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An AHP Based Way to Evaluate Appropriate Points for Installing Power Towers and Finding the Best Way for Power Transmission Lines by GA Algorithm

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Abstract- Today optimization is one of the most important issues in all engineering fields. According to importance of this issue in planning power transmission lines, appropriate areas have been accreted for numerous researches. Widespread usages of GIS application and its combination with GA base methods offer practical solution for power transmission lines design. In this paper, we first study about efficient criteria for selecting appropriate points for installing towers, and then we can evaluate available points for installing power towers by one of the multi-criteria decision-making analysis, named AHP[2]. As we know, all of these nodes are not suitable for being one of the transmission line Points. So by using this procedure (AHP) we calculate cost function of transmission line between towers. Finally, with GA algorithm, the best and the most optimum route between source and destination will be selected.

Keywords: Power Distribution Line, Geographical Information System, Genetic Algorithm, AHP Method

I. INTRODUCTION

The first step in installation of power lines is to find adequate criteria for assessment and selection of nodes. In this context, GIS techniques have been used as an efficient method for finding an appropriate assessment model. In order to select the best route for construction of power transmission lines network, at first it is needed to find appropriate nodes for installing power tower then we have to look for finding a function for calculating cost between nodes. In this paper both of mentioned process happens by AHP algorithm. An AHP algorithm is a hierarchical and layered algorithm that let us define our evaluation criteria, classified and based on priorities and dependences.

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Intelligent algorithms are always helpful in hard cases. Because of high flexibility and its quality variation, genetic algorithm is an appropriate strategy for calculating the best route for power transmission from a determined source to destination. The value of genetic algorithm clarifies when we face with numerous nodes as a power tower and the edges between them. Because in these situations old methods with fixed computational times such as Dijkstra's algorithm usually become frustrating and have high computational load.

In the beginning of this paper we will explain intended criteria for selecting appropriate nodes and also MCDA methods and their implementation necessity will be explain, and AHP method will represent as an optimum solution.

Then AHP algorithm will be implemented on specified criteria and we will find functions for calculating efficiency rate of power tower installation nodes and cost between the edges.

After that we will implement genetic algorithm on obtained routes to find the most optimized route in the minimum time. Finally we will demonstrate the resulting and will compare it with a similar method.

II. EVALUATION CRITERIA FOR INSTALLING POWER TOWER POINTS

To find an appropriate fitness function for selecting power tower points we need a series of criteria to make decision based on them and select the most optimal and the least costly nodes. Because of using AHP we can classify and prioritize our criteria. According to the research, the most important effective factors on selecting power tower nodes are divided into three categories: technical factors, natural environment factors and social environment factors. [1] Since engineering of lines construction has high importance, technical factors have more priorities. Of course each of three mentioned criteria divides to sub-criteria that we name them factor. Each factor has criteria for itself which are in lowest structure level and related expert is bound to give them weight. We say to these criteria index. Table 1 represents available criteria set in each layer. Available criteria are selected among the several criteria and they are more important than the other ones in author's opinion so they can be ignored.

Table 1 Evaluatio criteria for appropriate points

Criteria	Factors	Indicators
Technical	Executive	The observance of Authorized and legal privacy Absence of noise interferencing Points with lower angle
	Maintenance	Accessibility Resistance in difficult weather condition Security
	Economic	Establishing Time Minimum Cost
Natural environment	Absence of enviromental danger	Earthquake Flood Hurricane
	No damaging to the natural environment	
Social environment	Observing the general rules	Avoid crossing the residential areas and public facilities Avoid crossing agricultural land and Antiquities
	Coordination with regional Construction plans	

III. EVALUATION CRITERIA OF ROUTE

After finding recommended nodes for installing power towers, we need to calculate route cost function between nodes to select the most optimal route. For calculating of this function, we need to have a series of evaluation criteria. Certainly score achieved by each node in previous level is an appropriate criterion for this level. But we shouldn't neglect from economic cost of route between two nodes because it is more important than the other criteria. Environmental noises and avoidance of passing forbidden areas are the other factors.

IV.EVALUATION BASED ON MULTI-CRITERIA

MC Harg (1968) presented Systematic method for planning on using appropriate locations by using the Compatibility concept of several appropriate points. [2,3] He mentioned that there are effective factors in the selection of nodes that have different values. Therefore, optimizing them for a unique application is hard. He defined a simple matrix to determine the degree of compatibility. The main idea of MCDA is based on this concept. Over time the idea of multiple criteria decision by GIS system were advanced and converted to the multi criteria methodology concepts.

A. Integration of GIS and multi-criteria methods

Jankowski has proposed two methods for integrating GIS and Multi-criteria techniques: the loose coupling strategy and the tight coupling strategy. The main idea of the loose coupling strategy is to facilitate the integration by using a file exchange mechanism. The assumption behind this strategy is that multi-criteria techniques already exist in the form of stand-alone computer programs. The results of the decision analysis may be sent to GIS for display and spatial visualization. The loose coupling architecture is based on linking three modules (GIS module, Multi-criteria technique module and file exchange module), as seen in figure 1.[4]

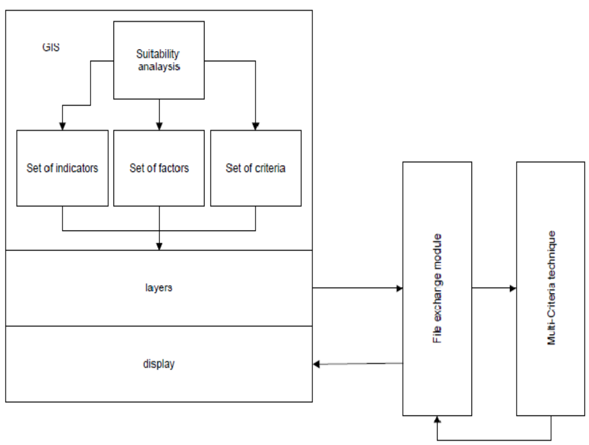

Figure 1: Architecture of Loose Coupling

B. AHP

It is a MCDA method and uses hierarchical architecture for showing the problem and spread of criteria and their priority based on user’s judgment. This method was developed by Saaty (1980). Saaty showed that weighing process in multi-criteria decision is carried out effectively by using hieratical structures and two by two comparisons. Two by two comparisons based on judgment between two specific elements are done instead of comparison between all of the elements together.

Today AHP is spread in three main fields: [5]

- Compensatory techniques: These techniques require accurate and reliable weights since the Decision-making center must assign weights to the criteria in the form of a decision-making rule. They are based on the premise that a high value for one alternative can be compensated by a low value for the same alternative with regard to other criteria. The other specifications of this method are weighted linear sum that is one of the most frequently used methods because of its simplicity.

- Non-compensatory techniques: These techniques require a smaller cognitive weight since they only assign an ordinal value to the criteria.

- Fuzzy techniques: These techniques deal with problems whose boundaries are not clearly defined.

C. Calculating the rules of criteria

At first we find importance of each criterion rather than the other. Their importance level is depending on the judgment of experts. In AHP standard, following table is used to calculate the level of importance.

Table 2: Fundamental scale

Importance level	Concept	*aij*	*aji*
1	Equal	1	1
2	Between	2	$\frac{1}{2}$
3	More important	3	$\frac{1}{3}$
4	Between	4	$\frac{1}{4}$
5	Essential	5	$\frac{1}{5}$
6	Between	6	$\frac{1}{6}$
7	Very strong	7	$\frac{1}{7}$
8	Between	8	$\frac{1}{8}$
9	Absolute	9	$\frac{1}{9}$

If our criteria to be n, we place all the criteria in an n × n square matrix and we enter the degree of importance of corresponding elements. Suppose aij is the importance of element i (criterion) to element j, in this case aij is equal to the reverse of them. For example technical criteria are much more important than natural environment criteria. Therefore, its corresponding value is equal to 5 and the amount of its corresponding element in row and column reversed is equal to 1/5. Table 3 represents values assigned to each element.

D. Calculating fitness function for selection of nodes

Since we have 3 main criteria, coefficient matrix will be a 3*3 matrix.

Table 3: Criteria importance coefficient

	Technical	Natural invironment	Social invironment
Technical	1	5	3
Natural invironment	$\frac{1}{5}$	1	$\frac{1}{3}$
Social invironment	$\frac{1}{3}$	3	1

After calculating the importance of criteria, we write them as decimal numbers in order to work with them simply. Now it is needed to normalize elements. For this target, each element is divided into the sum of all elements of its column. Tables, number 4 and 5 show the stages of this process. At last, the percentage of the overall importance of each of the 3 criteria is determined with taking the average of its related row. As you see in this table technical criteria with 63% has the most importance.

Table 4: Criteria importance coefficient and sum of columns

	Technical	Natural invironment	Social invironment
Technical	1	5	3
Natural invironment	0.2	1	0.33
Social invironment	0.33	3	1
Sum of culomns	1.53	9	4.33

Table5: Normalized value and final weight of criteria

	Technical	Natural invironment	Social invironment	Final weight
Technical	0.65	0.55	0.69	$\sum\frac{1.89}{3} = 0.63$
Natural invironment	0.13	0.11	0.08	$\sum\frac{0.32}{3} = 0.11$
Social invironment	0.21	0.33	0.23	$\sum\frac{0.77}{3} = 0.26$

E. Evaluation of Factors and Indicators

Each of calculated criteria at previous level includes some factors that sub factors of each criterion are standardized separately. Each factor is also included a few indicators and it is necessary to standardize them. For calculation, we will do the same operation for each of the factors. Following figure represents the whole conclusions of these calculations.

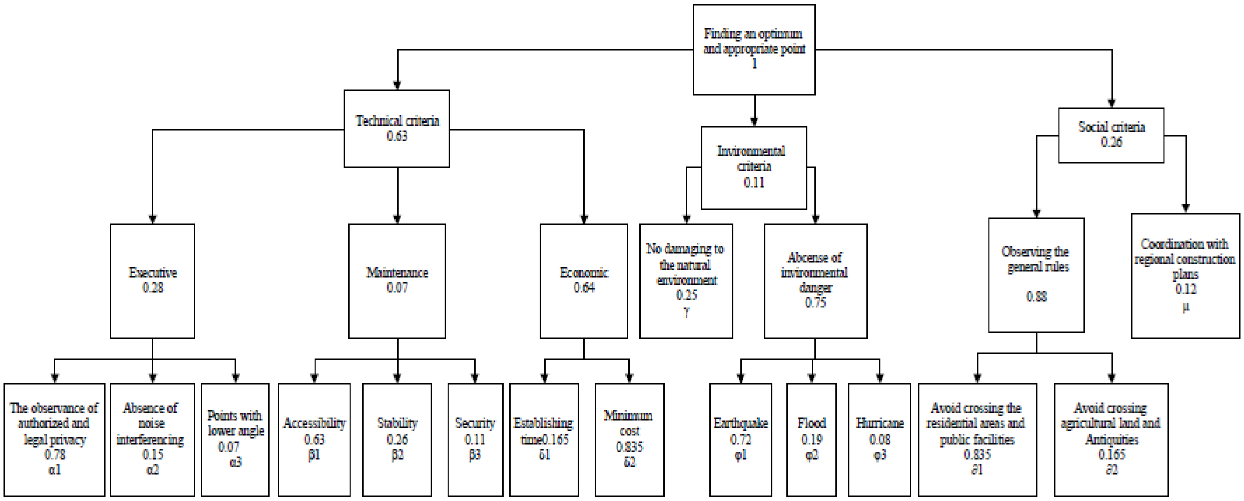

Figure 2. Structure of criteria for selecting appropriate points

F. Calculating cost function of nodes

After calculating the value of different criteria, we have a hierarchical structure with specified coefficient like following figure. Now we can find appropriate evaluation function according to formula 1.

$$F(x) = (.138)\alpha_1 + (.027)\alpha_2 + (.012)\alpha_3 + (.028)\beta_1 + (.012)\beta_2 + (.005)\beta_3 + (.068)\delta_1 + (0.336)\delta_2 + (.059)\phi_1 + (.017)\phi_2 + (.008)\phi_3 + (.028)\gamma + (.192)\partial_1 + (.038)\partial_2 + (.032) \quad (1)$$

G. Evaluating the cost of route selection

As we said, for calculation of this function we have to consider 5 criteria. According to selected criteria for the level of selection nodes, the criteria of this level just have one stage and are not layering. In the table 6, we have calculated final value of these criteria with AHP method.

Table 6: Final weight of criterias

	Distance and cost	Value of node1	Value of node2	Forbidden area	Existence noises	Final weight
Distance and cost	0.52	0.54	0.54	0.49	0.39	$\sum \frac{2.48}{5} = 0.5$
Value of node1	0.17	0.18	0.18	0.21	0.22	$\sum \frac{0.96}{5} = 0.19$
Value of node2	0.17	0.18	0.18	0.21	0.22	$\sum \frac{0.96}{5} = 0.19$
Forbidden area	0.07	0.06	0.06	0.07	0.13	$\sum \frac{0.39}{5} = 0.08$
Existence noises	0.06	0.04	0.04	0.02	0.04	$\sum \frac{0.2}{5} = 0.04$

H. Calculation of route cost function

Figure number 3 represents criteria structure and their coefficient.

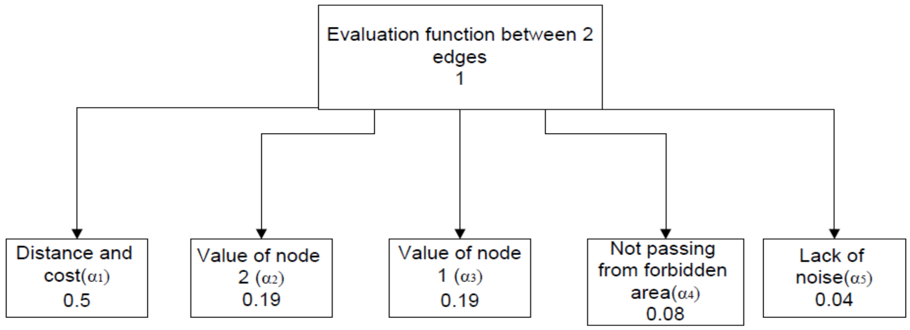

Figure 3. Structure of criteria for selecting appropriate cost

According to above coefficients, cost function is like this:

$$F(x) = 0.5\alpha_1 + 0.19\alpha_2 + 0.19\alpha_3 + 0.08\alpha_4 + 0.04\alpha_5 \qquad (2)$$

V. DISCUSSION ON CONSISTENCY IN AHP ALGORITHM

An important issue in distribution of coefficients and weighing to criteria is consistency discussion that represents rate of dependencies. In one consistent matrix, dominant eigenvalue is equal to rank of matrix. So for rate of inconsistency, we can calculate eigenvalue deviation from rank of matrix with formula 3: [6, 7]

$$IC = \frac{\lambda_{max} - n}{n - 1} \qquad (3)$$

Now for more accurate calculation of inconsistency coefficient it's better to compare it with inconsistency coefficient of a random matrix that has high inconsistency. The coefficients of random matrices are written in table 7 with rank from 3 to 9.

Table 7: Inconsistencies index for random matrix

n	3	4	5	6	7	8	9
C.R	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Thus formula 4 is obtained:

$$CR = \frac{IC}{CR} = \frac{\lambda_{max} - n}{(n-1).CR} \qquad (4)$$

Until this coefficient is less than 0.1, we have a consistent matrix. For instant in table 5 the value of λ_{max} is equal to 2.976 that with use of above formula the value of CR is equal to 0.02 that represents the consistency of matrix. But when this rate goes higher than 0.1 we need to review for finding evaluation error. This error can be caused by typing mistake in entering a coefficient or be outcome of a bad interpretation. In this case, it is better to review the coefficients and if it is necessary, we should revise the amount of coefficients. Finally, this task can be delegated to someone who will be able to create stable matrix.

VI. IMPLEMENTATION OF GENETIC ALGORITHM FOR FINDING OPTIMUM ROUTE

Use of genetic algorithm due to operating randomized for complicated and high cost issues is customary. When we are facing the vast volume of data and we don't have appropriate and stable solution, artificial intelligence techniques, especially genetic algorithms will help us. We want to find the best route among the available routes between determined source and destination. An appropriate solution with clear computational order for routing is Dijkstra's algorithm. However, the computational order at best state is equal to $O(|E| + |V| \log|V|)$, Which E is edges and V is vertices. With little pause we realized that for large number of nodes and routes, this algorithm requires high computational time. So we use genetic algorithm to reduce the computational load with the following algorithm techniques that we mention to them .Of other reasons for choosing the genetic algorithm are high diversity and high flexibility which prevent significant changes in computational load despite of change in network size.[8] A genetic algorithm includes several parts. First, we have to define the desired issue in a way that any solution can be placed in a chromosome. Genes form Parameters of this chromosome guide us to the solutions. Then we create a sample population of chromosomes (parents), (which it is called initialization stage) and we perform mutation and crossover operation on them until new chromosomes (offspring) are created. By using a suitable criterion, we can select chromosomes among the offspring for next generation. Also we can perform this selection among the parents. Now we repeat previous cases on the new generation produced as much as we reach an optimal answer. We need an appropriate Fitness Function so as to reach optimal answer. We run this function in each repetition of loop and if we achieve optimum answer or after several repetitions the best answer does not change, we end this algorithm.

A. Creation of chromosome

Since selecting the best route between the source and destination is our issue so, we form the chromosomes that its genes are route nodes. The first gene is source point and the last gene is destination point and the genes which are between them are nodes of a choice route. Since different routes have different number of nodes, chromosomes are not fixed-length. However there are methods provided with fixed-length that in regard to their computational complexity, their performance are less effective than this method. [10]

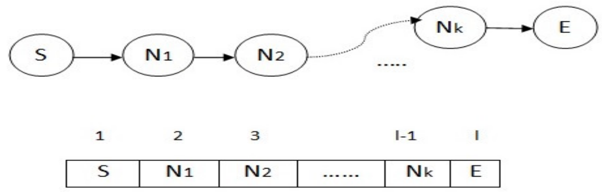

Figure 4. Structure of intended chromosome

B. Initialization stage

At this stage we want to create initial population proportional to intended population size. There are several ways to perform this method. We can randomly place nodes on the chromosomes. Since this method may be producing small number of chromosomes that have a route from beginning to end, it does not seem as a suitable solution. At first It is better to randomly choose a node among the nodes which are linked to the initially node by an edge. Then we should do the same for the nodes connected to the selected following node and continuing this loop to reach destination node. Another way is using heuristic methods to perform initialization. Although this method probably causes to have better routes in the beginning, it would reduce the diversity of chromosomes. It is worth noting that the more population size cause the more probability of reaching optimum answer but it also cause higher computational load.

C. Crossover operation

We randomly choose two chromosomes for crossover and then we identify Nodes which are common in both chromosomes (except the initial and final node) and we choose a node among them. Now from the following point, we perform crossover operation and then we attach second part of each chromosome to the next chromosome like the following figure. The important point is the possibility of loop existence in the new created chromosome that we must have a correction function for such conditions to identify the loop and remove it by omitting edges and repetitive nodes. The coefficient considered for probability of crossover operation (PC) is equal to 0.7. This means that crossover operation act on 70 percent of each generation of chromosomes. The high of this coefficient is due to crossover operation that causes to reach better solutions. There are also other methods for crossover operation which are not mentioned in this paper. [9, 10]

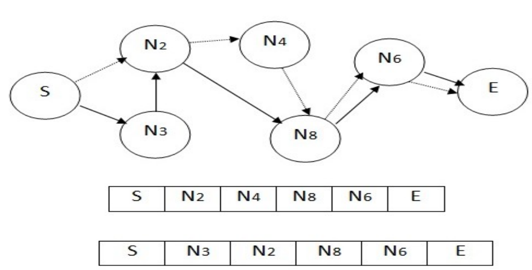

Figure 5. Two separate routes before crossover operation

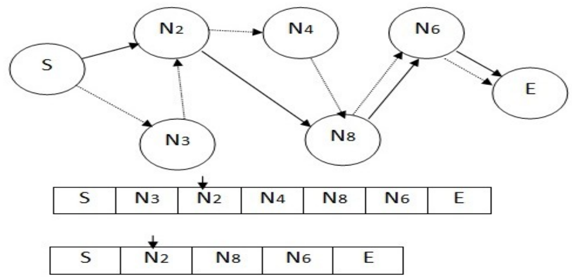

Figure 6. The new routes resulting from crossover operation

D. Mutation operation

For mutation, we randomly select a chromosome. Then we choose one of the genes (except the first and last genes). If we randomly replace this gene with another gene, the chromosome may no longer represent one answer; we do not perform any operation on the genes between source and selected case. For the point after that, we consider the intended gene as the source node and again we perform the operation like initialization operation to reach the destination node. This method may increase computational cost little more but, this little impact is not felt, because the mutation operation is done on the chromosomes with very low percent probability. The coefficient considered for probability of mutation operation (Pm) is equal to 0.1 in this paper. Mutation operation is used when the issue is trapped in the local minimum points and it needs a mutation to be lead to the global minimum.

E. Fitness Function

Since we want to find the best route based on cost, fitness functions is equal to reverse of total cost of available edges in the route. The larger outcome of this function means lower cost of the route.

$$F(x) = \frac{1}{\sum_{i=1}^{l} Cost(Node(i), Node(i+1))} \quad (5)$$

F. Selection criterion

In each generation after performing crossover operation, if chromosomes produced by the operation have more fitness than their parent, they are added to the population. After adding of chromosomes from mutation and crossover, a pool of chromosomes is caused by parents and offspring. By using tournament method with k=2 (size of tournament), the next generation of chromosomes are selected. However, the most valuable and the least valuable chromosome is transferred to the next generation to improve each generation.

VII. IMPLEMENTATION RESULTS

We evaluate our genetic algorithm in different topologies with 10 up to 50 nodes. We assume there is a path between every two nodes. Cost of routes is determined by evaluation functions that have calculated in last steps. In these examples, costs are generated randomly for any iteration. Table 8 shows final results of every topology with 100 iterations. For certainty we compare our results with Dijkstra's algorithm.

Table 8: Accuracy and speed of proposed algorithm (Population size=100)

Avarege of elapsed time(second)	Optimum results (%)	Number of nodes
0.13	100	10
0.67	100	20
4.06	98	30
6.2	95	40
9.23	95	50

Figure 7 is the chart that illustrates percentage of correct answeres. As you see, percentage of correct answers didn't have any obviouse diffrence by changing number of nodes. For example in state of 50 nodes, there are 1225 paths that the optimum answer was found in 9 secends with 95% confidence.

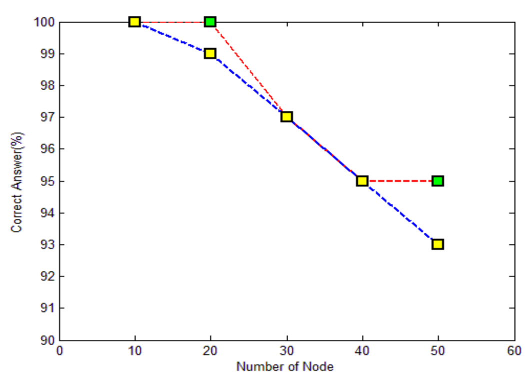

Figure 7. Percentage of correct answers(Red :Popzie 100, Blue:Popsize50)

It is obviouse that by enhancement of iteration, the percentage of correct answers are increased, but complexity and computational time increase too. Also this is right about size of population.

Table 9: Accuracy and speed of proposed algorithm (Population size=50)

Avarege of elapsed time(second)	Optimum results (%)	Number of nodes
0.15	100	10
0.46	99	20
1.04	97	30
3.8	95	40
7.75	93	50

For more understanding we compared obtained results with another research [11] by 100 nodes and with population size equal to 50. It is observable from following table that both accuracy and complexity improved by our algorithm.

Table 10: Comparision between proposed algorithm and another research

Algorithm	Number of nodes	Accuracy	Elapsed time
Proposed algorithm	100	72	17.64
Compared algorithm	100	64	634.42

IIX. Conclusion

In this paper we proposed a method based on MCDA for selecting appropriate points for installing power towers. Because of wide usage of MCDA methods (especially AHP) in problems with high complexity, we calculated cost of intended points with AHP method. These points create several routes with variant costs. Since genetic algorithm has high diversity and consistency in front of changing size of route nodes, using this algorithm is very suitable for finding best route. For more realization we implement this method on several topologies and at the end we compare our proposed method with another implementation. Obtained results show that our proposed algorithm has higher accuracy than the compared algorithm. It is also true about elapsed time. Of course we can reduce computational time by using paralleling method and multi population method that will be a good idea for future researchs.

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Biography

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