

An Optimized Delivery System Model in Order to Zero Ebola Cases

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Abstract. Based on the graph theory and immune algorithm, this paper produces a medicine delivery system in West Africa where the largest and most complex Ebola outbreak takes place. Firstly, the delivery destinations where vaccine or drug is badly needed are selected using the map of cumulative cases in different regions. Then the problem how to determine locations of distribution centers is transformed into a goal programming problem. In this model, object is defined as the minimum cost of delivery transport. The cost is calculated by the product of needed vaccine or drug in each destination and the distance from this destination to its potential delivery center. Finally, the goal programming problem is solved by immune algorithm. This model can also be used in other similar cases where such an optimized delivery system is needed urgently.

Introduction

Ebola virus disease (EVD) is a severe, often fatal illness in humanity. The most recent outbreak in West Africa has involved over 22000 individuals and caused nearly 9000 deaths [1]. Therefore, aiming to zero Ebola cases, it's important to build a model which can help to deliver medicine. In this paper, there are three steps to build and solve an optimized delivery system model:

1. Select several *delivery destinations*.
2. Transform the model to determine *distribution centers* into a goal programming problem.
3. Solve the goal programming problem by *immune algorithm*.

Delivery Destinations

The status with crowded confirmed cases are defined as locations of *destinations* that vaccine or drug delivered to. Therefore, Ebola Treatment Centers (ETC) Status may be a good choice as the compact status. Data of ETC can be found in figures from the WHO website [2]. In order to search locations of ETC which can stand for sites of regions, there are some necessary assumptions:

1. Theoretically Added Ebola Treatment Sites: In some regions, ETC haven't been built or are currently under construction. It's assumed that there are enough Ebola treatment sites.
2. Location of Added Sites: Added Ebola treatment sites mentioned in the above assumption are assumed in the center of cities. These sites can be assumed as status with crowded confirmed cases.
3. Combination of Adjacent Sites: Some regions may only have less than 50 total confirmed cases. It's assumed that no more Ebola treatment sites will be set in these locations.

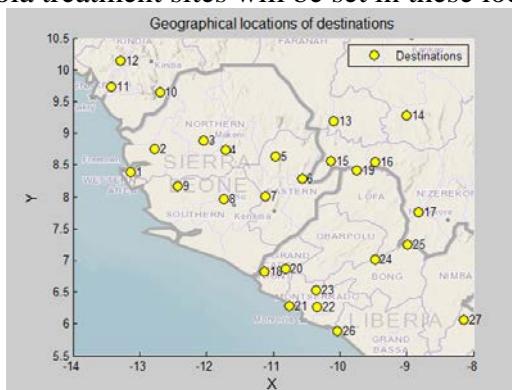


Fig.1 Geographical locations of destinations

The result can be seen in the above figure.

In order to obtain the mathematical expression of these destinations, *adjacency matrix* X in *graph theory* is used in this model. At first, each element X_{ij} is defined as the direct distance between the i -th and the j -th destinations. However, people cannot go from one place to another directly because of diverse obstacles, such as houses or railways. Therefore, X_{ij} is revised considering the degree of transportation convenience.

Distribution Centers

Among destinations of delivery, to decrease costs of medication transport, how to choose *distribution centers* is important. The practical problem to determine locations of distribution centers can be transformed into a *goal programming* problem [3].

Decision variable

h_j represents whether the j -th point can be a distribution center; thus, the decision variable h_j is:

$$h_j = \begin{cases} 1 & \text{Set the } j\text{-th point as distribution center} \\ 0 & \text{Don't set the } j\text{-th point as center} \end{cases} \quad j \in M \quad (1)$$

where $M = \{1, 2, \dots, m\}$ stands for a set of several center alternatives.

Express Z_{ij} in terms of the vaccine or drug of i -th destination that is delivered by the j -th point; so, the decision variable Z_{ij} is:

$$Z_{ij} = \{0, 1\} \quad i \in N, j \in M \quad (2)$$

where $N = \{1, 2, \dots, n\}$ stands for a set of delivery destinations.

Constraints

To confirm that supplies of a certain destination can only be delivered by one center, one constrain is defined as:

$$\sum_{j \in M} Z_{ij} = 1 \quad i \in N \quad (3)$$

To avoid exceeding the maximum number of centers, the next constrain is:

$$\sum_{j \in M} h_j = p \quad j \in M \quad (4)$$

where p is the maximum number of centers.

To confirm that only distribution centers can deliver supplies to other regions, the last constrain is:

$$Z_{ij} \leq h_j \quad i \in N, j \in M \quad (5)$$

Object

The goal of the model is to minimize the cost of delivery transport. So, the object is defined as the minimum product of needed vaccine or drug of one certain destination and the distance from this destination to its delivery center.

$$\min F = \sum_{i \in N} \sum_{j \in M} w_i d_{ij} Z_{ij} \quad (6)$$

where w_i means the needed amount of vaccine and drug in the i -th destination.

Above all, the optimization model is:

$$\begin{aligned} \min F &= \sum_{i \in N} \sum_{j \in M} w_i d_{ij} Z_{ij} \\ \text{s. t.} \quad &\sum_{j \in M} Z_{ij} = 1 \quad i \in N \\ &\sum_{j \in M} h_j = p \quad j \in M \\ &Z_{ij} \leq h_j \quad i \in N, j \in M \\ &Z_{ij}, h_j = \{0, 1\} \quad i \in N, j \in M \end{aligned}$$

Immune algorithm

Immune algorithm belongs to the artificial immune systems field of study concerned with computational methods inspired by the process and mechanisms of the biological immune system [4]. In immune algorithm, affinity among antigens is equivalent to fitness of object, affinity among antibodies is equivalent to fitness of feasible solution, and affinity between antigen and antibody is equivalent to fitness between object and feasible solution. To avoid the premature convergence, this model relies on immune algorithm to optimize the delivery centers.

The main algorithm is described below [5]. Produce initial Q antibodies randomly

$$Ab = \{Ab_1, Ab_2, \dots, Ab_Q\} \quad (7)$$

Each antibody has L genes which is in terms of decision variables.

- Evaluate the initial antibody swarm above. Calculate affinity between antigen and antibody. Affinity is calculated by

$$Aff(Ab_i) = \frac{1}{F(Ab_i)} \quad (i = 1, 2, \dots, Q) \quad (8)$$

Where $F(Ab_i)$ means the object value of feasible solution in Ab_i . $Aff(Ab_i)$ increases as $F(Ab_i)$ decreases; thus, antibody with the highest affinity is the best antibody.

- Clone antibodies. The number N_i of clone is in proportion to affinity.

$$N_i = \text{Int} \left[N_c \frac{Aff(Ab_i)}{\sum_{j=1}^Q Aff(Ab_j)} \right] \quad (i = 1, 2, \dots, Q) \quad (9)$$

- Variation of antibodies. The probability of variation is P_m .
- Select better antibodies. Based on the affinity of antibodies, select antibodies with higher affinity.
- Iterate algorithm b. to algorithm e. until antibody meet the requirement of termination.

In this model, parameters are set as table 4.

Table 1 Parameters of immune algorithm

Parameters	Value
maximum times of iterations	100
number of initial antibodies	50
probability of variation P_m	0.15

Results

In immune algorithm, the requirement of termination is set as maximum times of iterations. The number of distribution centers is set as 6.

w_i means the needed amount of vaccine and drug in the i -th destination. Since the amount of vaccine and drug is observed to be positively correlated to treatment property [6]. It's considered that w_i can be replaced by cumulative cases that represent the needed average degree of treatment property in each region. So the value of w_i is set as cumulative cases of the i -th destination in order to determine the best locations of distribution centers.

Process of optimization evolution can be seen in Fig.2.

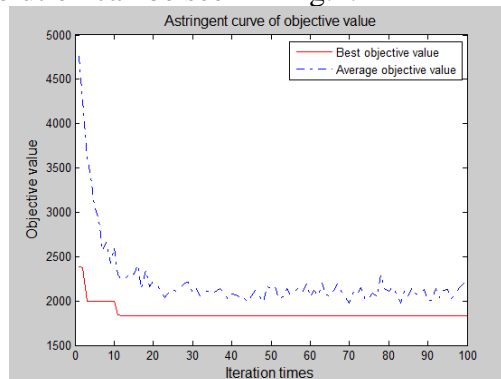


Fig.2 Astringent curve of objective value

The best affinity is 0.000428, while the satisfying objective value is 2.258×10^3 .

Rational distribution centers are listed in the following table. Fig.3 shows the geographical locations of distribution centers and their destinations.

Table 2 Selection results of distribution centers

Distribution Centers	X	Y	Destinations	Surroundings
1	-13.132	8.388	1,9	bay and airport
2	-12.775	8.76	2,10,11,12	bay and airport
3	-12.046	8.883	3,4	major city
7	-11.116	8.006	5,6,7,8	airport
16	-9.471	8.542	13,14,15,16,17,19,25	major road
21	-10.761	6.288	18,20,21,22,23,24,26,27	bay and airport

The order number of the distribution centers is the same as destinations in Fig.1.

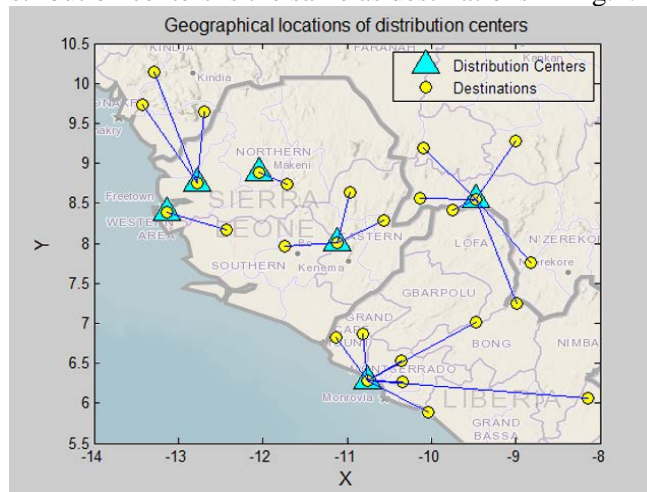


Fig.3 Geographical locations of distribution centers and their destinations

Model Testing: By searching surroundings of the selected centers which can be seen in the last column of table 3, it's concluded that distribution centers are all with convenient transportation. So this model has much relation to reality.

References

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