RECENZIRANI ČLANKI | PEER-REVIEWED ARTICLES

NOVA METODOLOGIJA NAČRTOVANJA POTI Z MINIMALIZACIJO RAZLIK MED VIŠINSKIMI KOTAMI NIVELETE IN TERENA

A NOVEL ROUTE DESIGN METHODOLOGY BASED ON MINIMIZING LEVEL DIFFERENCES BETWEEN GRADE AND GROUND LINE

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IZVLEČEK

Metoda načrtovanja poti, ki je predstavljena v članku, temelji na določitvi najmanjših višinskih razlik med niveleto poti in terenom. V ta namen je treba določiti potek linije nivelete, tako da je čim bližje terenu. Ciljna funkcija v predlaganem modelu je oblikovana skladno s topografskimi značilnostmi obravnavanega območja. Nagib nivelete je pri tem privzet kot pogoj, ciljna funkcija pa se doseže z minimizacijo višinskih razlik med niveleto in terenom. Odločitvene spremenljivke v metodi so horizontalne (ploskovne) koordinate znotraj območja obravnave. Najprej se izračuna predlagana niveleta poti in določi njen položaj iz začetne in končne točke, ki sta podani s prostorskimi koordinatami (x, y, z). Sledi določitev položajev prečnih profilov na enakih intervalih vzdolž nivelete. Njim ustrezne horizontalne (ploskovne) koordinate položajev točk na terenu je mogoče dobiti s presekom linije višinskega položaja posameznega prečnega profila s terensko črto v posameznem profilu. Zanesljivost modela je odvisna od standardne deviacije višinskih razlik vzdolž (skozi dobljene točke izrisanega, op. prev.) profila poti. Rezultati raziskave kažejo, da je model mogoče uporabiti kot vodilo pri izbiri poteka poti z upoštevanjem topografskih značilnosti terena na obravnavanem območju. Metodologija je bila razvita z uporabo grafičnega vmesnika in funkcij, razvitih v programskem jeziku Matlab.

KLJUČNE BESEDE

načrtovanje poti, topografija, digitalni model terena, optimizacija, pogoj nagiba, Matlab

ABSTRACT

The route design method developed here is proposed to define the least-elevation differences between the grade and ground line. The method is based on setting the grade line as closely as possible to the natural ground level. The objective function of the proposed model is thus described with the topographic features of the area. The longitudinal gradient is taken as a condition and the minimization of the elevation differences between grade and ground line performs the objective function. The decision variables of the method are the horizontal coordinates within the boundaries of the study region. Initially, the proposed grade profile of the route is computed and determined by the three-dimensional coordinates of given start and end points. Then, the cross section stations are taken at regular intervals along the grade line. The adequate horizontal coordinates of the cross section stations are obtained by intersecting the grade lines and contour levels. The reliability of the model relies on standard deviation of elevation differences along the profile. The results show that the model may be used as a guide for route selection facilities based on topographic features of the area of interest. The methodology is implemented using a graphical interface and function developed in Matlab programming language.

KEY WORDS

route design, topography, elevation model, optimization, grade condition, Matlab

1 INTRODUCTION

In the literature review, the route optimization problem can be described as determining the best route between two given points (Jong et al. 2000; Jha 2003; Jong and Schonfeld 2003; Kim et al. 2004; Jha and Schonfeld 2004; Kim et al. 2005). The planning constraint is strongly related to the aim of the planning type and aim of the project and several alternative routes may be generated depending on the feature of the planned project. To determine the optimal route among these several alternative routes, the decision makers and designers should take into considerations many factors such as topography, soil conditions, socioeconomic factors, environmental effects of the field (Jha, 2003) and generate the economical routes depending on them. Afterwards, the process continues by selecting the most appropriate one into them (Jong et al., 2000; Jha, 2003; Jong and Schonfeld, 2003; Kim et al., 2004; Jha and Schonfeld, 2004). In conventional method for determining the route corridor, topographic features of the area of interest is one of the most critical decision factors for cost evaluations. The properly functional route facilitates reducing the earthwork cost component in accordance with the compatibility to the surface. Cheng and Lee (2006) states that most of the researches on route alignment optimization problem focus on the design of vertical alignments that minimize the sum of cost items, such as, earthwork, construction, land use, and user cost (Hayman 1970; Easa 1988; Goh et al. 1988; Fwa 1989; Moreb 1996; Lee and Cheng 2001; Fwa et al. 2002). Moreover, Lee and Cheng (2001) stated that a significant portion of the costs comes from earthwork related components. As mentioned before, one factor that significantly influences the selection of a route location is the terrain of the land, which in turn affects the laying of the grade line. The primary factor that the designer considers on laying out the grade line is the amount of earthwork that will be necessary to achieve the selected grade line. One method to reduce the amount of earthwork is to set the grade line as closely as possible to the natural ground level. This is not always possible, especially in undulating or hilly terrains. Also, the least overall cost may be obtained if the grade line is set such that there is a balance between the excavated volume and volume of embankment (Garber and Hoel, 2009). Besides, Rees (2004) indicated that there are more usage areas of route searching for people in social or economic activities and also people investigates the routes between locations for a variety of reasons. However, due to various affects, designing the three-dimensional alignment of a highway requires cumbersome computations (Easa et al. 2002). Thus, the search of optimal horizontal and vertical route should be done simultaneously so as to produce efficient or desired results.

Jha (2003) stated that in previous works many optimization methods have been proposed for route planning problem (Howard et al., 1968; Thomson and Sykes, 1988; Shaw and Howard, 1981, 1982; OECD, 1973; Turner and Miles, 1971; Turner, 1978; Athanassoulis and Calogero, 1973; Parker, 1977; Trietsch and Handler, 1985; Trietsch, 1987a,b; Hogan, 1973; Nicholson et al., 1976) such as calculus of variation, dynamic programming, numerical search, linear programming, and network optimization. Moreover, genetic algorithms have become a significant method in recent years especially for simultaneous vertical and horizontal solutions.

In this paper, a method for route generation is examined which will automate the predefine process and lead to better results within a short time. This paper is divided into three sections: introduction, model generation and experimental study. In the next section, the criteria for minimizing grade and ground line differences and workflow of the proposed approach will be given by its mathematical expressions. The hypothesis of the model has been constructed to provide the minimum differences as mentioned in subtitle of Section 2. Then, a case study with computational results has been performed for performance evaluations of the method. The methodology has been coded in Matlab programming language with a user-friendly interface. The method is based on minimizing earthwork cost. However, the implementations of the other factors can be added to the model with restricted areas easily by the help of used data format.

2 MODEL

This section describes the proposed model and its construction items with computational equations. Generally, the goal of the vertical alignment problem is to determine the vertical profile of a route to minimize some given cost items while satisfying certain specifications (Lee and Cheng, 2001). As mentioned in the introduction section, one important method employed in route location to reduce the amount of earthwork is to set the grade line as closely as possible to the natural ground line. By joining the consecutive grade lines, a vertical profile of the route is obtained. The vertical profile of a route consists of piecewise linear lines, at where grade changes, and may be smoothed by vertical curves depending on the type of the route. In this study, it is assumed that the vertical grade line of a route is defined as the final vertical profile in order to satisfy the balanced earthwork amount, and then the horizontal path of this predefined vertical profile is investigated on the study region.

2.1 Data requirements

The first step of the processing stage is to obtain a terrain model that reflects accurately feature of the topography. Real-world topography is frequently represented using a rectangular grid node format in which elevation values are available besides the horizontal plane values. Thus, topography, defined by a DEM is required, which is the well-known and frequently used terrain modeling method. Since there are several data sources for producing and representing the topographical characteristics of the region, in this study we use LIDAR (Light Detection and Ranging) data set for generating the digital elevation models (DEMs). LIDAR provides high accurate and dense topographic data sets (Liu et al., 2007) and has become a very popular methodology and a major source of data for digital terrain (Raber et al., 2007) modeling as it gives three-dimensional features of the earth or object surface. Airborne LIDAR is a fast spatial data acquisition technique formed by a combination of three different equipments: a laser scanner, the Global Positioning System (GPS) and an inertial navigation system (INS) (Ackermann, F., 1999; Brovelli et al., 2002) mounted on an aircraft with the aim of obtaining very accurate 3D coordinates (x,y,z) of points located in the earth surface (Gonçalves, 2006). Two kind of digital models can be produced from the LIDAR datasets which are objects on the earth's surface and the earth surface itself (Brovelli et al., 2002). By employing filtering algorithms, points labeled as ground measurements can be obtained in which they are described as the bottom of the object or earth surface (bare-earth). The bare-earth LIDAR dataset are then used to generate DEMs by the help of interpolation models. Here, matrix format is employed to define surface of the regions of study, which can also be partitioned into the several equal dimensional cells. Digital elevation model is then converted to the contour line representation and vector data format is generated to store the spatial information. The number of the contour lines is determined based on the minimum and maximum elevation data values. Each contour level has an elevation value associated with its feature. In the method, all associated contour lines are stored into different matrices in which their elevation values and horizontal coordinates of them are associated. The elevation values, which should be defined in the first step of the flowchart of the method, are the specific contour levels evaluated from the search interval. On the basis definition of area of interest, the regular and smooth contour lines are evaluated to determine the contour vertexes accurately. However, this procedure may fail in some cases. Contour lines, especially near the boundaries, may cause residual lines that are not relevant to the route corridor. However, in the automatic generation of contours, these lines are drawn if they are included into the dataset. Although these contours satisfy the gradient condition along the vertical profile, they may not reflect the real topography. Thus, to make the model more general and efficient, it should be supported by some subsequent processes, such as filtering processes if required.

2.2 Model construction

The methodology considers a linear correlation between topography and the horizontal profile to be determined. The processing stage of the method starts with modeling the objective function of the algorithm. A simple function based on the earthwork amount is handled to formulation. To minimize the earthwork amount, elevation differences between grade line and natural ground line are involved to the function.

The objective function of the model is as given in Eq. 1;

$$Minimize\ H = \sum_{i=1}^{s} \left| earthwork\ amount \right| \tag{1}$$

Where, s = the number of cross sections laying on the vertical profile. The earthwork amount is calculated from the elevation differences between grade line and natural ground level at each cross section, which may be regarded as a measure of earthwork cost. The goal of the function is to adjust the residuals in terms of negative or positive elevation distribution. Fig. 1 illustrates the graphical view of the proposed model. Since, as seen in the figure, the vertical route indicated in profile view section satisfies the balance of the earthwork in theory; in the plan view section the route's points are somewhere onto the xy plane in the study region. The optimal route points will intersect with each cross section lines. The decision variables of the proposed approach are the horizontal coordinates of the cross sections. The constraint herein is limited by the maximum and minimum allowable grades.

The flowchart of the proposed method can be seen in Fig. 2. The required datasets are composed of three components; (a) gridded form high-resolution digital elevation model (DEM), (b) three dimensional coordinates of the start and end points, (c) cross section interval. After DEM data logging into the model with definition of the cross section interval and description of the conditions about grade-ground lines, data processing stage with a loop is then carried out using intersection function of two non-parallel lines. In the first sub stage, the ground elevations of the predefined vertical alignment are performed. Here, the grade line elevations are taken as final vertical elevations and thus, the horizontal coordinates of them are calculated as line segments. Then, the intersections between contour line segments and vertical cross sections are carried out at each section station. If the intersection is performed, the horizontal coordinates of the intersecting point are taken as optimal route point. In some cases, there can be more than one intersection due to the region topography along the cross section line. The closer point to the straight line of start and end points is considered as the route point in such cases.

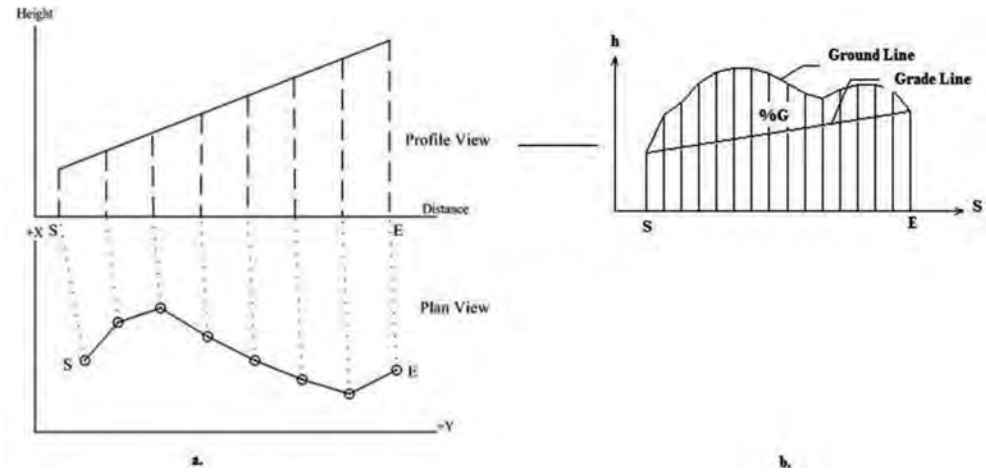


Figure 1: Illustration of the proposed method a. Planimetric views of profile and plan of the optimum route b. Predefined grade line and ground line of the route.

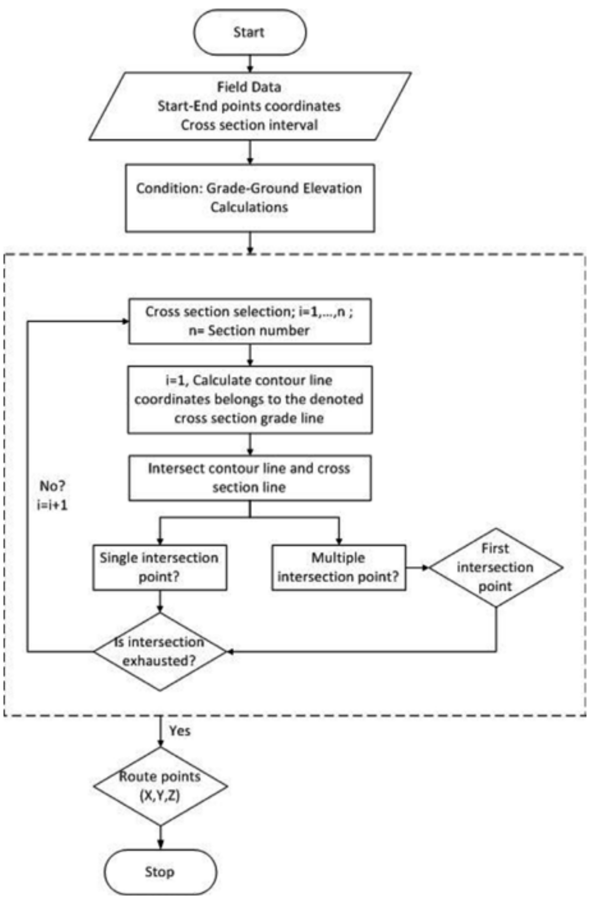


Figure 2: Flowchart of the model.

2.3 Horizontal profile definition

For each cross section point, let S(x_S, y_S) and E(x_E, y_E) be the start and end points of the route respectively, then coordinates of the cross section points (denoted as CP) onto the SE can be calculated by using Eq.2, 3, 4.

$$S_{SE} = \sqrt{(x_S - x_E)^2 + (y_S - y_E)^2} \tag{2}$$

$$\alpha_{SE} = \arctan\left(\frac{y_E - y_S}{x_E - x_S}\right) \tag{3}$$

$$\begin{bmatrix} x_{CP_i} \\ y_{CPi} \end{bmatrix} = \begin{bmatrix} x_S \\ y_S \end{bmatrix} + a \cdot i \cdot \begin{bmatrix} \cos\alpha \\ \sin\alpha \end{bmatrix} \tag{4}$$

SE is the Euclidean distance between points S and E; a is the cross section interval; α is the azimuth angle of S and E. $\begin{bmatrix} x_{CP_i} & y_{CPi} \end{bmatrix}$ is the horizontal coordinates of cross section points.

Assume that the study area is limited to maximum and minimum x and y data values. Then, there are six cases to determine the U_d and L_d depending on azimuth angle. Here, U_d and L_d denote upper bound distance and lower bound distance, respectively, and α is the azimuth angle of start and end points computed from Eq.3.

For $\delta = \alpha + 100^g$; $i = 1 : n$, n =T otal cross section number;

Case 1: $\delta = 0^g$ or $\delta = 200^g$

$$U_d = \left(x_{\max} - x_i\right) \tag{5 a}$$

$$L_d = \left(x_{\min} - x_i\right) \tag{5 b}$$

Case 2: $\delta = 100^g$ or $\delta = 300^g$

$$U_d = \left(y_{\max} - y_i\right) \tag{6 a}$$

$$L_d = \left(y_{\min} - y_i\right) \tag{6 b}$$

Case 3: $0^g < \delta < 100^g$

$$U_d = \min\left\{\left(\frac{x_{\max} - x_i}{\cos\delta}\right), \left(\frac{y_{\max} - y_i}{\sin\delta}\right)\right\} \tag{7 a}$$

$$L_d = \max\left\{\left(\frac{x_{\min} - x_i}{\cos\delta}\right), \left(\frac{y_{\min} - y_i}{\sin\delta}\right)\right\} \tag{7 b}$$

Case 4: $100^g < \delta < 200^g$

$$U_d = \min\left\{\left(\frac{x_{\max} - x_i}{\cos\left(200 - \delta\right)}\right), \left(\frac{y_i - y_{\min}}{\sin\delta}\right)\right\} \tag{8 a}$$

$$L_d = \max\left\{\left(\frac{x_{\min} - x_i}{\cos(200-\delta)}\right), \left(\frac{y_i - y_{\max}}{\sin\delta}\right)\right\} \tag{8 b}$$

Case 5: $200^g < \delta < 300^g$

$$U_d = \min\left\{\left(\frac{x_{\max} - x_i}{\cos(\delta-200)}\right), \left(\frac{y_{\max} - y_i}{\sin(\delta-200)}\right)\right\} \tag{9 a}$$

$$L_d = \max\left\{\left(\frac{x_{\min} - x_i}{\cos(\delta-200)}\right), \left(\frac{y_{\min} - y_i}{\sin(\delta-200)}\right)\right\} \tag{9 b}$$

Case 6: $300^g < \delta < 400^g$

$$U_d = \min\left\{\left(\frac{x_{\max} - x_i}{\cos\delta}\right), \left(\frac{y_i - y_{\min}}{\sin(400-\delta)}\right)\right\} \tag{10 a}$$

$$L_d = \max\left\{\left(\frac{x_{\min} - x_i}{\cos\delta}\right), \left(\frac{y_{\max} - y_i}{\sin\delta}\right)\right\} \tag{10 b}$$

The decision variables and their associated boundaries have been defined. Then, the coordinates of start and end points of each cross sections can be obtained from U_d and L_d distances as given:

$$\eta = \begin{bmatrix} \cos\delta \\ \sin\delta \end{bmatrix} \tag{11}$$

$$\begin{bmatrix} U_x \\ U_y \end{bmatrix} = \begin{bmatrix} CP_x \\ CP_y \end{bmatrix} + \eta . \begin{bmatrix} U_d \\ U_d \end{bmatrix} \tag{12 a}$$

$$\begin{bmatrix} L_x \\ L_y \end{bmatrix} = \begin{bmatrix} CP_x \\ CP_y \end{bmatrix} + \eta . \begin{bmatrix} L_d \\ L_d \end{bmatrix} \tag{12 b}$$

Here, $[U_x\, U_y]$ and $[L_x\, L_y]$ are the upper and lower horizontal boundary coordinates of the study region, respectively. For the first route's point determination, $[S_x\, S_y]^T$ is employed instead of $[CP_x\, CP_y]^T$. In Fig. 3, the graphical description of determination of the U_d and L_d coordinates can be found. To figure out where the route points whose grade line elevations are predefined, the cross section lines are drawn perpendicular to the boundaries of the area of interest. According to this, the decision variables and associated boundary coordinates for each route cross sections have been determined for all cases that can be occurred according to the positions of the start and end points.

The place of the intersection point that yields along a direction at the desired grade line elevation represents the horizontal coordinates of the route. To achieve the intersection, the contour lines belong to the each cross section points, grade line elevations should be determined by their three-dimensional coordinates. The contour line includes horizontal and vertical data features of a topographic surface that joins points with same elevations. Here, E_z and S_z are the grade elevation values of two given points,

$\%E$ is the longitudinal gradient value, $\bar{U}$ is the distance vector between cross sections, E_{gr} denotes the grade line elevations.

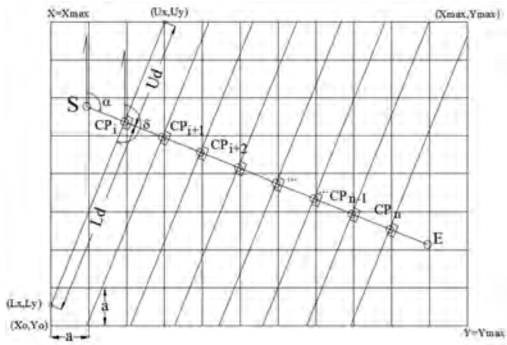


Figure 3: The graphical representation of the boundary determination.

$$\%G = (Ez - Sz) / S_{SE} \tag{13}$$

$$E_{gr}(i) = \left[S_z + \%G.\overline{U}(i) \right] \tag{14}$$

According to the determined E_{gr}, the contour lines belong to each cross section points have been drawn and the three dimensional coordinates of them have been stored in a vector matrix. The generation of the contour points has been performed with Matlab function and there is no prior information about how many points that the contour line may include. Therefore, it expresses the point of intersection problem of two non-parallel lines in two-dimensional space, which may be found from the equations of intersecting two lines. Fig. 4 represents the intersection of a contour line and a cross section line as explained above. Here, this iterative search avoids backtracking of the route in which the solution yields forward consecutively. In Fig. 4, IP denotes the intersection point, namely route point.

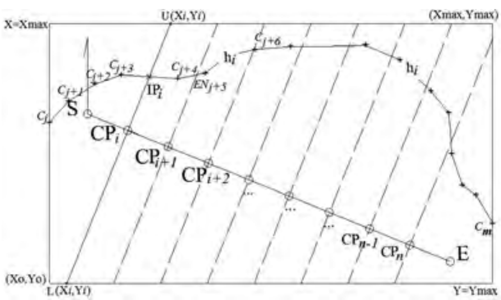


Figure 4: Intersection of contour line and cross section.

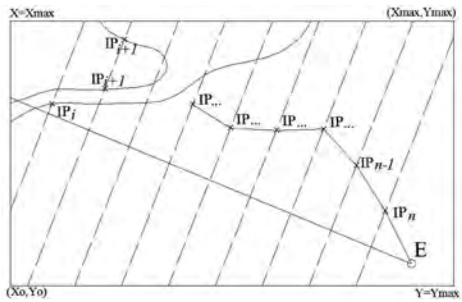


Figure 5: Selecting the intersection point for the same elevation.

If the intersection is performed on multiple points along the cross section line, the closest point to the SE line has been selected as the reference route point to ensure the shortest route (Fig. 5).

3 CASE ILLUSTRATION

For the test study, a real field data on the Mount Saint Helen region of the state of Washington, United States of America, have been used to demonstrate the proposed model and algorithm for selecting a 3D route alignment. To evaluate the effectiveness of the proposed algorithm, airborne LIDAR data was employed as required field data to produce the digital elevation model, see Fig.6. These data were acquired from the Washington State Geospatial Data Archive (WAGDA) via web. The used LIDAR dataset is composed of 1,341,886 data points with three-dimensional coordinates. The best-fit grid interval of the study region is calculated as 2.29 m depending on the topographic surface. According to this, the gridding interval has been chosen 3 × 3 m equal spaced grid, and Kriging interpolation method has been implemented to generate digital elevation model. The generated model has 579 × 1334 grid node dimensions on the xy plane with 1734 m × 4000 m area dimensions. Furthermore, the elevations of the area range from 751.143 m to 1417.432 m, and study area has a hilly-partly mountainous topographic texture. The chosen route and the topographic features of points can be seen in Fig. 6. The points of the paths have been chosen randomly in terms of providing different topographic paths features as negative or positive longitudinal slopes.

	Y(m)	X (m)	Elevation (m)	Distance (m)	h (m)	Grade (%)
A	556235.3927	5130242.0507	1174.97	-	-	-
B	556406.3116	5129826.9204	1188.16	448.94	13.19	0.029
C	556998.0276	5129189.3322	1167.24	869.85	-20.92	-0.024
D	557876.0240	5129456.5607	1227.75	917.76	60.51	0.066
E	557786.2480	5129837.0393	1258.36	390.93	30.62	0.078

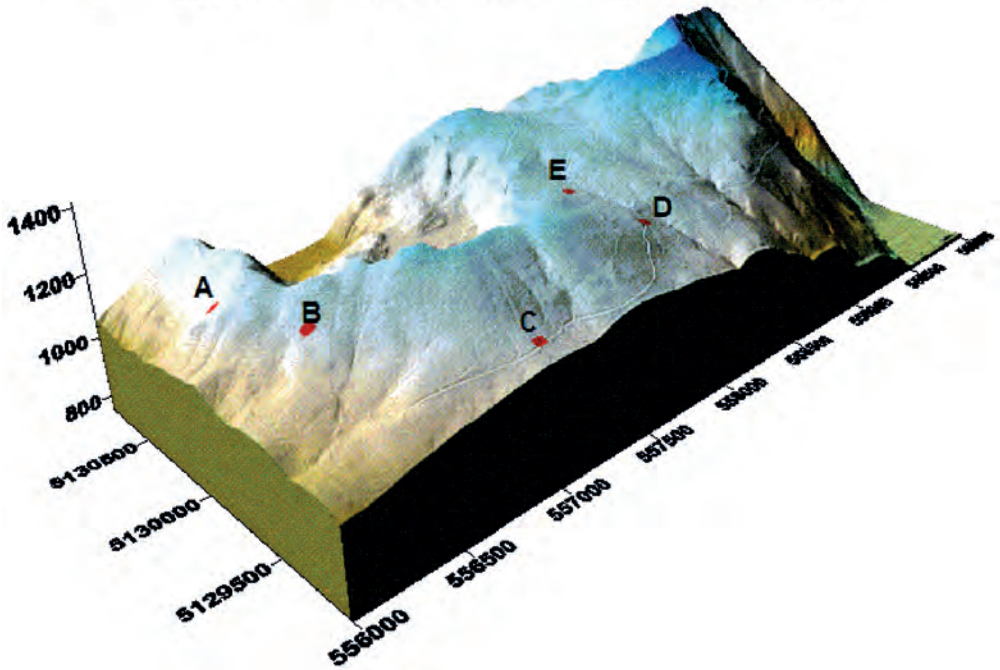


Figure 6: The view of area of interest with given points and topographical information.

As indicated in the model definition section, the three input datasets namely, the field data, start and end points, and cross section interval are fed into the model. Firstly, the centerline coordinates of the cross sections have been determined with a given cross section interval between route's points. Based on the experiences performed on the trials, the cross-section interval is selected two or three times bigger than digital elevation model grid size to eliminate the storage capacity problems. Here, it is taken 10 m for each route. The decision variables, boundary coordinates of the cross sections, have been calculated for each cross-station. Moreover, vertical profiles of grade and ground lines elevations have been generated which is the objective function of the model. From this point, based on the grade line elevations, the horizontal coordinates (linear distance along the route alignment) are mapped onto the boundaries. The intersection is performed between the contour line segments and cross section lines. At each cross section station, the intersection point which will be the candidate route point, is satisfied the third dimension found from predefined grade elevation, and then horizontal coordinates of the intersection point is taken as optimal point of the route. Once this algorithm has been performed for all points at each iteration, the coordinates of the corresponding points of the route are placed in a matrix. The resulting alignments of the routes can be seen in Fig. 7 obtained from running the algorithm.

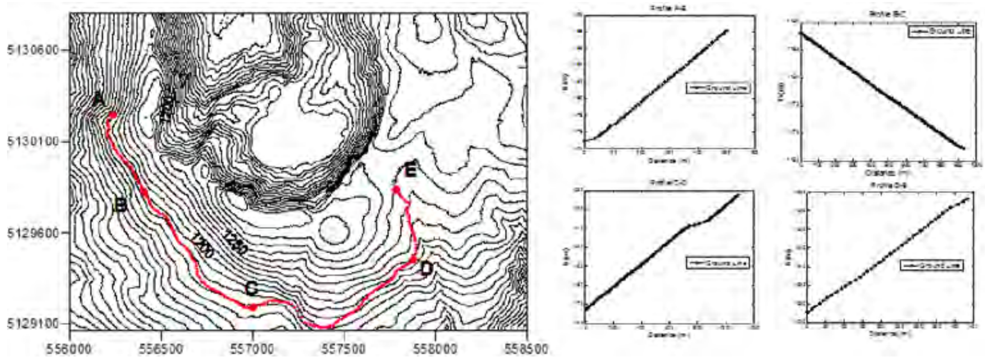


Figure 7: Final routes: vertical and horizontal views.

The elevation differences between grade and ground lines and their statistical information can also be seen in Fig. 8. According to this, the second route has the least elevation difference from a range of 0.000 m to 0.338 m and ±0.095 m standard deviation of it. That proves the method can generate close to optimum solutions on hilly fields. The maximum differences have been obtained for third route from a range of +3.138 m to -1.382 m, and standard deviation of the differences is ±1.342 m. The nature of the approach gives a longer horizontal route solution due to searching the desired grade line elevation and generates the differences from the calculated initial longitudinal grade.

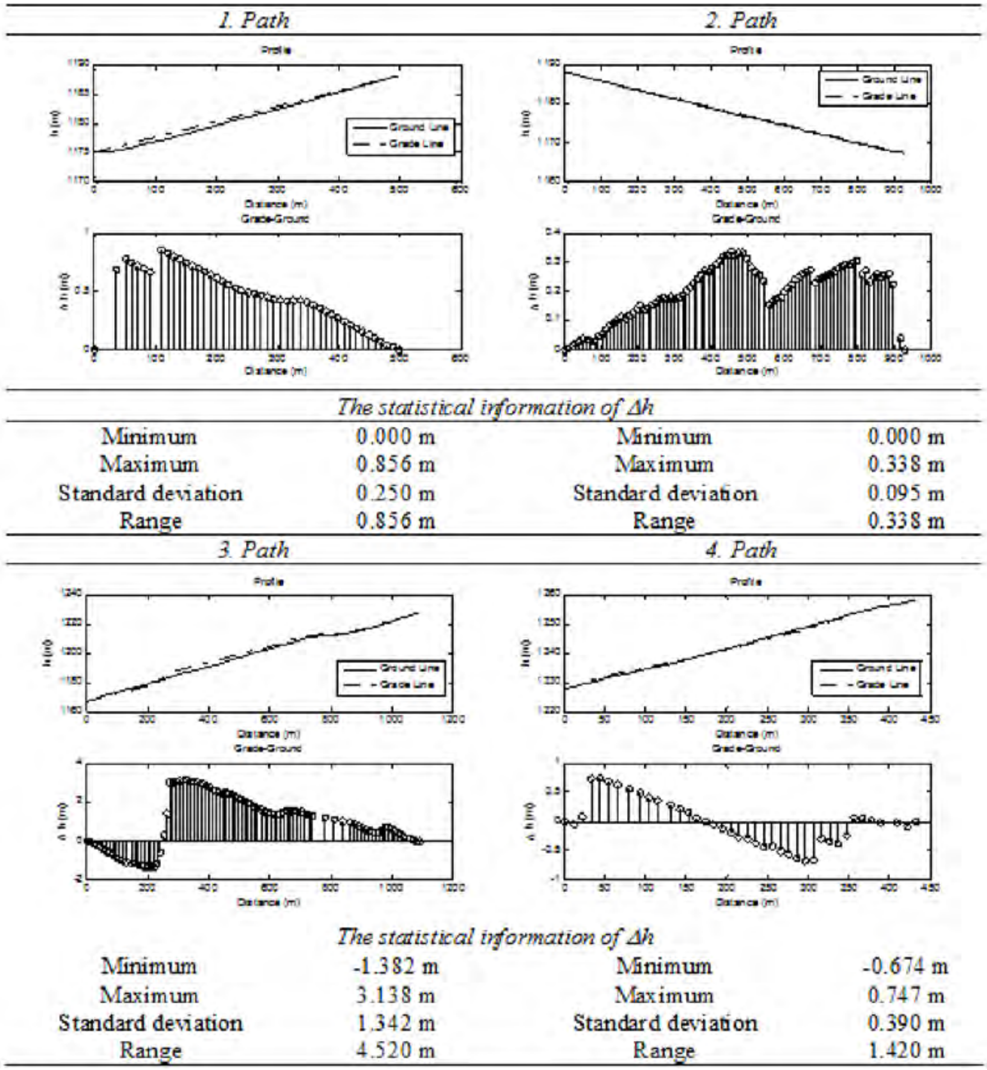


Figure 8: Elevation differences between grade and ground lines.

Although the obtained routes satisfy the grade line elevations as desired, they consist of several consecutive broken lines. To eliminate this problem and to satisfy the smoothness of the routes, a high degree polynomial function has been implemented on the integrated route. The selection of the polynomial degree is done by evaluating the minimum values of the sum of the residual errors with an upper degree limitation, in which it is 30 in this study to avoid ondulations along the route. In the evaluations, the observation weights are equal to each other and weights are 1. The fitting procedure is implemented on x coordinates to cumulative distance, and y coordinates to cumulative distance, respectively. The orders of the polynomial functions are determined as 29 and 16 for x- distance and y- distance evaluations, with 22.535 m and 29.069 m standard deviations, respectively. Fig. 9 shows the implementation of the polynomial functions for the integrated horizontal routes.

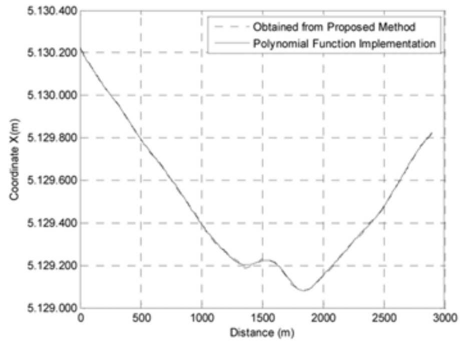
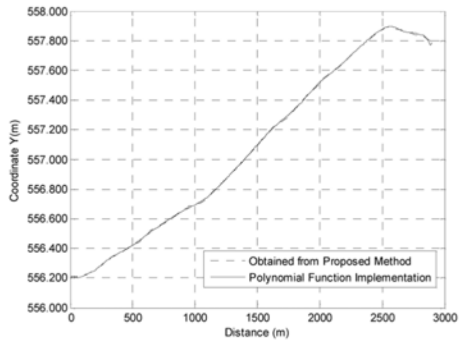
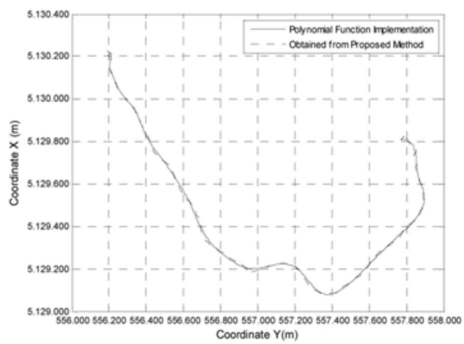
	The integrated path		
The Graphic of X- Distance			
The Graphic of Y- Distance			
The Graphic of X-Y			
Statistical Information		Polynomial Degree	Standard Deviation
	(X-Distance):	29	22.535 m
	(Y-Distance):	16	29.069 m

Figure 9: The implementation of the polynomial function to the horizontal route.

To overcome the discrete problem on vertical profile and to estimate the geometric design elements of the profile, curve radius estimation approach from the equation of circle has been implemented. To achieve this case, the profile data has been separated into two subsections: straight lines and remaining points between two straight lines. For the circular curve definiton, the remained points between two straight lines have been fitted using Newton's method with an iterative process by solving non linear equations. The final vertical alignment has 8.047 m elevation differences from a range of -4.238 m to 3.809 m, with ±1.156 m standard deviation. The obtained differences are good enough to consider the routes as final alignment. These results show that the proposed method may be a reference to select the appropriate routes.

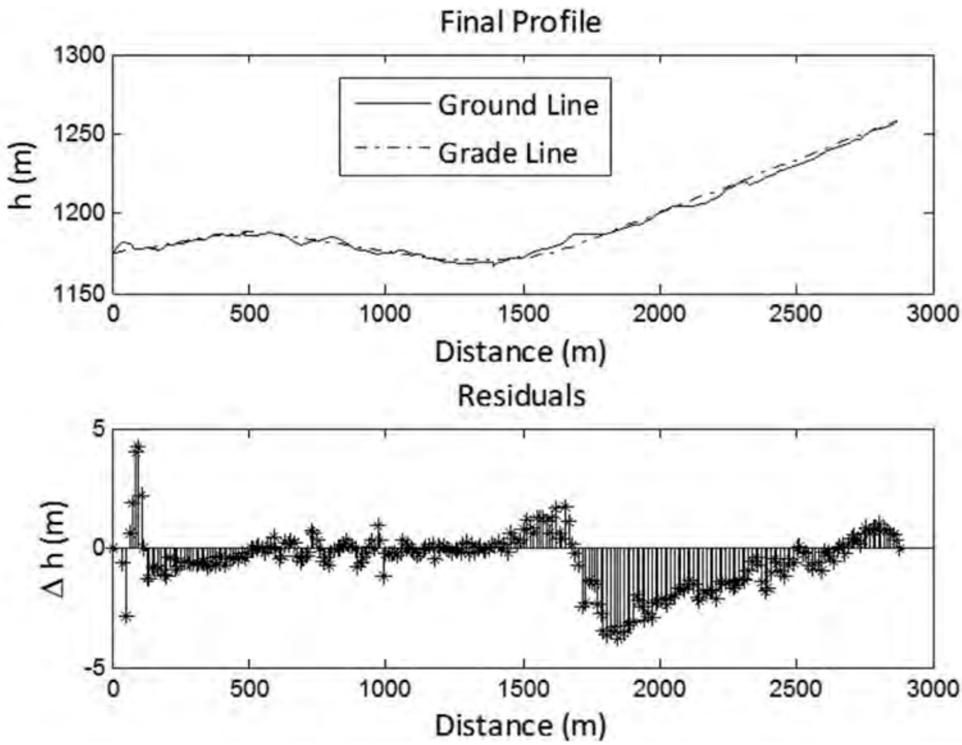


Figure 10: The final vertical profile.

4 RESULTS AND CONCLUSION

A simple searching algorithm of route selection due to the grade constraints of the study area is investigated in this paper. The methodology that may be a reference to select the route in the path design has been implemented with its subsequent calculations. The method is based on minimizing grade and gound level differences by means of constant gradient condition that should be performed by the final profile. In the final route, the horizontal alignment consists of several discrete- consecutive points. To eliminate this and to satisfy a smoothed path surface, a curve-fitting model with high degree polynomials has been implemented to join the horizontal lines. The curve radius estimation approach has also implemented to the vertical alignment. Because the integrated route has more than two consecutive vertical routes.

According to the proposed methodology, the vertical alignments may be determined for several different grade lines. As seen from the computational test, the method gives appropriate solutions on hilly-mountainous terrains. The elevation differences on these terrain types help to perform the contour line and cross section line intersections. The performance of the method on flat terrains is not good enough for generating consecutive points due to the cross section intervals. Here, the method requires very close cross section intervals to search the grade elevations for each centerline points and then satisfy the intersections.

The results show that the model may be used as a guide for route selection facilities based on topographic features of the area of interest. As stated in Cheng and Lee (2006), the initially vertical alignment design has been focused on route alignment definition in this study. Moreover, as indicated in the study of Lee and Cheng (2001), earthwork volume has been mentioned with the grade and ground line level differences to minimize total volume.

The investigation described here takes no consideration of the any other cost components except earthwork. However, the implementation of the method is based on gridded digital elevation method. Thus, these deficiencies can be met by adding more data layers that are including other features of the study area by multiplying the attributes with criteria cases.

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