalities or inequalities that signify necessities in the problem that needs to be satisfied.
3. an objective function: an expression, as relationships between the variables representing price, benefit or amount which needs to minimized or maximized as subject to the constraints.

Definitions

Problem Constraints:-The linear inequalities which we get from the optimizing problem are called problem constraints.

Non-Negativity Constraints:-The linear inequalities y_1>=0 and y_2>=0 where y_1 and y_2 are usually the number of things manufactured and there cannot be a negative number of items manufactured, the least number of items that one could manufacture is zero. These are not (usually) specified, they are understood.

Corner Point:-A vertex of the feasible region is called a corner points. Every intersection of lines is not a corner point. The corner points only arise at a vertex of the feasible region. If there is an optimal solution to an LPP, it will arise at one or more corner points of the feasible region, or on a line segment between two corner points of the feasible region.

Bounded Region:-When a feasible region is encircled in a boundary, called bounded region. A bounded region has both a maximum value and a minimum value.

Unbounded Region:-When a feasible region that cannot be encircled in a boundary.

Feasible Region:-Feasible region, feasible set, search space, or solution space is the set of all potential points of an optimizing problem which satisfies all of the given constraints.

Feasible Solution:-A set of values for the decision variables that satisfies all of the given constraints in an optimizing problem is called feasible solution. All feasible solutions' set provides the feasible region of the given problem.

Infeasible Solution:-A linear program is said to be infeasible if there does not exist any solution that satisfies all of the constraints.

Convex Set:-If every point on line segment joining any two points, lies on set, then it is called convex set.

Mathematical Formulation

Max or (Min) $x= k (y_1 , y_2 , \ldots\ldots\ldots\ldots ,y_n)$

Subject to the constraints $b_1 (y_1 , y_2 ,\ldots\ldots\ldots\ldots, y_n) \{<= , = , =>\} c_1$

$b_2 (y_1 , y_2 ,\ldots\ldots\ldots\ldots, y_n) \{<= , = , =>\} c_2$

.

.

$b_m (y_1 , y_2 ,\ldots\ldots\ldots\ldots, y_n) \{<= , = , =>\} c_m$

$y_j >=0$, $j=1,2,3,\ldots\ldots,n$ where either $k(y_1 , y_2 ,\ldots\ldots\ldots\ldots, y_n)$ or some $b_i(y_1 , y_2 ,\ldots\ldots\ldots\ldots, y_n)$

$i = 1,2,3,\ldots\ldots\ldots,m$; or both are non-linear.

WHAT IS BIOGEOGRAPHY- BASED OPTIMIZATION (BBO) ?

Mathematical representations of biogeography describe how some species migrate from one habitat to another which are geographically isolated from each other, how new populations appear, and how populations go extinct.

Habitat Suitability Index (HSI): When some habitats are more appropriate for habitation residence for biological population than others. This can be considered as a dependent variable.

Suitability Index Variables (SIVs): Variables that determine the habitability are called SIVs. These are the independent variables of the island.

Areas that are geographically highly suitable for habitation residences for biological population are believed to have a high habitat suitability index (HSI) .Features that correlate with HSI include such as rainfall, fertile region, temperature, land areas, variety of vegetation, and variety of topographic factors. A large variety of species population are found in high HSI habitats, while in a low HSI habitats have a very lesser number of species population. Regions with a high HSI have numerous species that choose to leave i.e emigrate to neighboring regions, because of the huge number of population that they hold. Regions with a high habitat suitability index have a low immigration rate because they are already crowded with species. Hence, high HSI regions show less changes in their population distribution than low HSI regions. In the same way, high HSI regions have a high emigration rate of species; the maximum number of population on high HSI habitats have numerous chances to emigrate to nearby regions.

1. Simon, 2009. First, gave the idea of natural biogeography, and generalized that to get an algorithm of optimization. Second, Simon compared and distinguished BBO with algorithms in the literature. At last he studied and applied Biogeography-Based optimization to solve the actual world problem.

2. Zhang, Wang, Chen, Mao, Liu, Liu, and Dou, published 6 April 2020, presented Laplacian BBO, is an alternative of BBO which progresses the performance of Biogeography-Based optimization mostly. That is why an improvised Laplacian BBO

is introduced. First, an active two differential perturbing operative is projected. Second, a two worldwide paramount controlling operator is presented .Third, an improvised Laplacian operator is framed for the last habitats' enhancing to improve the operability and secure the convergence speed.

3. Wang, Deb and Cui in 2019 presented monarch butterfly optimization. The goal of this paper were twofold: first, by learning the relocation activities of the monarch butterflies, Monarch Butterfly Optimization, was introduced. In MBO, we have two lands only where all the monarch butterfly individuals are specified and situated, viz. Southern Canada and the northern USA and Mexico. Consequently, there are two ways to update the positions of the monarch butterflies. The relocation operator and butterfly adjusting operator helps to obtain the direction of these butterfly folks in MBO algorithm. Second, they compared and contrasted MBO with other population-based optimization methods.

4. Wen, Chen, Li, Shi and Duan, published 13 September 2017, presented Enhanced BBO using Quantitative Orthogonal learning and multitopology. Two faults of biogeography-based optimization (BBO) are found by examining the governing migration operator's characteristics. To cure this, a new migration operator is proposed by improving topology and copy mode is presented to BBO. Moreover, diversity mechanism is also proposed. The new results show that the given approach has benefit regarding solution quality, convergence performance, as compared with standard BBO algorithms.

5. Zheng, Ling and Xue in 2014 proposed a new algorithm of BBO, named Ecogeography -based optimization (EBO), which concerns the islands' population (solutions) as an ecological system with a native topology. EBO hires a local topology to distinguish non-neighbors and neighbors of each habitat, and describes two new migration operators to enhance distribution between the habitats without harming the exploitation skill of BBO. A real world presentation has authorized the EBO on an operational problem in an emergency. Zheng, Ling and Xue showed a real world presentation of the proposed EBO to an emergency airlift problem in the 2013 Ya′an–Lushan Earthquake, China.

6. Taheri and Jalili in 2016 proposed Enhanced Biogeography-based Optimization: A New Method for Size and Shape Optimization of Truss Structures with Natural Frequency Constraints .An effective algorithm, called the Enhanced Biogeography-

based optimization (EBBO), has been proposed to moderate early convergence problem of the basic BBO algorithm. In the projected algorithm, to improve the overall performance of the basic BBO algorithm, the new mutation and migration operators are proposed. These two new operators improve the ability to converge of the ordinary BBO algorithm and further discharge premature and stagnation convergence.

7. Kamal, Kumar and Singh in 2010 presented a new optimization method biogeography based optimization (BBO) for antenna array combination. With the help of BBO algorithm, an ideal set of magnitudes of antenna components which provides an outline of radiation with supreme side part level decrease .At last, they compared and contrasted this with other optimization methods. Antenna array combination goals at finding a physical arrangement whose radiation design is near to the desired.

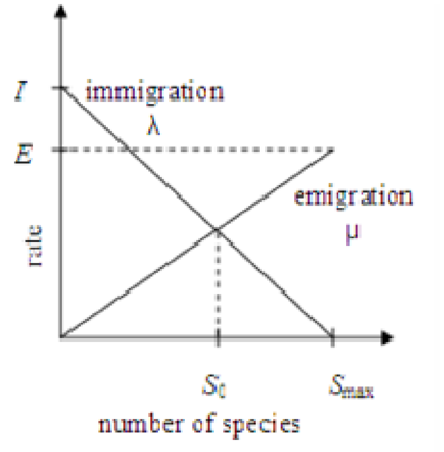
8. Farswan and Bansal in 2018 proposed a mixture algorithm acquired by combining concept of fireworks explosion of Fireworks Procedure and biogeography-based optimization and named as fireworks-inspired biogeography-based optimization (FBBO).The main feature in the projected FBBO algorithm is the combination of two dissimilar abilities to advance solution worth. The projected algorithm is verified on CEC 2014 standard problems.

9. Mathur in 2014 proposed a Biogeography-Based Optimization (BBO) algorithm to explain many types of Economic Load Dispatch (ELD) problems of the thermal power plants . The presented algorithm can manage monetary load report problems with limitations like communication losses, forbidden functioning regions, etc. The efficiency of the projected algorithm has been tested with few trial arrangements.

10. Wang and Song in 2016 made an elaboration in the simple migration equilibrium model of biogeography concept. The algorithm process is formed on the basis of population characterized by migration device of BBO algorithm. Description of seven linear or nonlinear migration relation models have been made. Replication trials are tested on eight testing purposes to confirm the presented migration ratio models.

WHY TO CHOOSE BBO?

Like PSO and GA, BBO shares data between results. Genetic Algorithm results vanish at the last of every generation, although Particle Swarm Optimization and Biogeography Based Optimization results last always. Particle swarm optimization results have more possibilities to cluster with each other in alike sets, while Genetic Algorithm and Biogeography Based Optimization results do not certainly have any natural inclination to form cluster.



$$\mu_k = \frac{Ek}{n}$$

$$\lambda_k = I\left(1 - \frac{k}{n}\right)$$

Figure shows a demonstration of species richness in a particular area. The immigration rate λ and the emigration rate μ are functions of the number of species in the area.

When we look at the curve which shows immigration, **I** is the maximum possible immigration rate, which arises when there are no (zero) populations in the area. When the total of population keep on increasing, the area gets more populated, and only fewer population are able to effectively continue immigration to the territory, and the immigration rate starts decreasing. **S_{max}** is the maximum number of population that a territory can hold, and at that point the immigration rate declines to zero. Now when we look at the emigration curve, the emigration rate is zero when there are zero population in the territory. When the total number of population increases, the area gets more populated, more species gets the chance to explore other territories for residences, and in this way the emigration rate rises .***E*** is the maximum possible emigration rate, which arises when there are maximum number of population in the habitat that it can hold.

In BBO algorithm, calculation of emigration rate and immigration rate plays an important role in the selection of territories whose SIVs will be chosen for migration operation. The concept of immigration and emigration can be represented mathematically by a probabilistic representation. Let us consider the probability that the habitat contains exactly species at changes from time to time as follows:

$$P_s(T + \Delta T) = P_s(T)(1 - \lambda_s \Delta T - \mu_s \Delta T) + P_{s-1} \lambda_{s-1} \Delta T + P_{s+1} \mu_{s+1} \Delta T$$

A. when there were S population present at time T, and there were zero immigration or emigration happened between time T and T + Δ T;
B. when there were (S-1) population present at time T, and arrival of only single species (immigrated);
C. There were (S+1) species at time T, and departure of only single species (emigrated).

$$\dot{P}_s = \begin{cases} -(\lambda_s + \mu_s)P_s + \mu_{s+1} P_{s+1}, & S=0 \\ -(\lambda_s + \mu_s)P_s + \lambda_{s-1} P_{s-1} + \mu_{s+1} P_{s+1}, & 1 \le S \le S_{max} - 1 \\ -(\lambda_s + \mu_s)P_s + \lambda_{s-1} P_{s-1}, & S = S_{max} \end{cases}$$

OPERATORS USED

1. Migration

In BBO algorithm a population of candidate solution can be represented as vectors of real numbers. Each real number in the array is considered as one (SIV). Using this SIV, the fitness of each set of candidate solution, i.e., HSI value can be evaluated. In an optimization problem high HSI solutions represent better quality solution, and low HSI solutions represent an inferior solution.

Elitism

In order to prevent the best solutions from being corrupted by immigration process, some kind of elitism is kept in BBO algorithm.

2. Mutation

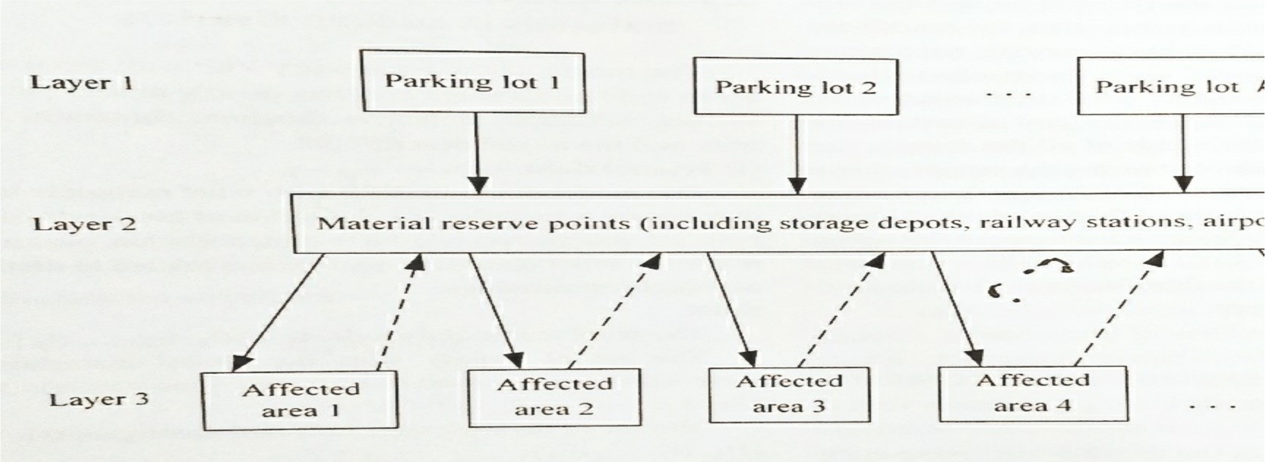
Some cataclysmic events or other events can suddenly change the high suitability index (HSI) of natural territory. This type of event in BBO is represented by suitability index variable (SIV) mutation and species total probabilities are used to decide mutation rates. Mutation system happens to increase heterogeneity among the species. Without this variation, the extremely possible solutions will inclined to be more dominant in the species. Mutation method helps low habitat suitability index solutions possible to mutate, giving them a chance for improvement and also helps high habitat suitability index solutions possible to mutate, again giving them a chance to make improvement than they already have.

Extremity Automobile Directing Problem with Relief goods in unexpected Disasters

The objective of this research was to decide a main problem for extremity natural disaster aid: the extremity automobile directing problem with relief goods in unexpected disasters. Whenever calamities happen, early logistics model is energetic for emergency liberation job. Even though quick improvements in technologies have improvised the capability to guess nearly natural phenomenon with confidence, still unexpected calamities are danger for the existence of local inhabitants and for the safety of public and financial development. Although experts can guess an adversity early, hindrances such as long distances of transport and small notice times make it problematic to shield endangered populations in the intermission between the prediction and the incident. So, early crisis calamities aid materials system is vital to preparing release and help many populations. There are mainly two areas of concern. First, scholars have discovered ways how to calculate the unit of effect of a natural calamity. The calculation determines the amount of call for emergency aids, and the materials for the circulation. Second, studies have inspected the geographies of crisis material circulation systems, including the crisis automobile directing problem.

If the effect of an unexpected calamity is huge, then the circulation of crisis goods need a range of automobile facilities. For now, we only focused on single transportation mode, supposing that relief goods transported by air, railways, and ocean had by then reached at different transport facilities. The main aim was to find ways to allocate automobiles from Layer I to transfer aid goods from the several storing areas to the main disaster sites. An outline of the entire arrangement included in the extremity automobile directing problem with goods in unexpected calamities as presented in figure.

As presented in Figure, the calamity aid goods circulation arrangement is designed as a three layer arrangement. Transferring the goods is crucially an automobile directing problem which involves moving from various parking lots to various material storage areas, and then to various affected points.



Layer I contains the parking lots; vehicles which are allocated to transport help materials start from this area.

Layer II contains material reserve storage sites, which includes all the storage depots, railway stations, airports, etc. We suppose that the aid supplies may vary at each site of this layer, and the total of assured types of resources is unaltered throughout the tragedy time,

At last, Layer III, includes all the disaster areas which are the stoppages for aid circulation.

From Layer I to Layer II, only automobile move, and no relief aid is transported. Furthermore, this is a single direction flow, where the automobiles flowing from the garages only to the several Layer II areas. They are not coming back to the Layer I until the need is fulfilled. Between material reserve points and disaster areas, there are both resources and automobile flow. There is single way unidirectional movement of materials from Layer II to Layer III, although the automobiles create a both directional movement between Layer II to Layer III. When an automobile reaches at an affected area, it does not straightaway return to the Layer I, but instead stays there waiting. As soon as a different circulation duty is demanded, the automobile will return to the suitable Layer II plot to start a fresh circulation. Hence, there are two possible situations for the automobile after it reaches at a disaster area from a Layer II plot. Either it stays in the Layer III to fulfill fresh demands, or assigned a fresh duty straightaway, in that case it comes back directly to the Layer II to start the fresh circulation duty, presented in Figure by the dotted lines.

Both automobiles and materials move between reserve points and affected areas. No linking is formed between each point of the same layer .The main aim of after-disaster circulation is to fulfill the maximum demands of all the affected areas while decreasing the flowing time of the whole circulation system. With this method, damages at each disaster point, and the price of means of transportation are decreased. The vehicle is again used between the Layer II and the Layer III until all the demands of the affected areas are fulfilled.

<u>The model of the Extremity automobile routing problem with relief goods in unexpected disasters</u>

The model of the extremity automobile routing problem with aid goods in unexpected disasters involves mostly of four parts: definition of the codes, objective function, constraint condition, and description of the model.

Code definition

The model of the extremity automobile routing problem with aid goods in unexpected disasters includes the definition of codes of five kinds: set, parameters associated with vehicle, parameters associated with aid goods, parameters associated with distance, and decision variables.

1) Set of

Materials: $M = (M_1, M_2, \dots\dots\dots\dots, M_p \};$
Supply site: $G= \{G_1 ,G_2, \dots\dots\dots\dots, G_n\}$
Affected area: $A= \{A_1, A_2, \dots\dots\dots\dots\dots, Am\}$
Parking areas: $P = \{P_1, P_2, \dots\dots\dots\dots\dots\dots, P_k\}$
Vehicles: $V = \{V_1, V_2, \dots\dots\dots\dots, V_l\}$
Edges: $E= \{(k, i)(i , j)|k \in P, i \in G, j \in A\}$.

2) Parameters associated with vehicle

Veh_l: the maximum Volume of the vehicle l;
Cap_l: the maximum tons deadweight of the vehicle l;
S_l: the Speed of the vehicle l.

3) Parameters associated with aid goods

W_g: the unit Weight of good type g;
C_g: the unit Volume of good type g;
T_g: the total time needed for loading and unloading good g.

4) Parameters associated with distance

D_{ki}: the distance between Layer I and Layer II;
D_{ij}: the distance between Layer II and Layer III.

5) Decision variables

X_{lijg}: the number of good g that is transported from the supply site i to j by vehicle l;

Z_{lijg} = 1 Vehicle l delivers good g from supply site i to j
= 0 Otherwise

$l \in V , i \in G , j \in A , g \in M$

Y_{lki} = 1 Vehicle l passes edge (k, i)
= 0 Otherwise

$l \in V , k \in P , i \in G$

Y_{lij} = 1 Vehicle l passes edge (i, j)
= 0 Otherwise

$l \in V , i \in G , j \in A$

(2) Objective function

$$\text{Min } T = \sum_{l\epsilon V} \sum_{k\epsilon P} \sum_{i\epsilon G} * D_{ki} / S_l * Y_{lki} \tag{1}$$

$$+ \sum_{l\epsilon V} \sum_{i\epsilon G} \sum_{j\epsilon A} \sum_{g\epsilon M} * \; T_g X_{lijg} Y_{li} Z_{lijg} \tag{2}$$

$$+ 2 * \sum_{l\epsilon V} \sum_{i\epsilon G} \sum_{j\epsilon A} * \; D_{ij} / S_l * Y_{lij} \tag{3}$$

$$+ \sum_{l\epsilon V} \sum_{i\epsilon G} \sum_{j\epsilon A} \sum_{g\epsilon M} * \; T_g X_{lijg} Y_{lj} Z_{lijg} \tag{4}$$

(3) Constraint condition

$$X_{lijg} * W_g <= Cap_l \tag{5}$$

$$X_{lijg} * C_g <= Veh_l \tag{6}$$

$$\sum_{g\epsilon M} * \; Z_{lijg} = 1 \tag{7}$$

$$\sum_{i\epsilon G} * \; Y_{lki} = 1 \tag{8}$$

$Y_{lki} \in \{0,1\}$, $Y_{lij} \in \{0,1\}$, $Z_{lijg} \in \{0,1\}$ (9)

$Y_{li} \in \{0,1\}$, $Y_{lj} \in \{0,1\}$ (10)

$1<=l<=|V|$, $1<=i<=|G|$, $1<=j<=|A|$, $1<=g<=|M|$ are the ranges of the index in constraints.

(4) Description of the objective function

Equation 1 shows the total time taken by the vehicle from parking sites to the material storage sites;
Equation 2 shows the total time taken to load materials at the material storage sites;
Equation 3 shows the total time taken by the vehicle from supply sites to the disaster areas;
Equation 4 shows the total time taken to unload materials at the disaster sites;

Description of the constraints conditions

Equation 5 shows that the relief aids delivered by each means of transportation cannot surpass the tons deadweight of the vehicle;
Equation 6 shows that the materials transported by each means of transportation cannot surpass the maximum volume of the vehicle;
Equation 7 shows that the each means of transportation can carry only single good at a time from the good storage areas to the disaster sites;
Equation 8 shows the single way flow of vehicles from Layer I to Layer II;
Equation 9 and 10 shows that the decision variables satisfy the 0 to 1 integer constraint;

Results and Discussion:

In this paper, a novel attempt is made to apply BBO to the problem of sudden disaster relief material. The presented problem is a discrete, np hard problem which is extremely difficult to solve. BBO is originally proposed for continuous variable optimization problems. A novel attempt is made in order to apply BBO to this difficult problem.

BBO used for this problem is modified version of original BBO. It is based on constant mutation rate and with elitist strategy. Elitist parameter is set equal to 2. Which represents the best 2 solution saved after each iteration and get replaced with 2 worst solution. This helps in retaining the best solution obtained. In the next generation, it will be updated as well using migration and mutation operators like all other solutions. Hence, exploration and exploitation balance is maintained as well.

In review of the art- of the state and No free lunch theorem of David Wolpert and William Macready appears in the 1997 "No Free Lunch Theorems for Optimization “, it is always desirable to test a nature inspired optimization technique for a real life problem. The results are obtained in form of the objective function value. Time represents the objective function value and the purpose of the application is to minimize the time. However, results obtained by modified version BBO is given the Table 1. The bold entries gives the results obtained. However in comparison to MBO, modified BBO has performed poorly.

	ABC	BA	Modified BBO	CS	DE	EMBO	PSO
Best	158.31	154.10	**152.3**	143.43	142.52	109.06	157.19
Mean	162.96	161.27	**160.0849**	145.26	144.68	118.18	159.03
Worst	167.35	167.86	**186.20**	150.21	146.10	140.77	162.23
Std	2.2516	3.1246	**8.573617**	1.3777	0.8202	13.2842	1.4138

Table 1: obtained results and comparison of BBO with state of the art algorithms.

Conclusion and future scope: A novel attempt is made to solve presented problem by Biogeography based optimization. The results obtained and compared with the existing literature. The comparison shows that MBO is more suitable candidate for solving sudden relief material problem. However, there are many variants of BBO is presented in literature that can be tested for solving the problem.

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Name/Signature of Student

Signature of Supervisor

Signature of Co-Supervisor