Genetic Algorithm in Electrical Transmission Lines Path Finding Problems

Hasan Eroğlu[1], Musa Aydın[2]

[1] Department of Electrical & Electronic Engineering Gümüşhane University, Gümüşhane, TURKEY
hasan.eroglu@gumushane.edu.tr
[2] Department of Electrical & Electronic Engineering Selçuk University, Konya, TURKEY
aydin@selcuk.edu.tr

Abstract

Today, Geographic Information Systems (GIS) solutions have entered every corner of the engineering studies like Electrical Transmission Lines (ETL) route optimization, vehicle routing, power plant siting and so on. Raster-based maps generated by GIS are very useful solutions for this kind of route optimization problems. The weighted sum of all the data can be converted to raster-based maps and gathered consecutively in GIS for ETL route optimization. In this paper, Genetic Algorithm (GA) is applied to ETL route optimization problems in order to find the best route on raster-based maps.

1. Introduction

ETL routing is one of the most difficult problems in electrical engineering. As considering all the criteria like slope, landslide, road/railway/pipeline crossing, ice zone, distance to roads, national parks, archaeological areas, residential areas forests, river crossing etc. is impossible with human brains, GIS solutions should be used in this kind of problems. Processing all the data relevant to ETL routing is an easy process in GIS.

The Total Weighted Surface Raster Map (TWSRM) should be obtained by weighting criteria related to ETL, collecting all the data about these criteria, processing these data, converting to raster format -basically a regular matrix of square cells where each cell represents an area and position- gathering consecutively all the data in ArcGIS in order to find the best route for ETL routing [1]-[4].

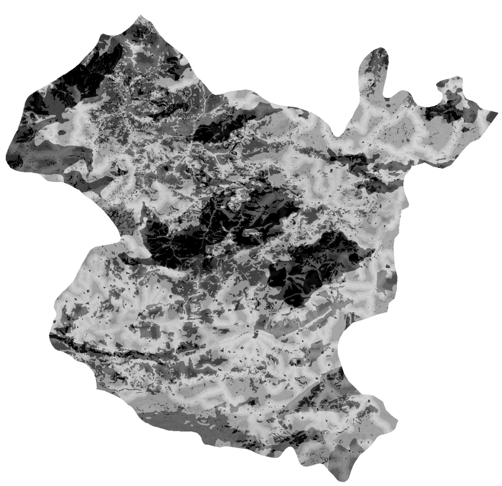

Fig. 1. Total Weighed Surface Map obtained by unifying the raster-based weighed maps via Raster Calculator toolbox of ArcGIS.

In weighting of criteria, Analytic Hierarchy Process (AHP) and the Fuzzy AHP are used. Weighting is made according to previous studies in literature [3]-[9]. All the data relevant to ETL routing are processed in ESRI's ArcGIS software and the TWSRM is gathered as shown in Figure 1.

In the map, the darkness of the pixels represents more passing difficulty.

The size of the pixels is 25 meter that is a proper value for this kind of studies. Every cell has a value that represents the passing difficulty through them. If the value is higher it means the passing of the ETL will be difficult and vice versa.

Sometimes ArcGIS software can find routes that have a lot of curves with big angles. So the GA is used on different start and end points of the TWSRM to find the best routes for ETL as an alternative to the ArcGIS software.

2. Genetic algorithm

GA is an optimization algorithm introduced by John. H. Holland. GA that tries to mimic the natural behavior in searching processes associated with rules of reproducing populations as inheriting good genes (parts) from good performance parents is widely used in optimization studies [10]-[14].

In order to generate the population of the GA, chromosomes (individuals) should be encoded from the study material. In this study, the TWSRM is converted to a text file that has all the values of the map and chromosomes (Figure 2.) are generated from this text file.

As illustrated in Figure 2, every chromosome that represents a randomly generated route consists of lots of genes. These genes represent "nrows" and "ncols" values of the text file matrix. The addresses of the genes are memorized with their rows and columns number in a series named "Map Series" (MS). Also the raster values of these genes are memorized with another series named "Value Series" (VS).

The genes of the chromosomes are selected randomly by starting from the beginning gene to the end gene. New genes should be selected from the genes around the current gene in order not to break off the route. This control named break off control is made in every gene generation. The generation process stops when the destination gene is reached. In every selection, the control of re-selection is made in order not to use the same gene again.

After generating the population, GA applies crossover and mutation operations and runs until the number of the iteration is reached. The fitness functions (a weighted sum of the pixel

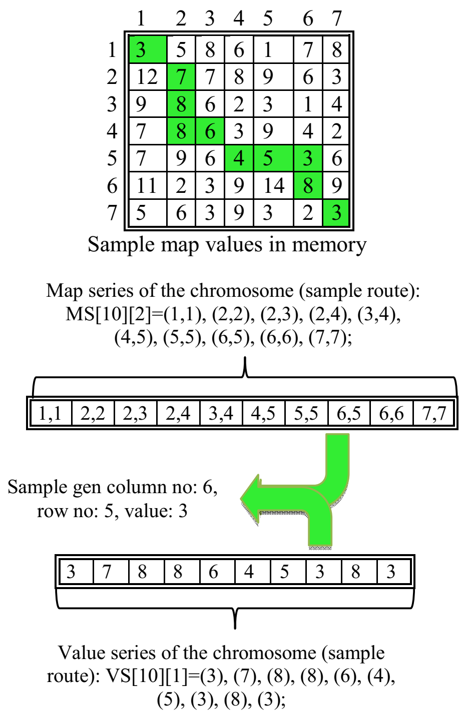

Fig. 2. Sample chromosome (route) Generated by the algorithm.

values) of all the chromosomes are calculated for selection. In each iteration, routes (chromosomes) with lower weights (lower passing difficulty of ETL) have a greater probability of selection with the help of the "Roulette Wheel" (RW) selection method.

The crossover operation of the algorithm is slightly different from classical crossover operations. There should be common points between two parent chromosomes selected by the RW selection method to prevent breaks of the routes. In the proposed crossover operation of the algorithm, all the common points of the two chromosomes are identified and then the crossover operation is applied by changing the parts that have big fitness values with the parts that have small fitness values as illustrated in Figure 3.

Mutation operation means changing some parts or values of the chromosomes with new randomly generated parts or values that have smaller fitness values as shown in Figure 4. The break off control is important in this operation because the start and end point of the part shouldn't be changed in order not to break the route. Several beginning and end points are selected randomly for the operation.

The flowchart of GA used in this study is presented in Figure 5.

After these processes, the algorithm runs until the number of the iteration is reached and then selects the best chromosome for solution.

3. Experimental results

The performance of the proposed algorithm is tested by comparing the routes generated by the algorithm with the routes generated by ArcGIS software.

A large population size proportional to the rows and columns number of the study area is selected to make variety for the algorithm.

Two different start and end point are selected for three experiment and the results of the algorithm and ArcGIS software are shown in Figure 6.

In order to determine the proper iteration number and population size, the algorithm is run many times on the first map in Experiment 1 and the results are shown in Table I.

Because of the random characterization of the algorithm the values in the Table I aren't linear (e.g. the fitness value of the seventh run is expected to be smaller than the fitness value of

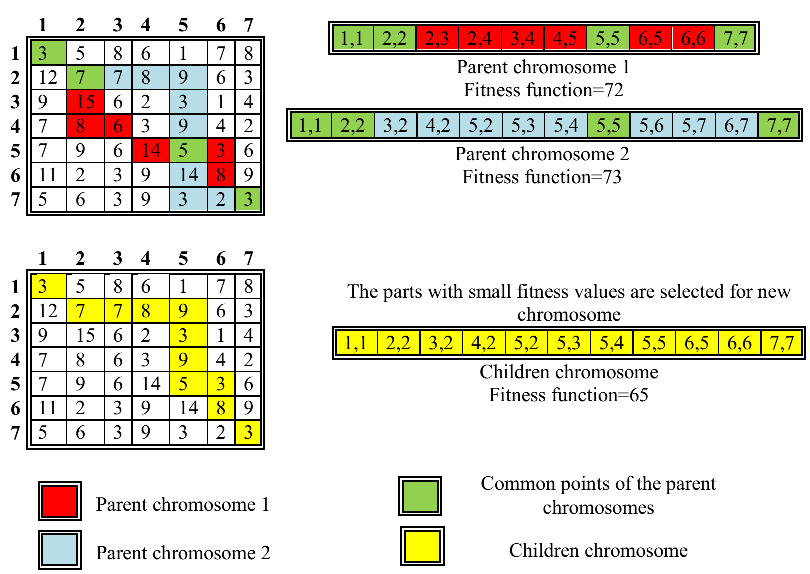

Fig. 3. The Crossover operation used in the GA.

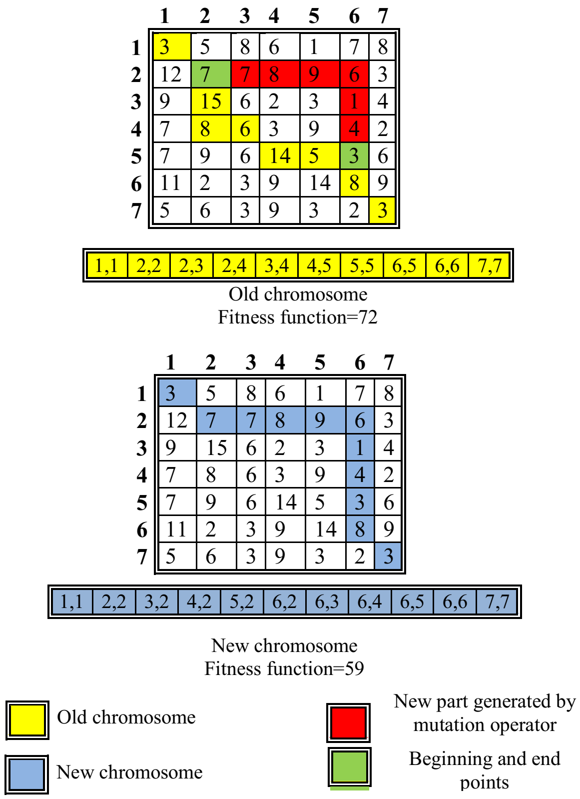

Fig. 4. The Mutation operation used in the GA.

the sixth run. Also in every run, the time and fitness values vary at the same population size and the number of iteration. So it is very hard to decide which value is more appropriate for algorithm.

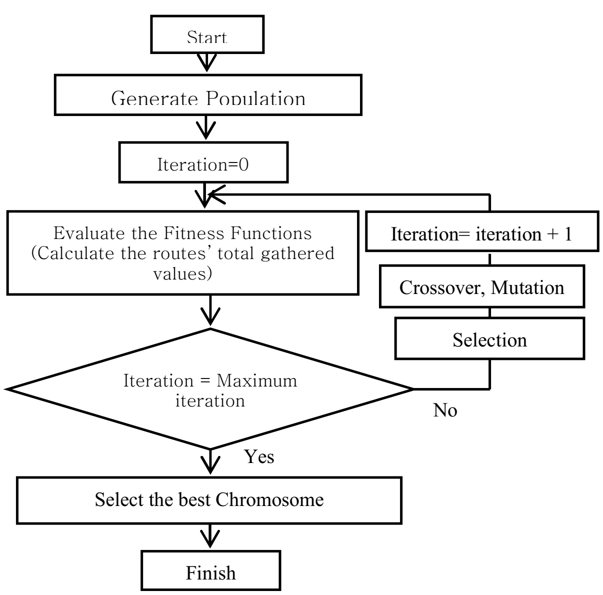

Fig. 5. Flowchart of GA used for route optimization.

Table I. Experimental values of the algorithm

Experiment Number	Algorithm Values			
	Population Size	*İteration*	*Fitness Value*	*Time*
1	25	25	1109	1 sec.
2	50	50	1100	5 sec.
3	50	5000	1050	4 min. 15 sec.
4		250	1071	15 sec.
5		500	1068	35 sec.
6	100	1000	1065	55 sec.
7		1500	1066	1 min. 05 sec.
8		5000	1049	4 min. 20 sec.
9		250	1086	30 sec.
10		500	1086	43 sec.
11	250	1000	1066	1 min. 22 sec.
12		1500	1067	2 min. 15 sec.
13		5000	1053	6 min. 20 sec.
14		250	1091	44 sec.
15		500	1062	1 min. 20 sec.
16	500	1000	1066	2 min. 20 sec.
17		1500	1059	3 min. 30 sec.
18		5000	1061	7 min. 35 sec.
19		250	1081	1 min. 23 sec.
20	1000	500	1063	2 min. 15 sec.
21		1000	1072	4 min. 25 sec.
22		1500	1069	7 min. 35 sec.

The Pn and In values in the experiment 8 are accepted as the optimum population size and iteration number in this paper and they are formulated in (1) and (2) where Pn is the population size and In is the iteration number.

$$Pn = (nrows \cdot ncols) / 22 \quad (1)$$

$$In = (nrows \cdot ncols) / 3 \quad (2)$$

In Figure 6, the fitness value of the route found by the algorithm is 1049 (Experiment 3). It is very close to the fitness value (1029) of the route found by ArcGIS. The routes are also very close to each other in Experiment 2. But the speed of the proposed algorithm is not as fast as the speed of the ArcGIS.

Making lots of iteration with very long strings reduces the speed of the algorithm.

In Experiment 3, the fitness value of the proposed algorithm's route (1745) is smaller than the fitness value of ArcGIS software's route (1748).

The resemblance of the routes proves the accuracy of the proposed algorithm while the differences of the proposed algorithm in every experiment with the same iteration number and population size will help the researcher to select the optimum route with minimum angle of curves.

In ETL routing studies, the angle of the curves of the lines are very important as they affect the conductor type and the peak force of the poles of the lines. So the curves with big angles increase the cost of the ETL. The algorithm used in ArcGIS gives only one route that can make lots of curves with big angles in order to find the best route.

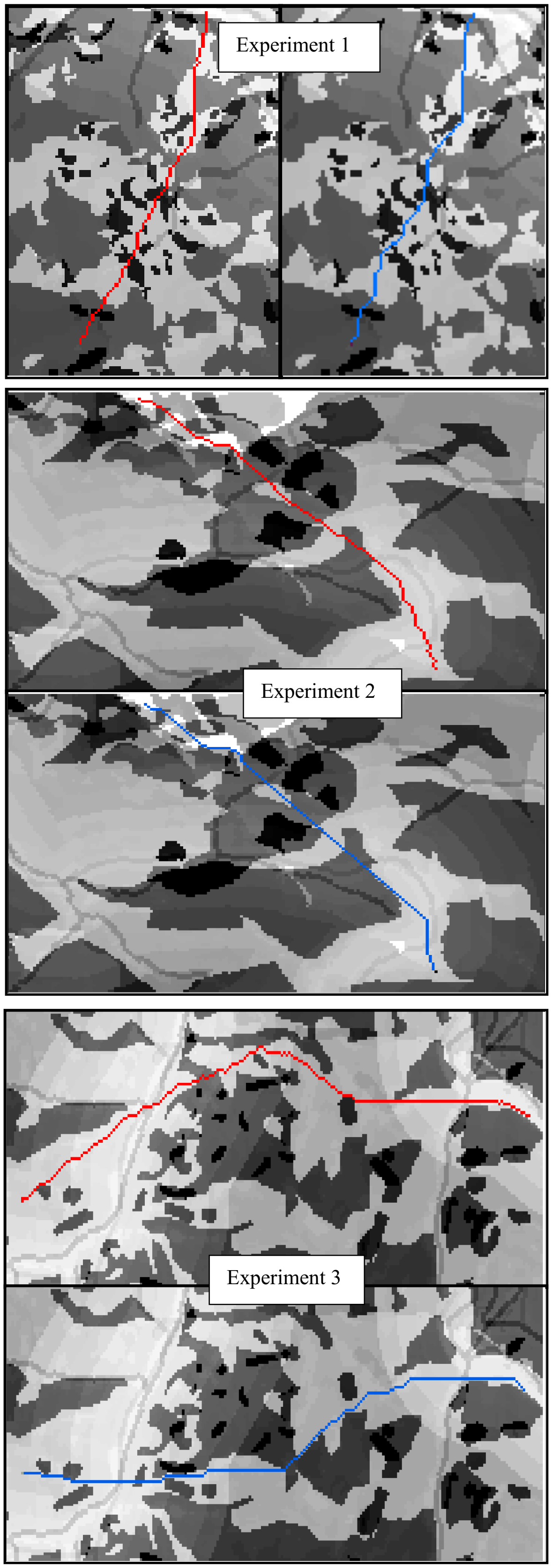

Fig. 6. The Routes generated from the proposed Algorithm (red) and ArcGIS (Blue)

In order to select the best route with minimum curves, alternative routes should be generated. In this respect, the proposed algorithm is very useful for ETL route optimization studies although the speed of the algorithm is poor.

4. Conclusion

In this paper, optimum solution for ETL routing is tried to find with GA. The algorithm's functions like crossover and mutation are adapted to the problem. The results of the algorithm are compared with the results of ArcGIS. In some cases, the proposed algorithm can find routes with smaller fitness values than ArcGIS software.

With the help of the study, new route alternatives will be served to the researchers who are trying to find the best route in raster-based maps.

5. References

[1] C. Monteiro, I. J. Ramirez-Rosado, V. Miranda, P. J. Zorzano-Santamaría, E. García-Garrido, and L. A. Fernández-Jiménez, "GIS spatial analysis applied to electric line routing optimization," *IEEE Trans. Power Del.*, vol. 20, no. 2, pp. 934–942, Apr. 2005.

[2] C. Monteiro, V. Miranda, I.J. Ramirez-Rosado, P.J. Zorzano-Santamaría, B. García-Garrido, and L.A. Fernández-Jiménez, "Compromise Seeking lor Power Line Path Selection Based on Economic and Environmental Corridors," *IEEE Trans. Power Syst.*, vol. 20, no. 3, pp. 1422-1430, August 2005.

[3] V. Yildirim, and R. Nisanci, "Developing a geospatial model for power transmission line routing in Turkey," presented at the XXIV FIG Cong. – Fac. the Chall. – Build. the Cap., Sydney, 2010.

[4] V. Yıldırım, "Development of a Raster Based Dynamic Model with Geographical Information System for the Determination of Natural Gas Transmission Pipelines." PhD thesis, Karadeniz Technical University, 2009.

[5] F. Husain, N. A. Sulaiman, K. A. Hashim, and A. M. Samad, "Multi-Criteria Selection for TNB Transmission Line Route Using AHP and GIS, " in Proc. Int. Conf. on Syst. Eng. and Tech. (ICSET), 2012, pp. 1-6.

[6] S. Demircan, M. Aydin, and S.S. Durduran, "Finding optimum route of electrical energy transmission line using multi - criteria with Q – learning," *Exp. Syst. with Appl.*, vol. 38, pp. 3477-3482, 2011.

[7] J. A. Schmidt, Implementing a GIS Methodology for Siting High Voltage Electric Transmission Lines. Minnesota: Saint Mary's University of Minnesota University Central Services Press, 1999.

[8] S. Demircan, "The Road Optimization of Energy Transmission Line with Multi Agent Systems." M.A. thesis, Selçuk, 2009.

[9] G. Houston, and C. Johnson, EPRI - GTC Overhead Electric Transmission Line Siting Methodology. Georgia, CA: Georgia Transmission Corporation, 2006.

[10] Y. Y. Hong, and R. C. Lian, "Optimal Sizing of Hybrid Wind/PV/Diesel generationin a stand-alone power system using Markov-Based Genetic Algorithm," *IEEE Trans. Power Del.*, vol. 27, no. 2, pp. 640 – 647, April 2012.

[11] A. Arabali, M. Ghofrani, M. Etezadi-Amoli, M. S. Fadali, and Y. Baghzouz, "Genetic-Algorithm-Based optimization approach for energy management," *IEEE Trans. Power Del.*, in press.

[12] J. H. Heo at al., "A Reliability-centered approach to an optimal maintenance strategy in transmission systems using a genetic algorithm," *IEEE Trans. Power Del.*, vol. 26, no. 4, pp. 2171 – 2179, October 2011.
[13] X. Lin, S. Ke, Z. Li, H. Weng, and Xionghui Han, "A fault diagnosis method of power systems based on improved objective function and Genetic Algorithm-Tabu Search," *IEEE Trans. Power Del*., vol. 25, no. 3, pp. 1268 – 1274, July 2010.
[14] M. A. S. Masoum, M. Ladjevardi, A. Jafarian, and E. F. Fuchs, "Optimal Placement, Replacement and Sizing of Capacitor Banks in Distorted Distribution Networks by Genetic Algorithms ," *IEEE Trans. Power Del.*, vol. 19, no. 4, pp. 1794 – 1801, October 2004.