Application of GA on Location of the Health Care Facilities

遺伝的アルゴリズムを用いた医療施設の配置モデル

Fauzy AMMARI[1], Takaji SUZUKI[2] and Toshihiko MIYAGI[3]

Introduction

This study aims at developing the formulation and the solution procedure for allocating hierarchical health care facilities. The health care facilities (HCF) of each of several types serving a given region offers an efficient indicator of hierarchy. This is related to (1) the patients weighted distance, (2) the cost of producing services, and (3) the frequency with which people in a region use HCF. The services are divided based on degree of care in several groups. We adopt Genetic Algorithm (GA) in terms of computational efficiency and applicability of large scale problems. GA provides a flexible solution strategy that permits modelers to exploit the underlying structure in any optimization problem by defining the constraints to chromosome pattern. We have applied the GA to the model within a network of 35 nodes. The network describes the condition of North Maluku Regency in east part of Republic Indonesia.

In this study, to establish a short average distance or travel time to a site of health care facilities contains a meaning in same manner as to maximize services to an existing population. Degree of heaviness of a value of travel distance is strongly related to a condition of patients. Distance will influence the motivation of individual to contact with a physician. Illness behavior and death risky are positively related to the distance from a physician. Thus it can be hypothesized that with increasing distance from a health care facility, individual will be more sensitive to the aetiological development of disease. Girth (1973) evaluate that the decision to seek medical care is thus a result of "transaction between individuals and situations, rather than of either one in isolation," this stress having reached a level sufficient to invoke interaction between the individual and his physician. Gore (1991) describe that it would involve specifying rules of access regarding eligibility, priority, and location of the service and relating those to the person's actual position in the system, including endowment, location, and a wide range of other phenomena relevant to access.

Developing Formulation for Allocation Model of Hospitals and Health Centers

A hierarchical health cares facilities system may consist of health centers, hospitals, and medical centers. Such facility systems are generally successively inclusive. That is, in such a system, health centers provide primary care; hospitals provide primary care and some additional services; medical centers provide specialized care in addition to services available at a hospital and a health center. However, Daskin (1995) suggests a simple model to minimize the total patient (demand) weighted distance between a village and the nearest health care facility based on median problem may be described as follows; suppose we want to locate H hospitals and C health centers in any area. Area should be viewed strictly as a plain or a set of many small islands. Generally, H less than C. In more detail and complete, the following assumptions have been made in order to achieve a tractable problem structure. (1) We consider a health care facility system consisting of hierarchically coordinated two level facilities (hospital and health center) capable of exchanging patients, personnel, equipment and services. (2) The facilities are located on some demand nodes in bounded plane and or many small islands, also an infinite set of potential facility locations is considered. (3) The patients are allocated to the nearest health care facilities. A deliberate simplification, as is the assumption that patient usage of health facilities is independent of their minimum travel distance from such facilities (Dokmeci, 1977). (4) Capacity of a hospital and a health center are given by parameter α and β, respectively. It is related to the total patients for medical treatment in a day. (5) In health care

Keywords: Hierarchical Facility Location, Genetic Algorithm, Health Care Problem

[1]Graduate Student member of JSCE, M.Eng., Graduate School of Engineering, Gifu University, E-Mail: fauzy@cc.gifu-u.ac.jp
[2]Lecturer, Faculty of Economics, ChuKyo University,
101-2, Yagotohon-Machi, Showa-Ku, Nagoya City 466-8666, Japan, E-Mail: takaji@mecl.chukyo-u.ac.jp
[3]Professor, Faculty of Regional Studies and Graduate School of Engineering, Gifu University,
1-1, Yanagido, Gifu-City 501-1193, Japan, TEL. +81-58-293-2442, FAX: +81-58-230-1528, E-Mail: miyagi@cc.gifu-u.ac.jp

system, the most important is to save patients as quickly as possible. The main reason is to reduce the death risk of patients, therefore we need a critical distance. Thus, each health center must be located within a unit critical coverage distance of the hospital. Otherwise, the requiring time for sending paramedic and medicine is also reduces. (6) It is use zero-one variables to model whether or not a discrete location is executed. Zero-one variables are interesting to compute by genetic algorithm.

Mathematical formulation and notations are written as follows:

H = maximum number of hospitals to be located
C = maximum number of health centers to be located
d_{ij} = minimum travel distance between node i and candidate hospital j
d_{ik} = minimum travel distance between node i and candidate health center k
l_{jk} = minimum travel distance between candidate hospital j and health center k
h_i = number of patients (proportional to population) in node i
D_{HC} = critical coverage distance
α = a given capacity of a hospital
β = a given capacity of a health center

Input Variables

$$a_{jk} = \begin{cases} 1: \text{if candidate site health center k is within } D_{HC} \text{ distance unit of candidate hospital j} \\ 0: \text{if not} \end{cases}$$

Decision Variables

$$X_j = \begin{cases} 1: \text{if candidate hospital site j is selected} \\ 0: \text{if not} \end{cases} \quad W_{ij} = \begin{cases} 1: \text{if demands at node i are satisfies by a hospital at candidate site j} \\ 0: \text{if not} \end{cases}$$

$$Y_k = \begin{cases} 1: \text{if candidate health center site k is selected} \\ 0: \text{if not} \end{cases} \quad V_{ik} = \begin{cases} 1: \text{if demands at node i are satisfies by a health center at candidate site k} \\ 0: \text{if not} \end{cases}$$

$$\min imize \quad \sum_i \sum_k h_i d_{ik} V_{ik} + \sum_i \sum_j h_i d_{ij} W_{ij} \qquad (1a)$$

$$subject\ to \quad \sum_j X_j \le H \qquad (1b)$$

$$\sum_k Y_k \le C \qquad (1c)$$

$$\alpha H + \beta C \ge \sum_i h_i \qquad (1d)$$

$$\sum_j W_{ij} + \sum_k V_{ik} = 1 \quad \forall i \qquad (1e)$$

$$l_{jk} a_{jk} \le D_{hc} \quad \forall j,k \qquad (1f)$$

$$Y_k \le \sum_j a_{jk} X_j \quad \forall k \qquad (1g)$$

$$W_{ij} - X_j \le 0 \quad \forall i,j \qquad (1h)$$

$$V_{ik} - Y_k \le 0 \quad \forall i,k \qquad (1i)$$

$$X_j, Y_k = 0,1 \quad \forall j,k \qquad (1j)$$

$$W_{ij}, V_{ik} = 0,1 \quad \forall i,j,k \qquad (1k)$$

The objective function (1a) minimize the total patient (demand) weighted distance between a village and the nearest health care facility. Constraint (1b) stipulate that the hospital must be located no more than H hospitals. Constraint (1c) state that no more than C health centers are to be located. Constraint (1d) state the capacity of hospitals and health centers. Constraints (1e) require each node i to be assigned to exactly one facility either health center or hospital. Constraint (1f) state the guarantee of critical coverage distance for the distance between the health center and the hospital. Constraint (1g) state that at candidate health center k can be covered by more than one selected hospital. Constraint (1h) state demand at village i can only be assigned to a hospital at candidate site j if we locate a hospital at candidate site j. Constraints (1i) similar to constraints (1h), it is assigned to health center. Constraint (1h) and (1i) link the location variables and allocation variables. Constraint (1j) and (1k) are the integrality.

GA Approach and It's Application

For testing the model and to see GA performance, the application will be demonstrate on North Maluku network. North Maluku is an archipelago regency in Indonesia, consisting of 320 small islands. The total area is 103.789 square kilometers with 22% land territory and 78% sea territory. Our network will be pointed out the south part of Halmahera islands, Obi islands, Bacan islands, and Kayoa islands. There are a lot of towns and villages in this area but there is no hospital and less health centers located in this area (figure 1).

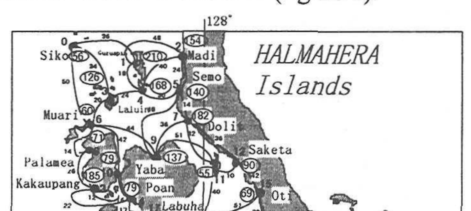

Figure 1. Network with demand node and distance unit in km.

North Maluku regency also face with the problem of tropic disease, that is malaria, cholera, tuberculosis, and others. The implementation of equity in health care system may be positive impact on the case finding.

Actually, our meaning of calculation is pointed out to the GA operations. Because initialization is done once and it is only prepare a set of source variables. The procedures are shown commonly in figure 2.

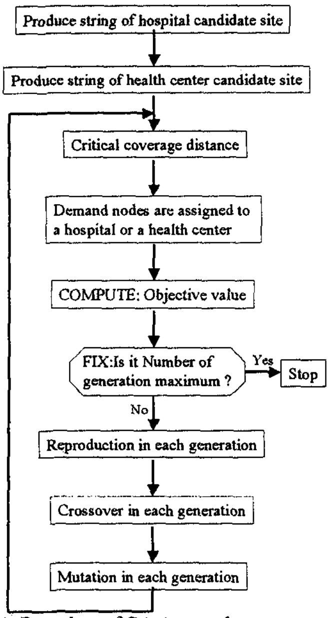

Figure 2. Procedure of GA Approach

The choice of facility site is running randomly in GA Approach. We keep it based on all constraints in a long iteration. We have two strings in each individual. The first string states the candidate site of hospital and second string states the candidate site of health center. Health center will be located if within a critical coverage distance to at least one hospital. Then all demand nodes are assigned to one of the health care facility under minimum path. Some of the computation running could be shown in figure 3.

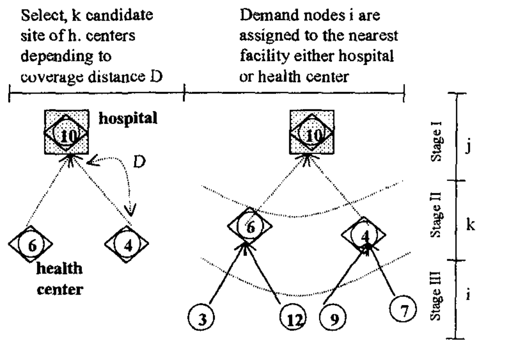

Figure 3. Hierarchy of hospitals, health centers and demand nodes.

Some results as follows. Trial for searching location of 6 hospitals and 12 health centers within related network are showing in figure 4. An alternative for locating these facilities and the diagram patient flows in Halmahera islands are given in figure 5.

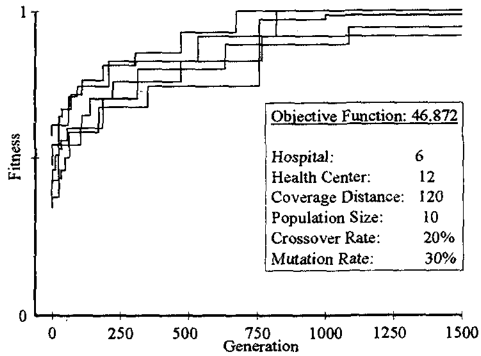

Figure 4. Calculation results of 5 times trial.

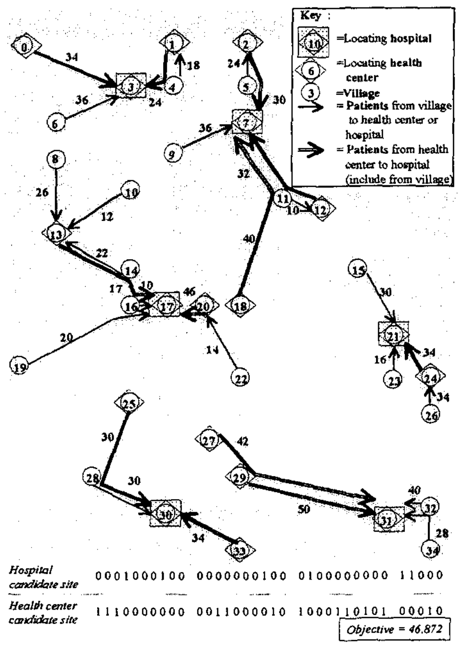

Figure 5. An alternative location and patient flows diagram.

As indicated in the formulation, median problem always pointed out a set of connecting calculation in a given demand and it's minimum distance access to facilities. Also, such a behavioral perspective leads us to a clear delineation of location goals within a given coverage distance. In this case, we deal with the distance between hospital and health center in term of hierarchy. Daskin (1995) evaluate a commonly cited statistic is that if a person's brain is denied oxygen for more than 4 minutes (a stroke or heart attack, for example), the likelihood of the individual surviving to lead a normal live drops below 50 percent. Since the related model is to provide "cover" for demand by all services. We show some behavior of the model in figure 6, figure 7 and figure 8.

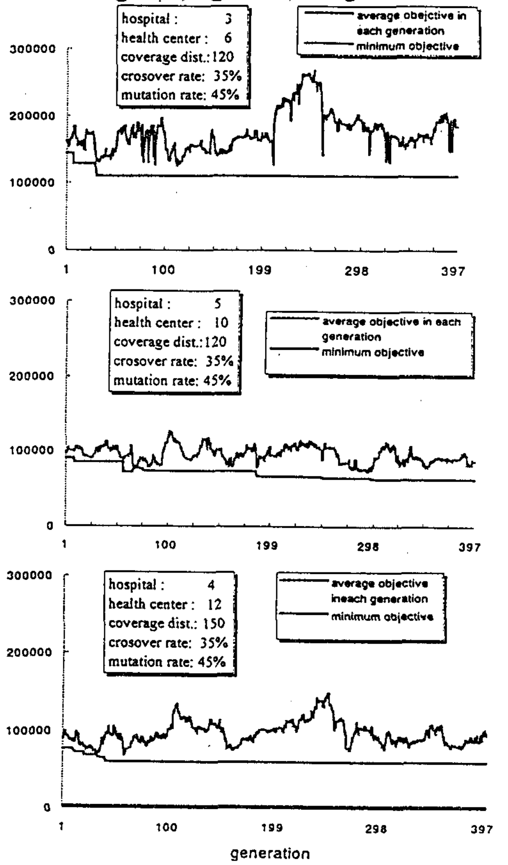

Figure 6. GA performance and It's variation of Objective value.

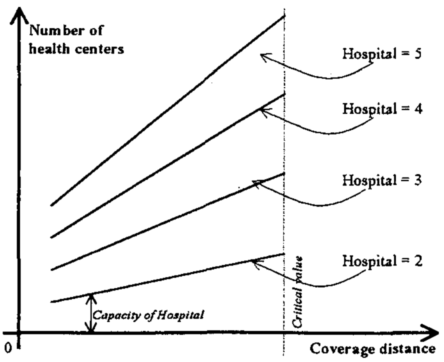

Figure 7. Coverage distance Vs. Number of health centers for a given number of hospitals.

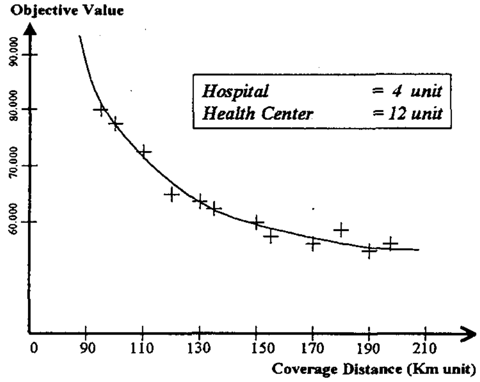

Figure 8. Interaction between objective function and coverage distance.

Conclusion

Hospital and health center are occupy an important role of health care activity. The application gives the feature of the model and the performance of the capability and efficiency of GA approach in searching minimum objective value of patients weighted distance as a reflect of locating these facilities in demand node precisely. We show the GA performance in a network with 35 nodes, it gives the GA capability and efficiency. The approach solution algorithm presented here can be serve primarily as aid the health planner in the choice of solution method of health care facility location based on median problem. Since public sector investment are often complicated in which beneficiaries of one investment may agree to support projects from which they do not directly benefit. Although the formulation has a problem in relation to a health care delivery system, the result of this thesis maybe plausible and applicable to a number of other systems with similar features, including fire station, post office system and so on.

References:

1. C G Gore (1991), Location Theory and Service Development Planning: 'Which Way Now?', *Environment and Planning A*, Vol.23, p. 1095-1109.
2. Daskin, Mark.S (1995) Network and Discrete Location, John Willey & Sons, Inc., New York.
3. Dokmeci, F (1977) A Quantitative Model to Plan Regional Health Facility Systems, *Management Science*, Vol. 24, No. 4. p. 411-419.
4. Girt, John L (1973) Distance to General Medical Practice and Its Effect on Revealed Ill-Health In A rural Environment, *Canadian Geographer*, XVII, 2. p.154-166.
5. Ministry of Health Republic of Indonesia, Health Resources, 1997.
6. Monograph KD.II Maluku Utara · (North Maluku Regency), Republic of Indonesia, 1993.