Finding the shortest route surveying through proposed genetic algorithm

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Abstract: Surveying has long been one of the techniques used by human beings to determine the limits of lands. Today, this science is witnessed in all engineering tasks. The main objective of surveying is to determine the relative position of points on land surface or close to it. To survey on area, the distance between the existing lands must be covered. This paper intends to locate a tree in the area so that the shortest route may be covered. Therefore, the satellite map of the area is studied prior to surveying and a graph, which involves five benchmarks and their distances, is attained. The minimum spanning tree between the locations is then obtained by means of metaheuristic genetic algorithm (GA). When the tree (i.e., route) is located, surveying of the area can be made via covering the shortest route, decreasing the surveying time and increasing its efficiency.

Keywords: surveying; benchmark; genetic algorithm; GA; graph.


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1 Introduction

The objective of surveying is, in fact, to determine the locations of points on the earth. Measuring tapes or chains require that the surveyor personally pass through all the terrains of the region. Surveying methods have already undergone considerable changes due to the development of satellite navigation systems such as the US global positioning system (GPS), the Russian global navigation satellite system (GLONASS), and the forthcoming European satellite navigation system (GALILEO) (Fidanova, 2007). Continuous research on naturally occurring social systems offers the prospect of creating artificial systems that generate applied solutions to many metaheuristic techniques have been developed to find proper solutions for these problems within desired time limits (Osman and Kelley, 1996). They try to solve complex optimisation problems by incorporating processes which are observed at work in our real life (Corne et al., 1999).

Zhang et al. (2014) An effective method to highway and railway by utilising vehicle-borne GPS/INS kinematic surveying system which is merge of the GPS and Inertial Navigation System (INS) have suggested. And to improve the accuracy of GPS/INS have presented a model based on ground control points. Their experimental results show that the proposed method improves the accuracy of the high points of the route. Siebert and Teizer (2014) argues that despite systems unmanned aerial vehicle (UAV) as an information platform and a measurement tool is attractive to many surveying applications plans, their Performance is not well understood for this special works. They have evaluated the performance of a UAV system that has been made to achieving data surveying of three-dimensional mobile phones fast and automatically and have developed a performance model to estimate the position of the error. Kennedy (2014) with regard to the availability of a wide range of surveying equipment has focused on the surveying system such as electronic distance metre, total station, and terrestrial laser scanner and believes the way to choose a proper system is depend on

1 the accuracy required
2 field conditions
3 reliability of benchmarks
Puente et al. (2013) with respect to importance of the potential of LIDAR-based mobile surveying technology have analysed the current performance of some outstanding mobile terrestrial laser scanning systems and presented an overview of the position scan and imaging integrated device in these systems. They have offered a systematic comparison between navigation and LIDAR features which is provided by the manufacturers. Their investigation has shown that mobile laser scanning systems, depending on the goal, accuracy, range and resolution requirements can be divided mainly in two categories (mapping and surveying). Cooper (2013) knows the first evidence of a measuring system of land from clay tablets of ancient Mesopotamia that dating back to approximately 3,500 BC and in a article showed that this practice why and how began and was developed until 2,500 years after the Old Babylonian period. Archaeological evidence suggests that the interdependence of Mesopotamian mathematics and land surveying as a response to practical needs have been possible with the invention of writing. Qingjuan and Hui (2012) regarding the importance of waterway surveying in an article have argued about how to improve surveying and effective design of the waterway. They have provided a model for surveying part through surveying the opposite side of internal process and the whole parts and mapping part and diagramming techniques and have shown that the new model greatly helps to improve surveying method and drawing. Coutts and Strack (2012) in an article describe the origins of the New Zealand education system of surveying and provided more details on a series of training programmes in the Otago University. Tosun (2012) in a research has provided a metaheuristic model based on neural network and data envelopment analysis (DEA)-artificial to assess the performance of hospitals. He believes that despite the DEA method is robust but is time-consuming and combining it with neural network metaheuristic method cause to reduces processing time and achieve better results. Mukherjee and Ray (2012) have studied the optimisation problem of multistage multiple response processes in industry. They have used a modified metaheuristic tabu search algorithm to solve the problem and results have been compared with real-valued genetic algorithm (GA). They have also shown how stringent constraint conditions, reduces the quality of real-valued GA answers in this problem. Markham (2011) in a study has used the results of the ordinary least squares (OLS) method vs. a classification and regression tree (CART) to identify employees with high production. He has used a set of similar data to comparing CART and OLS. He indicated that results of the CART is better to classify and employee’s determining with high-performance. Azimi and Daneshvar (2010) studied travelling salesman problem (TSP), and presented a new heuristic algorithm based on combining branch and bound algorithm and a dynamic simulation model. This approach uses the simulation results for creating the best tours within the branch and bound tree. To design a measurement network for aerial photographs, Fidanova et al. (2010) studied the problem of surveying GPS. For the design of GPS surveying network, a series of maps must be continuously observed according to a timetable. The challenge is to search for the best order in which these observations must be made so that the scheduling time can become minimised. Thus, they used ant colony optimisation (ACO) algorithm which has been successful for solving hard combinatorial optimisation problems.

Olague and his colleagues (2008) have mentioned placing the cameras in proper locations to measure according to the pictures, and have developed individual evolution
attitude to solve the problem. Souffriau and his colleagues (2008) have solved the orienteering problem (OP) with GA and ACO algorithms. They believe that the OP is similar to the TSP; however, there are scores considered for passing the locations in the OP, and it is not required to pass all of them, and one must pass the location in a limited time span so that he can obtain the highest score. They have used GA to fine-tune the ACO parameters. To find the best order for the GPS of the surveying system within the framework of satellite surveying, Fidanova (2007) presented a metaheuristic algorithm based on Anil’s simulated method inspired by the nature. Markham et al. (2006) the results of attitude OLS with a GA combined with artificial neural networks (ANN) has compared to select employees with high efficiency. Accuracy of the classification results has shown that the two methods are very different. ANN results was significantly more accurate to identification and classification of employees with high performance. Saleh and Vanden (2005) have introduced an approach based on the behaviour of human genome to efficiently provide a general framework for optimising the application of space technology in surveying networks design.

This paper aims to study the process of surveying a region with a camera, and attempts to present a method to survey it through travelling the shortest route. The minimum spanning tree of the graph, formulated for the problem as its solution, is obtained through GA. Therefore, it may be stated that this problem is somewhat similar to other ones such as the TSP, the OP, etc.

2 Statement of the problem

The purpose of surveying is to show natural or artificial reliefs of an area on a sheet called ‘map’. Throughout history, maps have always invited humans to deeply think and consider different aspects of their tasks before spending, travelling, and displacement. A map plays a specific role in reducing costs, studying thoroughly, preventing from wasting the time, and decreasing errors. Surveying science can provide us with satellite maps of all regions. However, aerial photographs are not always as accurate as ground surveying. Thus, we may face numerous errors in photographs. To obtain a regional accurate map, we have to use the ground survey with more precise devices such as a surveying camera. Surveying a region with a camera is started from one point and continued as much as possible. Then, another point within the range of the present one called ‘the benchmark’ is selected and the surveying camera is transferred there. Surveying the environment starts again following the orientation of the camera. Hence, many benchmarks have to be selected throughout the region to survey it with camera. Each benchmark must be within the range of another. If we encounter a benchmark along the route not followed by another one, we must locate the camera on one of the pervious benchmarks to continue surveying, followed by surveying the remaining areas after orientation of the camera.

So in order to surveying, a lot of point in a region should be selected by surveyor to put the camera on them. Thus the surveyor should pass through these points and have a lot of hike. One of the surveyor’s concerns is finding the shortest path to the mapping region so that has less walking and get maximum use of time. According to experience, the average of mapping length in a day by a mapping group including a surveyor and a workmate approximately is 6 km. Now assume that the surveyor had to mapping an area which is slightly more than 6 km (e.g., 7 km). To be able to finish it in a day and save time and cost, among the available benchmarks, Surveyor Should choose the benchmarks
that by passing through them time reduces and the efficiency increases and larger length be mapped. For this reason, the scientific methods can be helpful. This paper uses GAs to find the best benchmark that leads to the shortest possible route in the region to mapping.

3 Methodology

Many tasks can be readily conducted with the advancement of technology in the modern world if we accurately consider them. Prior to visiting the area and starting to survey, its satellite map can be obtained and probable benchmarks can be determined through AutoCAD Software. These benchmarks play the role of locations for the problem. Then, using the Line menu in AutoCAD software, a line is drawn from each benchmark to those ones within its range. These lines play the role of chords in the problem. Then, the length of the chords can be measured through Dimension menu. Conducting these steps, we obtain some locations and chords, which have the role of a graph. By the use of heuristic and metaheuristic solving methods, the minimum spanning tree can be found on the graph so that it may pass through all the locations, helping us to obtain a complete survey of the area. Thus, we can travel the shortest pass to survey the area in a shorter time, causing to increase the efficiency and decrease the costs.

3.1 Genetic algorithm

GA is one of the most well-known and efficient algorithms that, by modelling genetic evolutions, provides models for solving the problem; therefore, it is known as GA. This algorithm establishes an effective searching method into very large spaces, ultimately leading to orientation towards finding an optimum solution (Alam Tabriz and Rahimi, 2008). The main idea of evolutionary algorithm was developed in 1960. GA, derived from these algorithms, is actually a computerised searching method based on optimisation algorithm as well as gene and chromosome structures set forth by Professor Holland, lecturer in Michigan University, and was later developed by some of his students such as Goldberg. Since GA works with a series of encoded strings instead of variables, it is different from other optimisation methods (Alam Tabriz and Rahimi, 2008). GA operates through iteratively updating a population of individuals, which are candidate solutions to the problem. These individuals are encoded as binary strings, known as chromosomes, and are assigned a fitness value based on their evaluation. The algorithm starts by evaluating an initial random population. Then, population is involved by stochastically selecting parent individuals on which genetic operators are applied to recombine parents and create new individuals, which are also evaluated. The process of selection, recombination and evaluation is called a generation or an epoch. Since individuals with a higher fitness have a higher probability to be selected as a parent, the population develops towards better solutions (Olague et al., 2008). Suppose that, to survey an area, a graph with X locations and Y chords is formed. By means of GA, we attempt to find a tree with the shortest routes between the locations (i.e., minimum spanning tree). Then, we start to act as follows.

3.1.1 Algorithm steps

1. **Creation of initial population**: an initial population of N chromosomes is provided.
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2 Parent selection: two chromosomes of the initial population are randomly selected.
3 Reproduction: to reproduce, mutation and crossing-over operators are used.
4 Objective function evaluation: the objective function value is calculated for the children.
5 Repetition: reproduction and evaluation of children’s objective function is repeated as many as \( P \) times.
6 Admittance lowest value of the objective function: among the children reproduced within \( P \) repetitions, the one with minimum objective function is admitted into the population.
7 Stop condition: if the stop condition is fulfilled, stop and report the best tree in the last population.
8 Return: if the stop condition is not fulfilled, return to the second step

Meta heuristic GA is used to solve big complex problems. It does not guarantee the optimum solution, but provides answers very close to the optimal scores. The result obtained from the above-mentioned algorithm is a spanning tree which is either optimum, i.e., minimum spanning tree, or close to the optimum. Whenever it is rather impossible to obtain answers through other methods due to different reasons, like increasing problem dimensions, metaheuristic techniques can be applied.

4 Numerical sample

A surveyor intends to survey an area called Sarāb-e-Doureh in Lorestan Province, Iran. Since it is better to think about how to do works before doing, the surveyor is thinking about what path in the region should be chosen which both cover the whole of the region and finish surveying in less time, and increase efficiency. The lower number of benchmark the less error in mapping. So the surveyor should try to choose those benchmarks that have more landscape. Therefore the satellite map of the region is studied, and locations of required benchmarks as well as lengths of possible chords between them are determined, and a graph is formed in Figure 1.

The purpose is to find the shortest route for surveying the area, and GA is used to solve the problem. The graph includes 34 chords and 25 locations, and its weight involving the sum of the distances between the locations (sum of the numbers on each chord) equals 4,186 unit of measurement. The first step in meta-heuristic GA is determined initial population which are formed of chromosome. In this problem each chromosome comprises an order of chords which can form a tree together. To construct any chromosome, each chord is randomly selected. It is important to remove the chords in order, and must be conducted in a way that it ultimately leads to a tree. Hence, an initial population of 100 chromosomes is provided (Step 1: Create the initial population). Then, two chromosomes are randomly selected as parents (Step 2: Parent Selection), and children are born; chromosomes are randomly broken at one point by means of single-point intersectional operator, and the broken parts are then displaced with each other (Step 3: Producing child). In order for the born child not to have repetitive chord number, pre-chromosome is used, i.e., two selected parent chromosomes change into pre-chromosomes so that their child may not have a repetitive chord. Among the selected
parents of the programme, intersection operator and mutation probably occur with 0.6% and 0.4%, respectively. Chord lengths which relate the locations are introduced into the programme as a matrix, presented in Appendix.

**Figure 1** Graph of the problem

As it was mentioned earlier, chords are randomly removed from the initial graph to produce a tree, and the weight of the tree is then calculated (Step 4: Evaluation of the objective function). In each step, tree production and weight determination are repeated 100 times (Step 5: Repetition). The best weight, being also the minimum of all, is then registered and placed into the population (Step 6: minimum value of the objective function). If no improvement is observed in the solution up to 20 repetitions, the algorithm will be stopped (Step 7: Stop condition). Otherwise, the parent selection process is repeated (Step 8: repeat the algorithm) to get optimal or near-optimal solution.

**5 Discussion**

Applying GA, the shortest path for surveying problem with 25 locations and 34 chords was solved in 9.94 seconds, and the optimum answer which sum of its chords length was 1,919 metres, and its tree is in Figure 2.

**Figure 2** Tree related to the problem solution

Considering the optimum tree, we may decide on which point to start surveying so that the shortest route can be covered. In this graph, it seems that starting to move from location 1 or 21 makes it possible for the surveyor to travel the shortest route, because
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these nodes are at the beginning or end of the graph. To start mapping, if a node be selected in the middle of the graph the surveyor must wend the path to the end node and then go back to the previous track to surveying in the opposite direction that it increases the time and mapping error, and causes fatigue. So choosing the right starting point for mapping the area is very important.

Figure 3 shows the value of the objective function in 20 repetitions. As observed, GA has reached 2,291 metres for the value of the objective function in its first repetition (Note: Each repetition involves the best value of the objective function from among 100 trees produced by GA). This value is the same 2,291 metres in the second repetition. Then, a descending trend is witnessed in the next repetitions, indicating the movement, of the algorithm towards a better solution. Finally, the algorithm reaches the optimum solution of 1,919 metres in the tenth repetition. Since this value does not change for the next repetitions, the algorithm stops after 20 repetitions (i.e., stop condition), whose ten repetitions are shown in the diagram.

Figure 3  GA evolutionary curve in 20 repetitions (see online version for colours)

Metaheuristic algorithms do not guarantee obtaining an overall optimum solution. However, in this problem, the solution is overall optimum and the tree is the minimum spanning one.

6 Results

The problem of surveying with a camera was studied, and attempt was made to provide a method to survey the area by travelling the shortest route and for this purpose the concept of graph theory is applied and then proposed GA is provided to find the minimum spanning tree that is answer of the problem. To forming problem graph the satellite map of a region called Sarāb-e-Doureh in Lorestan Province was used. The benchmarks required for surveying and their relationships (i.e., chords) and lengths of the chords were determined on the map, out of which a graph comprising 25 locations and 34 chords was obtained. To solve the problem, the minimum spanning tree of the graph with an objective function value of 1,919 metres was attained by proposed GA in 9.94 seconds that is optimum solution and another ways are certainly more than 1,919 metre. Considering the tree, we may decide on which point to start surveying so that the shortest
route can be covered. As a result, the area is surveyed with less time and energy, and the surveyor’s efficiency also increases. Resulting more area will be mapped in less time. Expenditures will reduce and revenue will increase. Ultimately lead to increase surveyor efficiency. GA is good for solving large problems that other methods are not able to find the answer. When the problem is small, heuristic algorithms like Prim, Kruskal and so on is also used to finding the minimum spanning tree. For future research can use other meta-heuristic algorithms to solve this problem in larger size and compare answers with each other.

References
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| Node | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  | 20  | 21  | 22  | 23  | 24  | 25  |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1    | 326 | 337 | 505 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 2    |     | 30  | 210 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 3    | 137 |     |     | 90  | 108 | 288 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 4    | 79  |     |     | 42  | 80  | 99  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 5    |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 6    | 45  |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 7    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 8    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 9    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 10   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 11   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 12   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 13   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 14   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 15   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 16   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 17   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 18   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 19   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 20   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 21   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 22   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 23   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 24   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 25   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |