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Using the Firefly algorithm for geoid determination

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Abstract

The geoid is a mathematically complex surface. For years' geoid determination has been the topic of geomatics engineering. There are many methods for Geoid Determination, such as Polynomial Interpolation, kriging interpolation, and The Least Square Collocation etc. Outlier measurement have a corruptive effect on parameter estimation. There are two methods that are frequently used for the determination of outlier measurement, in geomatics engineering. These are The Least Square Method and The Least Absolute Value Method. These methods have advantages and disadvantages over each other. Also nowadays, very complex problems can be solved with methods such as the rapidly developing Artificial Intelligence and Machine Learning Technologies with Metaheuristics Algorithm for obtaining a close to optimum solution. There are many metaheuristic algorithms developed and used nowadays. One of them is the Firefly Algorithm. In this study, the usability of the firefly algorithm was tested to determine the outlier measurement in the geoid determination process.

1. Introduction

In applied sciences, the parameter estimation is made using adjustment procedure, because the measurements number is more than the of unknown's number. in order to increase the accuracy and precision obtained from measurements and the results of measurements. The objective of adjustment are to find out the most suitable and highest probability value of the unknowns and unknown functions without leaving out any measurement from measurement groups (Wang, 1992). Geoid determination also has an important place in Geomatics applications. In geodetic applications, elevation is measured with reference to the surface of a geoid as orthometric height. Ellipsoidal height is measured with GPS. Hence, GNSS-derived ellipsoidal heights must be transformed into orthometric heights. There is a mathematical relationship between these heights (Heiskanen, 1967).

Metaheuristic algorithms have become popular in finding the best in recent years and are still used in many optimization problems (Canayaz, 2015). Its use in Geomatics studies has just begun.

In this study, point cloud data consisting of 333 points concerning to Samsun province in Turkey was used. Point cloud data was processed using the Cloud Compare program. The surface model of the point cloud was created using a 2nd degree polynomial. Outlier measurements were determined using The Least Absolute Value Method (LAV) and Firefly Algorithm (FA) method.

2. Method

2.1. Geoid determination and outlier measurement

The geoid is a complex surface and formed by the combination of the points have got zero potential value. The geoid determination is the most important problem in the earth. Because the geoid does not represent a regular shape. Local geoid determination studies aim was to determine a local geoid using the geoid determination methods for example Polynomial Interpolation Method (Akar, Konakoğlu, & Akar, 2022).

The polynomial technique is based on the determination of polynomial surface. The surface used to determine the geoid is generally expressed in high degree polynomials with two variables (Kirici & Sisman, 2017). The orthogonal polynomials can be represented are as follow;

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$$N(x,y)=\sum_{i=0}^{m}\sum_{j=0}^{k}a_{ij}x^{i}y^{i}$$

Polynomial equation can be written for 2nd order polynomial is as follow;

$$N=a_{00}+a_{10}x+a_{01}y+a_{20}x^{2}+a_{11}xy+a_{02}y^{2}$$

If the number of measures is greater than the unknown number in a problem, adjustment calculation is made for a univocal solution (Montgomery, Peck, & Vining, 2021). Adjustment is a means of obtaining unique values for the unknown parameters to be determined when there are more observations than actually needed; statistical properties may be determined as by products (Ogundare, 2018). A few methods have been developed to adjustment calculation. Although, the least square adjustment is known methods, the LAV method is one of the oldest robust methods.

2.1.1. The least absolute value method

The Least Absolute Value Method (LAV) developed by Laplace. To determine the unknown parameters in the adjustment measurement, a solution is made according to an objective function. LAV method solves with $\|pv\| = [P|v|] = min$ objective function (Sisman, Sisman, & Bektas, 2013)

In this method direct solution is not possible. The solution can be found as trial and error or linear programming problem. New unknowns are as follows for linear programming (Sisman, 2010).

$$\begin{bmatrix}A & -A & -I & I\end{bmatrix}\begin{bmatrix}X^{+}\\X^{-}\\V^{+}\\V^{-}\end{bmatrix}=\begin{bmatrix}l\end{bmatrix}$$

$$f=b^{T}X=\left[P|V|\right]=P^{T}V=P^{T}\left[V^{+}\quad V^{-}\right]=\min$$

The detail of LAV can be found in (Dielman, 2005)

2.2. Metaheuristic algorithm

Metaheuristic algorithms appear as comprehensive algorithms that are above heuristics and decide which method to use in solving problems. Metaheuristics have developed dramatically. (Osman & Kelly, 1997). In order for Metaheuristic algorithms to be usable, they must meet certain criteria. At the beginning of these criteria are the closeness of the solutions they found to the optimum value and the time they spent in obtaining these solutions. The fact that the algorithms are coded in a way that can be understood by everyone and provides ease of analysis is also an important factor in the selection of algorithms (Canayaz, 2015). There are many different metaheuristic algorithms in the literature. These are; Firefly Algorithm, Genetic Algorithm (Banzhaf, Nordin, Keller, & Francone, 1998), Shuffled Frog Leaping Algorithm (Eusuff, Lansey, & Pasha, 2006), Particle Swarm optimization (Lazinica, 2009), Ant Colony Optimization(Maniezzo, Gambardella, & Luigi, 2004) etc.

2.2.1. Firefly algorithm

Firefly Algorithm (FA) was developed by Xin She Yang (Yang, 2010b). This algorithm was based on the flashing patterns and behavior of fireflies. This method generally has three rules.

- Fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex.
- The attractiveness is proportional to the brightness, and they both decrease as their distance increases. Thus, for any two flashing fireflies, the less bright one will move towards the brighter one. If there is no brighter one than a particular firefly, it will move randomly.
- The brightness of a firefly is determined by the landscape of the objective function (Yang & He, 2013).

In the FA, there are two important issues: the variation of light intensity and formulation of the attractiveness. For simplicity, we can always assume that the attractiveness of a firefly is determined by its brightness or light intensity which in turn is associated with the encoded objective function. In the simplest case for maximum optimization problems, the brightness I of a firefly at a particular location x can be chosen as $I(x)/f(x)$. However, the attractiveness _ is relative, it should be seen in the eyes of the beholder or judged by the other fireflies. Thus, it should vary with the distance r_{ij} between firefly i and firefly j. As light intensity decreases with the distance from its source, and light is also absorbed in the media, so we should allow the attractiveness to vary with the degree of absorption (Yang, 2010a).

The light intensity $I(r)$ varies with distance r monotonically and exponentially (Farahani, Abshouri, Nasiri, & Meybodi, 2011). That is;

$$I=I_{0}e^{-\gamma r}$$

As firefly attractiveness is proportional to the light intensity seen by adjacent fireflies, we can now define the attractiveness by β of a firefly.

$$\beta=\beta_{0}e^{-\gamma r^{2}}$$

γ = light absorption coefficient

r_{ij} = distance between two fireflies

$$r_{ij}=\left|x_{i}-x_{j}\right|$$

The movement of the ith firefly towards the jth firefly, which is more attractive (Değertekin, Lamberti, & Ülker, 2015);

$$x^{i+1}=x^{i}+\beta_{0}e^{-\gamma r^{2}}(x^{j}-x^{i})+\alpha(rand-0{,}5)$$

Here, α is random selection parameter, $rand$ is random number.

2.3. Case study

In this study, a point cloud that contains 333 points, is used as a data set. The distribution of points with known x, y and h values is shown in Figure 1.

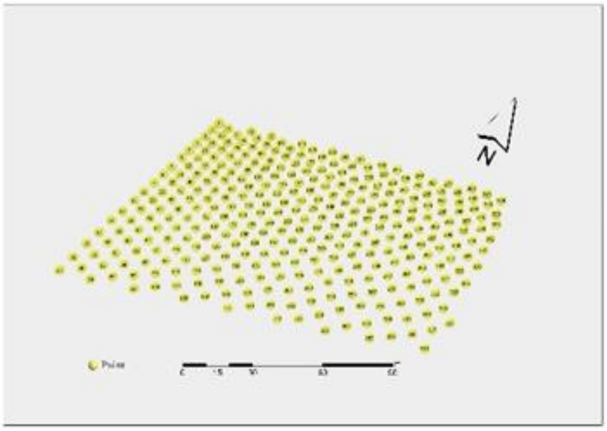

Figure 1. Data set distribution

At first, by using point cloud, surface model was created with 2nd degree polynomial equation according to LAV, which is one of the classical testing methods, then the outlier measurements were determined on this surface. After these steps, the Firefly algorithm, which is one of the metaheuristics algorithms, is applied to the same data set, and outlier measurements were determined with this method.

3. Results

LAV method determines 69 of 333 points as an outlier. This means that the 69 points do not belong to the surface and the surface belongs 264 points. Figure 2 shows the distribution of the outliers which are found by the LAV method.

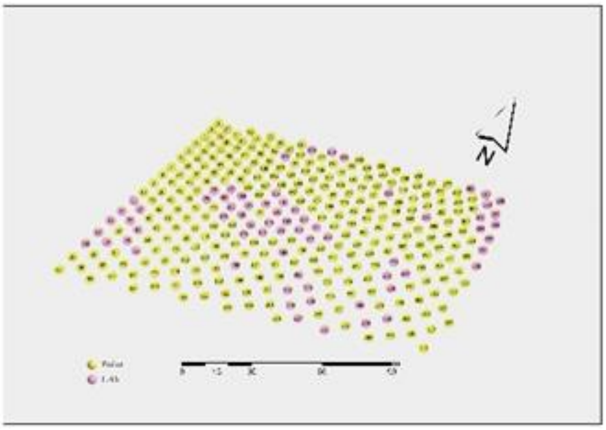

Figure 2. Outiler points of the LAV Method

Firefly Algorithm was applied to the data set and 50 of 333 points were determined as an outlier with this method. According to the firefly, the surface consists of 283 compatible points (Figure 3).

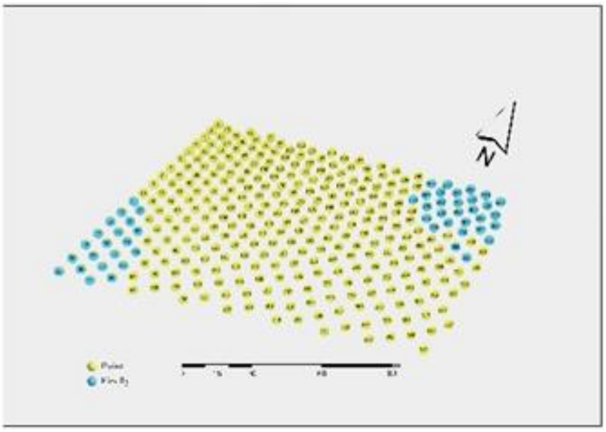

Figure 3. Outlier points of the Firefly Method

4. Discussion

As a result of LAV, 69 points were determined as an outlier while in the firefly algorithm 50 points were determined. When the points found in common by both methods are observed, it is seen that 21 points are common. Common points found by the two methods are shown in Figure 4.

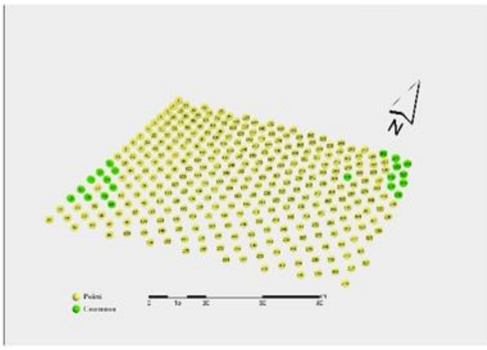

Figure 4. Common points

5. Conclusion

When the intersection points are examined, it is seen that they cover each other at the rate of 42%. The fact that the metaheuristic approaches, which is a modern method, gives consistent results with the results obtained with classical methods, reveals the usability of these methods in the field of geomatics engineering. Metaheuristic algorithms have limited use in geomatics fields, they are not widely used in geoid determination yet. In this study, the usability of the firefly algorithm in geoid determination was tested. In future work, this application can be improved by expanding the study area or by comparing the results with different methods.

Thesis should be written as Master's Thesis or Doctoral Thesis in the reference list.

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