DERIVATION OF TOPOGRAPHIC MAP FROM ELEVATION DATA AVAILABLE IN GOOGLE EARTH

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ABSTRACT

Topographic maps are most common source of terrain and elevation information for a given region. With the advancement of technology, other source of terrain and elevation data are now available at public domain. In this study, elevation data points (1600 in number) for Bahal region of Bhiwani district of Haryana extracted from the Google earth and a digital elevation model (DEM) was prepared. In order to evaluate the accuracy of the DEM, reference points comprising mostly of point elevations collected using GARMIN GPS along with few bench marks available in survey of India (SOI) topographic maps of 1: 50000 scale were collected. The accuracy of the Google earth derived elevation data are reported using root mean square (RMSE), mean error (ME) and absoluter mean error (AME). All these accuracy statistics were computed using 200 bootstrapped iterations to overcome the problems due to lesser number of reference points and bias, if any, in the selection of reference points. The study provides a procedural improvement in the accuracy statistics calculation and the results shows that Google earth can be a potential source of terrain information for many civil engineering projects.

KEYWORDS

Digital elevation model, DEM, Google Earth, GPS, accuracy assessment, bootstrap method

1.INTRODUCTION

Topographic data are essential to many Civil Engineering projects including construction of canal, dams, bridges, highways, large industrial and township development and many more. Elevation is one of the most sought data in topographic information. The success of the project sometimes required highly accurate elevation data with sufficient detail. Currently, several methods are being available and practiced for obtaining the terrain elevation data of a given topography. Some of the most common practices being the conventional surveying using total station, aerial photogrammetry, satellite photogrammetry, radar interfermometry, Lidar scanning, global positioning system (GPS) etc. Some of the global elevation data obtained using any of these methods are available publically. The public availability of elevation data has revolutionized the entire process of topographic data collection for engineering research and application [1].

Google Earth is a virtual globe based on 3D maps and geographical information program. It facilitate mapping of the Earth by the superimposition of images obtained from satellite imagery, aerial photography and geographic information system (GIS) 3D globe. Google Earth uses digital elevation model (DEM) data collected by NASA's Shuttle Radar Topography Mission (SRTM) enabling 3D view of the whole earth. Google Earth also supports managing 3D Geospatial data through Keyhole Markup Language (KML). Google Earth is useful for many applications such as earth resource mapping, visualizing earth feature, 3-D renderings of structures, town planning, simulation of disaster event such as of earthquakes using the Google Earth model, to monitor traffic speeds and congestion etc. Over the period Google earth has established itself as a useful tool for class room teaching, high end research, and data sharing and disseminating tool. This well supported by the fact that Google Earth has been downloaded more than a billion times since October 2011.

Google Earth provides high-resolution elevation data using the virtual globe system, which started in June 2005 and used Shuttle Radar Topography Mission (SRTM) data for its elevation baseline. Google EarthTM's elevation data are at a resolution 5 to 20 times higher than available South African 1:50 000 CDSM datasets [2]. However, at some places the RMSE error of SRTM DEM is more than its specified accuracy of ± 16m [3]. If the terrain is highly vegetated, slope steeply than accuracy may be further reduced. Although SRTM data underlie the Google Earth elevation data, it has undergone continuous refinement through successive addition of high resolution data from various sources as they become available [4], [5]. In view of the above facts it is imperative to carry out an accuracy assessment elevation data available with Google Earth. The main objective of the present study is to make a comparative accuracy assessment Google Earth with GPS derived elevation as a reference data.

2. METHODOLOGY

The following formatting rules must be followed strictly. This (.doc) document may be used as a template for papers prepared using Microsoft Word. Papers not conforming to these requirements may not be published in the conference proceedings.

2.1. Study Area

The study is carried out in relatively small area around the Bahal, a small sub-divisional town in the Bhiwani district of Haryana in India. The study area is geographically extends between the latitudes from 28.5621 degree N to 28.6611 degree N and from longitude 75.5720 degree E to 75.6723 degree E covering an area of approximately 80 km^2. The topography of the study area is generally sandy, undulating plain dotted with sand dunes of varying shapes and dimensions occurring in different directional dispositions.

2.2. Data used

Elevation data from three different sources are used for comparative accuracy assessment of Google Earth (GE) elevation as a source for topographic information. The first data comprises of XY location of some ground control points (GCPs) from open series topographic maps (2007 Edition) obtained from survey of India (SOI), Dehradun. The second data is GPS survey elevation data collected on the field using Garmin eTrex GPS during field surveying. The second elevation data are obtained from Google Earth (2014 Edition). The latter elevation dataset is evaluated for their vertical accuracy by considering GPS derived elevation as reference data.

2.3. Methods

In order to generate topographic maps of the Bahal region, sixteen hundreds (40 ×40 grid) point elevation data was collected from Google Earth version 2014. The extracted Google earth elevation points were imported into ArcGIS environment. The points were interpolated using inverse distance weighing (IDW) interpolation method of terrain analyst extension of ArcGIS to obtain the DEM of the area. For accuracy assessment, available (seven in numbers) benchmarks (BMs) were collected from georeferenced open series SOI topographic maps (2007 Edition). Besides these, 86 point elevations were also collected using Garmin eTrex 10 GPS. GPS collected data are reported to be of desired quality and are being used for various applications [6]. The 93 reference elevation point s and elevation extracted from Google Earth were brought to MS excel for accuracy assessment. Three accuracy statistics used are as below:

$$ME = \frac{\sum_{i=1}^{N}(y_i - y_j)}{N} \qquad (1)$$

$$MAE = \frac{\sum_{i=1}^{N}\left|y_{ij} - y_j\right|}{N} \qquad (2)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(y_i - y_j)^2}{N-1}} \qquad (3)$$

In the above formulas, y_i and y_j are i^{th} reference elevation point and Google Earth derived elevation points respectively. N= 93, is the total number of observations.

The above accuracy statistics were determined through 500 bootstrap iterations. Bootstrapping is a stochastic method for estimating the sampling distribution of an estimator. It resamples the data with replacement based on Monte Carlo algorithm. It is useful when the theoretical distribution of a statistic of interest is complicated or unknown. Finally, a four meter interval contour map of the study area was prepared using terrain analyst module of ArcGIS for visual assessment of the DEM.

3. RESULTS AND DISCUSSION

The set of sample elevation data used for accuracy assessment of Google Earth's elevation model is presented in Table 1.

Table 1: Sample points location along with GPS elevation and Google Earth Elevation data

S. N	Lat	Long	GE Ele (m)	GPS Ele (m)	S.N	Lat	Long	GE Ele (m)	GPS Ele (m)
1	28.61875N	75.63344E	244.00	248.00	48	28.62834N	75.61631E	250.00	244.00
2	28.63155N	75.6242E	249.60	247.00	49	28.62834N	75.61665E	249.70	244.00
3	28.63096N	75.62247E	250.30	246.00	50	28.62834N	75.61705E	249.09	248.00
4	28.63140N	75.6200E	249.39	245.00	51	28.62834N	75.61743E	248.48	246.00
5	28.63067N	75.61937E	248.78	246.00	52	28.63082N	75.61723E	251.52	249.00
6	28.63214N	75.62015E	249.39	243.00	53	28.63081N	75.61685E	250.61	249.00
7	28.63369N	75.62135E	248.17	243.00	54	28.63064N	75.61569E	249.09	247.00
8	28.63467N	75.62128E	246.95	241.00	55	28.63123N	75.61565E	249.70	250.00
9	28.63241N	75.62040E	249.39	244.00	56	28.6316N	75.61532E	250.00	249.00
10	28.6317N	75.6104E	249.08	247.00	57	28.63171N	75.61519E	250.30	250.00
11	28.63173N	75.61943E	249.39	244.00	58	28.63205N	75.61388E	247.87	256.00
12	28.63247N	75.61854E	249.08	252.00	59	28.63225N	75.61385E	247.26	253.00
13	28.63425N	75.61724E	248.17	243.00	60	28.6332N	75.61254E	244.82	250.00
14	28.63185N	75.6137E	247.87	246.00	61	28.63424N	75.61092E	246.95	250.00
15	28.63037N	75.61192E	248.17	241.00	62	28.63001N	75.61095E	246.65	247.00
16	28.62834N	75.6126E	249.09	238.00	63	28.62946N	75.61012E	247.26	250.00
17	28.62834N	75.61378E	250.61	237.00	64	28.62929N	75.61064E	246.95	249.00

18	28.62834N	75.61552E	250.91	241.00
19	28.62834N	75.62679E	246.65	241.00
20	28.62834N	75.62614E	247.26	241.00
21	28.62834N	75.62377E	246.95	244.00
22	28.62834N	75.62438E	247.26	240.00
23	28.62834N	75.62599E	247.87	238.00
24	28.62834N	75.61993E	247.87	244.00
25	28.62834N	75.61951E	248.48	241.00
26	28.62834N	75.61723E	248.78	242.00
27	28.62834N	75.61607E	250.30	241.00
28	28.62834N	75.61561E	251.22	243.00
29	28.62834N	75.61773E	248.48	243.00
30	28.62834N	75.61594E	250.61	239.00
31	28.62834N	75.6169E	249.09	246.00
32	28.62834N	75.61636E	250.00	243.00
33	28.62834N	75.61777E	248.48	242.00
34	28.62834N	75.61786E	250.30	243.00
35	28.62834N	75.61642E	250.60	246.00
36	28.62834N	75.61605E	250.90	251.00
37	28.62834N	75.61987E	247.87	251.00
38	28.62834N	75.61978E	248.17	236.00
39	28.62834N	75.6188E	249.09	251.00
40	28.62834N	75.62085E	246.95	256.00
41	28.62834N	75.62283E	247.26	248.00
42	28.62834N	75.61781E	248.48	245.00
43	28.62834N	75.61707E	249.09	249.00
44	28.62834N	75.61578E	250.61	249.00
45	28.62834N	75.61545E	251.22	249.00
46	28.62834N	75.61576E	250.91	250.00
47	28.62834N	75.61916E	248.78	245.00
65	28.62924N	75.61159E	248.17	247.00
66	28.62922N	75.61214E	248.17	246.00
67	28.62876N	75.61255E	248.48	245.00
68	28.62886N	75.61322E	248.48	247.00
69	28.62893N	75.61331E	248.48	247.00
70	28.62951N	75.61387E	248.17	248.00
71	28.62906N	75.61398E	249.09	249.00
72	28.62969N	75.61452E	247.56	246.00
73	28.62952N	75.61486E	247.87	247.00
74	28.62508N	75.61613E	248.48	246.00
75	28.62442N	75.61614E	248.48	246.00
76	28.62301N	75.61601E	250.91	251.00
77	28.62273N	75.61765E	250.00	257.00
78	28.62305N	75.61823E	248.78	256.00
79	28.6239N	75.61858E	247.87	254.00
80	28.62486N	75.62173E	246.95	251.00
81	28.62536N	75.62376E	245.43	255.00
82	28.62226N	75.61581E	250.61	253.00
83	28.62045N	75.61529E	247.26	250.00
84	28.62036N	75.61526E	247.26	250.00
85	28.61868N	75.61457E	248.78	251.00
86	28.61706N	75.61409E	249.39	255.00
87	28.61936N	75.61521E	248.48	255.00
88	28.61936N	75.61681E	249.09	254.00
89	28.61906N	75.6182E	248.48	256.00
90	28.61902N	75.61825E	248.17	256.00
91	28.61868N	75.61909E	248.48	256.00
92	28.61905N	75.61971E	247.87	254.00
93	28.61833N	75.61863E	248.78	254.00

Although 93 sample points were used for accuracy assessment, their distribution may not be free of bias. It is because when we were trying to collect elevation data for random points some of the points were falling in the areas which are not accessible. Hence, the collected may not be truly random one or correctly represent the population/topographic information the area. Hence, the accuracy statistics such as ME, MAE, and RMSE were computed using 500 bootstrap iterations. The frequency distribution of these accuracy statistics are shown in Figure 1-3.

The bootstrap iterations also provide an advantage of determining the accuracy statistics stochastically as opposed to prevailing practice of deterministic derivation of these statistics [3]. The figure (1-3) shows that the frequency distributions of all the three statistics follow a more or less normal distribution. Thus, 99.9% confidence can be described for the computed quantity using mean± three standard deviations obtained from the frequency distributions.

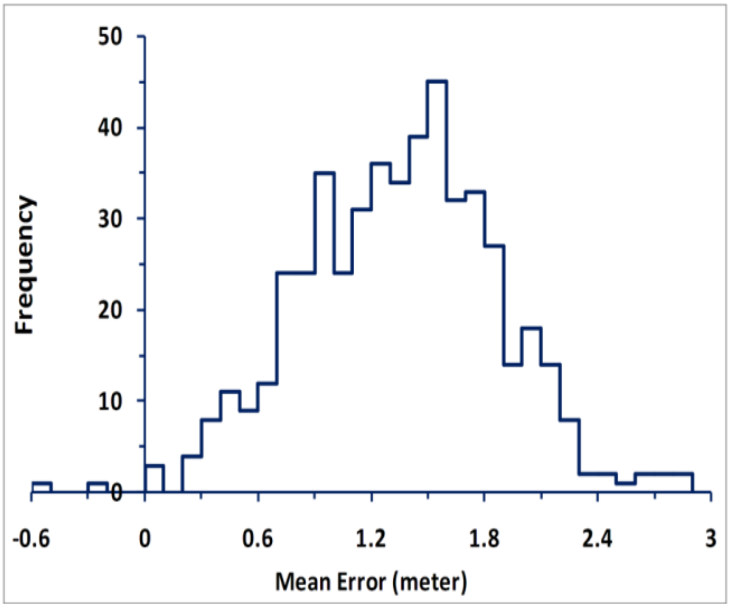

Fig 1: Frequency distribution of 500 bootstrap iteration for mean error

The value of mean error should be zero which ensures that the predictions are unbiased. However, we have obtained confidence range of 1.355± 0.5284 m. It is obvious that ME will not provide a true picture because of negation of +ve and –ve errors by each other. Hence mean absolute error (MAE) was determined and its confidence range was found to be 4.485± 0.3260 m.

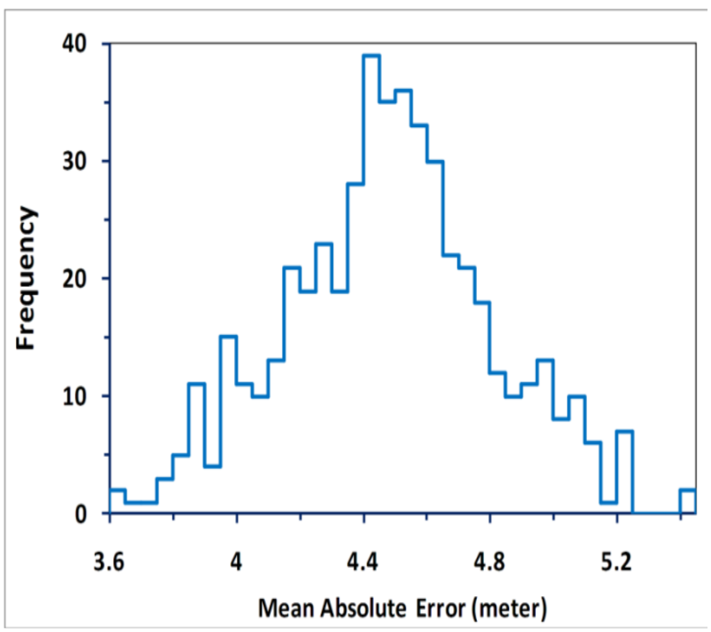

Fig 2: Frequency distribution of 500 bootstrap iterations for mean absolute error

The RMSE value with confidence interval was found to be 5.402±0.3253 m. The observation substantiates the previous findings that although Google Earth's elevation data models are based on Shuttle Radar Topography Mission (SRTM) DEM data, it provides more satisfactory high-resolution DEM for small area as compared to SRTM DEM itself [2].

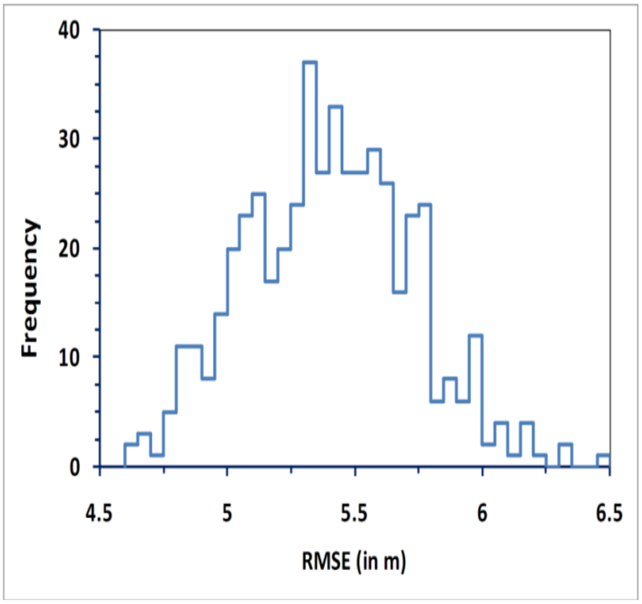

Fig 3: Frequency distribution of 500 bootstrap iterations for root mean square error

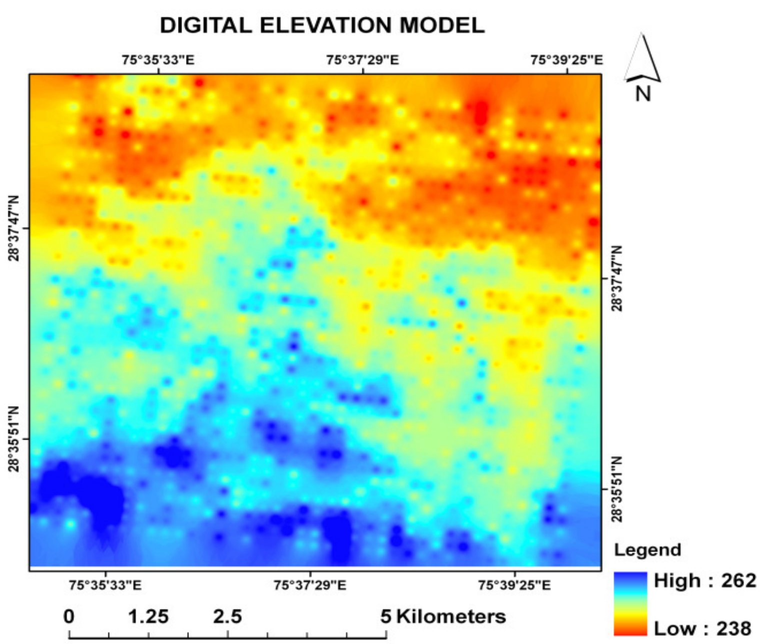

Fig 4: Digital elevation model of the Bahal region

The possible effect misregistration (miss-matching of XY location of a given in the Google Earth and GPS survey check point) was not studied except few checks at important road cross-sections. This check did not show any significant discrepancy. Thus, a direct comparison of elevation points of the two dataset would not be obscured results.

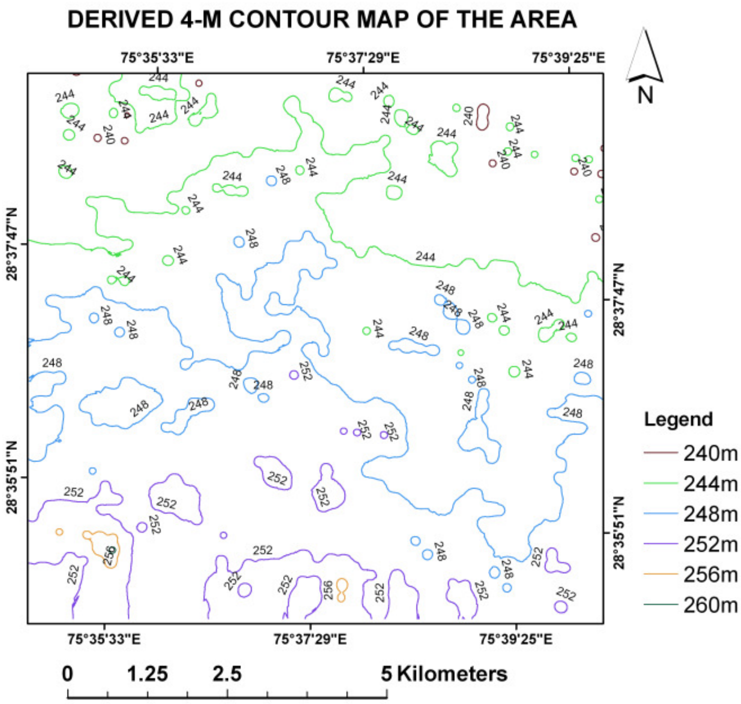

Fig 5: DEM derived contour map of the Bahal region

The Figure 4 shows the DEM of the study area obtained using 1600 Google earth elevation points. It indicates the reduced level of the study area varies between 238 m – 262 m above mean sea level. However, the DEM shows artifacts in the form of numerous circular points, corresponding to original sample point data. These artifacts may be due improper parameter (distance decay power function) used in IDW interpolation. The artifacts are quite conspicuous which necessities the use of either some other interpolation method or a proper choice of IDW interpolation parameters.

Figure 5 shows the derived 4m interval contour map of the region. The 240m and 260 m contour lines were visually inspected with respect tp contour line provide in the SOI open series topographic maps (1:50,000) scale of the area. It reveals that contour almost perfect drawn except few sharp sinuosities at some place. Contour lines other then these two were not evaluated due to non-availability of large scale contour map of the area.

4. CONCLUSION

Although Google Earth is able to provide fine resolution (submeter) imagery and aerial view of the earth, the elevation data provided along with it may also be of sufficient vertical resolution to prepare a high resolution DEM. The RMSE and AME error were found to be 1.355± 0.5284 m and 5.402±0.3253 m, respectively. The prepared DEM is of satisfactory accuracy for certain engineering application but inadequate to meet the standard required for fine/small scale DEM for very precise engineering study. In this perspective the LIDAR elevation data may be an alternate option which can provide a DEM of desirable vertical resolution for precise engineering project work. The proposed method of accuracy assessment is believed to be more robust than the prevailing methods of accuracy assessment. It is also concluded that the presented method allows the generation of high-resolution DEMs especially for areas where adequate relief information is either not available or too costly to generate.

5. REFERENCES

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