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Comparative Analysis of Total Station and Spirit Level in Generating a Digital Terrain Model (DTM)

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ABSTRACT:

The Study compares and analyses the data obtained using Total Station (TS) and level instruments in generating a Digital Terrain Model (DTM). To achieved the objective of the research, 43 points were established on the ground surface and their X,Y,Z coordinates were determined using total station. The heights of the same points were determined as well using level instrument through the process of leveling and computations. The data obtained using the two instruments were saved in Microsoft excel and were imported in to ArcGIS 10.3 and the DTM and 3D surface map of each method was generated using Inverse Distance Weighing(IDW) interpolation techniques and Surfer 10.0software respectively. Based on descriptive statistics, it was found that the total station gave a minimum height of 215.23m, and a maximum of 218.68m, while Spirit Level gave a minimum height of 215.22m and a maximum of 218.69m, this indicates that both instruments gave a very close results hence both total station and spirit level can be used in carrying out levelling for generating a DTM. However, statistically, the total station observations gave a better accuracy with a minimum standard deviation of 0.888 compared to a spirit level observations which gave a standard deviation of 0.907. Thus, the data obtained with the total station is more accurate than the ones obtained from spirit leveling.Time expenditure on each method revealed that the total expended time to acquire data with TS was 89 minutes while the total time expended to acquire data with spirit level was 102 minutes. This shows that using total station for topographic project is 7% faster than using spirit level.In the nut-shell the spirit leveling gives less accurate results than the total station because it has maximum standard deviation. The main advantage of total station compared to a spirit level is therefore the total station is faster in data capture, shorter time and safer means of data processing and the ability of data storage and retrieval electronically, and the telescope can be tilted to sight a point which the spirit level lacks.

Key word: Total Station, Spirit Leveling, Heights, Analysis, Digital Terrain Model

I. INTRODUCTION

Digital Terrain Model is a numerical representation of terrain features in terms of elevation and planimetric measurements obtained by sampling a topographic surface. In order words, it is a numerical representation of both planimetric detail and height information, which provides a continuous description of the terrain surface. Digital terrain modeling involves a digital representation of terrain features consisting of a set of X,Y,Z coordinates of points. Several other terms used to refer to DTM include Digital Elevation Model (DEM), Digital Height Model (DHM), Digital Ground Model (DGM) and Terrain Elevation Model (TEM). Digital terrain models may be used with appropriate software to perform terrain analysis and to generate a variety of products (Ndukwe, 2001).

Idris, 2019 defines digital terrain model as a three dimensional representation of terrain surface consisting of X,Y,Z coordinates stored in a digital form. It includes not only height and elevation but other geographical elements and natural features such as rivers ridge line etc. With the increasing use of computers in engineering and the development of fast three dimensional graphics, the digital terrain model is becoming a powerful tool for great numbers of application services.

Before the advent of modern technology, digital terrain model was carried out analogically; however, the advent of modern technology gave birth to Geographical Information System (GIS) which is a multidisciplinary tool, which integrates different types of data from various cartographic information and digital terrain model because of its versatility. A Geographic Information System (GIS), or geospatial information system is the system that captures, stores, analyzes, manages and presents data with reference to geographic location data. Geographic Information System (GIS) may also be defined as "a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular purpose" (Burrough, 1986). This new tool which has become so versatile in applicability, has gained tremendous importance in the last decade or so. Great advances in high speed computing devices, coupled with new instrumentation in spatial data collection and processing, which reflect modern technology are the main reasons for the advances made in GIS. GIS may be used in Archaeology, Geography, Cartography, Remote Sensing, Land Surveying, Public Utility Management, Natural Resource Management, precision Agriculture, Photogrammetry, urban planning, emergency management, landscape architecture, navigation, aerial video, and localized search engines.

A digital terrain model approximates a part or the whole of the continuous terrain surface by a set of discrete points with unique height values over 2D points. Heights are in approximation vertical distances between terrain points and some reference surface (e.g., mean sea level, geoid and ellipsoid) or geodetic datum. Mostly arranged in terms of regular grids, the 2D points are typically given as geodetic coordinates (latitude and longitude), or plane coordinates (North and East values). DTMs usually assign a single unique height value to each 2D point, so it cannot describe vertical terrain features (e.g., cliffs). DTMs are therefore "2.5D" rather than truly 3D models of the terrain (Weibel and Heller, 1991).

While DTMs represent the bare ground of the terrain, a Digital Surface Model (DSM) describes heights of vegetation e.g. trees and of man-made features e.g. buildings too, It is thus important to distinguish between DTM and DSM over vegetated or built areas. A closely related term is Digital Elevation Model (DEM), which is sometimes used synonymously with DTM, but often as an umbrella term to describe both DTM and DSM (Wood, 2008; Hutchinson and Gallant, 2005; Shingare and Kale, 2013). DEM is often used for elevation models from remote sensing e.g. radar or photogrammetry. These models are rather DSM than DTM unless vegetation and building heights are removed.

Digital elevation models are indispensable tools in many environmental and natural resource applications. This term characterizes a modeling technique rather than the data that are described by an elevation model. DEMs are frequently derived from contour lines. The accuracy of such DEMs depends on different factors. A DEM is a numerical representation of topography, usually made up of equal-sized grid cells, each with an elevation value. Its simple data structure and widespread availability have made it a popular tool for land characterization. The widespread availability of computing facilities and sources of DEMs enhance their utilization in many environmental and natural resource applications. The list of applications is progressively growing: visibility analysis, erosion modeling, surface hydrology, watershed modeling, geomorphology, land sliding, remote sensing applications, agriculture, and ecosystem modeling are some examples.

High-resolution DEMs are required to represent fine variations in topography, especially in complex terrain, which increases the volume of the data to be stored and might involve some redundancy. Furthermore, too small a grid cell size may result in estimates that are much more detailed than is relevant for the process being modeled. The solution is to select a resolution that is as coarse as possible while still meeting a defined accuracy to serve the specific purpose. Limited research has been carried out to assess the impact of the inaccuracy of the source data, processing errors, and the DEM resolution on the accuracy of the DEM and its derivatives (Yakar,2009).

DEMs are generated by different sources such as aerial photos, satellite images, contour maps, and field data. The most accurate DEM is generated by field data. As mentioned before, the only error source in field data is the measurement error. It is required that points are known coordinates X, Y, Z to generate DEM by field data. Point number and distribution are important in the generating of a DEM, but measurement of more points in the field increases the cost and the time. Creation of a three-dimensional (3-D) network structure of earth surface is among the application of DEM, created from digital elevation data by Triangulated Irregular Network (TIN), vertical/horizontal lines at regular intervals, is elevation curves, and profiles. Triangulated irregular network has adjacent triangular faces matching elevations sampled at irregular intervals, thus providing data distribution at variable intervals. The TIN model represents a surface as a set of contiguous, non-overlapping triangles. The triangles are made from a set of points called mass points. Mass points can occur at any location; the more carefully selected, the more accurate the model of the surfaceAdvantages of TIN are the ability to describe the surface at different levels of resolution and efficiency in storing data. Disadvantages of TIN are that in many cases they require visual inspection and manual control of the network (Yakar, 2009).

Surfer 8 software (Golden Software Inc., Golden and CO) is the most powerful, flexible, and easy-to-use contouring and 3-D surface mapping package available. Surfer 8 software easily and accurately transforms X,Y,Z data into spectacularly colorful contour, surface, wire frame, shaded relief, and image, post, and vector maps in minutes. This software quickly interpolates irregularly or regularly spaced data into a regularly spaced grid and creates grids from up to 1 billion X,Y,Z data points.

Terrain models play a fundamental role in geosciences and engineering, and have numerous applications. They can be used to calculate derived quantities, such as volumes, slope, curvature, sun exposure, hill shade, contours, visibility from given sites, drainage, and gravitational attraction. Application examples for DTM include its use as a base layer in geographic information systems (GIS), e.g. for planning of engineering structures roads, railways, canals, hydrology (drainage and catchment area analysis), coastal protection (inundation), mass movements in mountain areas, rendering visualizations and topographic maps, planning of radio networks and alternative energy power plants, and rectification of photogrammetric imagery (orthophotos).

In the narrower field of gravity field modeling and physical geodesy, DTM data is a pivotal data source providing geometry information of the topographic masses. Using gravity forward modeling techniques, the gravitational attraction of the masses is computed from DTM data, and can be subtracted from observed gravity values to highlight signatures of mass anomalies in the

Earth's interior, it also used as reduction in geoid determination, or utilized to predict a detailed gravity field over otherwise less surveyed areas.

A Total Station (TS) is a modern surveying instrument that integrates an electronic theodolite with an Electronic Distance Meter (EDM). Total stations use electronic transit theodolites in conjunction with a distance meter to read any slope distance from the instrument to any particular spot. They are hence two essential surveying instruments in one and when used with other technology such as mapping software are able to deliver the 'total' surveying package, from measuring to mapping. The development of total stations has markedly increased productivity in the surveying profession in many ways. Improved accuracy is one of the major advantages of total station. Now GPS technology can be used by a total station to include unseen points in the survey. Other increases in productivity are due to efficiency and functionality. Total Stations also include up-to-date image capture technology, which can record any image or screen-view from the surveying site, eliminating the need for costly revisits, and producing high-resolution images of site conditions. A total station has electronic documentation and sketching functions, which reduces the need for paper field notes.

Levelling is the operation required in the determination, or more strictly, the comparison of heights of points on the surface of the earth (Bannister et al., 1992). Levelling is useful in designing highways, railways and canals, setting out projects according to planned elevations, calculating volumes of stacks, earthworks and embankments, investigating and laying out of drainage systems among other uses. There are various methods of determining difference in elevation of points. They include; taping methods, differential levelling, barometric levelling, trigonometric leveling and the modern methods such as GPS levelling. Spirit levelling is a surveying technique that employs spirit levels to orient the line of sight to coincide with the horizontal line in order to determine change in elevations between two points. Spirit levelling observations were carried out with automatic levelling instrument and a levelling staff. The levelling procedure is performed by taking a back sight reading to a levelling staff placed vertically at a benchmark, then reading a foresight on a staff placed on a point whose height is to be determined.

STATEMENT OF PROBLEM

The creation of digital terrain model is becoming more and more popular since it has gotten many more applications like planning, construction works, surveying, mapping and so on. The comparisons of the terrain model have seemed to be the matter of interest in height determination. There are number of instruments of different precisions and relatively different field procedures which end with different results. Total station and spirit level are instruments used in obtaining elevations referenced to a particular datum in order to generate DTM for applications such as modeling water floor for hydrology, creation of relief maps, extracting terrain maps for geomorphology, rendering of 3D visualization etc. in this regard, the need to obtain a more reliable DTM cannot be overemphasized hence it is vital to investigate which of the instruments generates a better DTM.Therefore this study seeks to produce DTM using total station and spirit level instrument. In the process of producing the DTM comparison is made between the two data sets obtained using total station and spirit level.

II STUDY AREA

The study area is a compound at the ModibboAdamaUniversity, Yola – Nigeria. Its lies between latitude 09^0 21′ 18″ and longitude 12^0 30′ 30″ and latitude 9^0 20′ 59″ and longitude 12^0 30′ 36″. The area is located along the Yola- Maiduguri highway and 10km away from Yola the headquarters of Adamawa state.The climate of the study area exhibits typical tropical climate (Zemba et-al, 2010). The study area has average sunshine hours of about 7-8 hours daily and the wind speed average of 76.1km/h. The air temperature in the state as a whole is a typical West African Savannah Climate. Temperature in this region is generally high throughout the year. Yola has a seasonal change in temperature, from January–April the temperature increases because of the clearer sky view which permits the reception of solar radiation. The maximum temperature is 43°C which occur in April and the minimum temperature is 28°C between December and January. There is a distinct drop in temperature at the onset of rains due to the effects of cloud cover. The temperature decreases at the beginning of the raining season to the end which is as a result of the cloud effect. The temperature again increases after the cessation of the season (October - November) before the arrival of harmattan which leads to its drop (Adebayo, 1999).

III. MATERIALS AND METHOD

The materials used for the research include; Hard ware and Software.The hard ware are; i. Total station ii. Automatic level iii. 100m steel band tape iv. Computer laptop with 12G HZ and 1G of ram capacity and v. Deskjet printer. The software are i. Surfer 10.0 ii. ArcGIS 10.3 and iii. MS office Word 2013 and MS office Excel.

The method of acquiring data for the research involved the use of total station and automatic level instruments in acquiring field data for the research. The total station is an electronic/optical instrument incorporated with an Electronic Distance Meter (EDM) used in modern surveying and therefore capable of measuring distances as well as X,Y,Z coordinates of an unknown points relative to a point whose coordinates are known. On the other hand, the automatic level is a device capable of measuring the difference in elevation of points relative to a point whose height is known and by computations using rise and fall or height of instrument method, the heights of the unknown points can be deduced. Two sets of data were obtained from the total station and the spirit leveling process and were imported in to a computer laptop to create two Digital Terrain Model (DTM) of the same area under research. Hence the comparative analysis of the two sets of data obtained from the total station and spirit leveling process.

DATA TYPE AND SOURCE.

Basically two types of data sets acquired for the research, these include X,Y,Z coordinates of 43 selected points obtained using total station and the heights of the same 43 points obtained through the process of spirit leveling. The source of the data is a direct land survey field observations.

DATA PROCESSING

The X,Y,Z coordinates of the 43 selected points obtained from the total station and spirit level was saved in Microsoft Excel as Comma Separated Values (CSV) format, which allows the data to be saved in a table structured format for exchange in the ArcGIS 10.3 for analysis. 3D analyst tool was selected and the DEM was created using Inverse Distance Weighted (IDW) interpolation method. This method was used because the set of points in the study area is dense enough to capture the extent of local variation needed for analysis, the positions of the 43 points observed is hereby presented in figure 1 below. The DEM of the study area was generated from the two instruments of elevation determination i.e. total station and spirit level as presented in figures 2 and 3 for comparison. The elevations were determined from the same datum i.e. WGS84.3D Surface was also created in Surfer 10.0, to achieve that, grid file was created from the imported Excel file containing X,Y,Z of all the points established for this research and 3D surface tool was clicked to generate 3D surface maps as shown in figures 4 and 5.

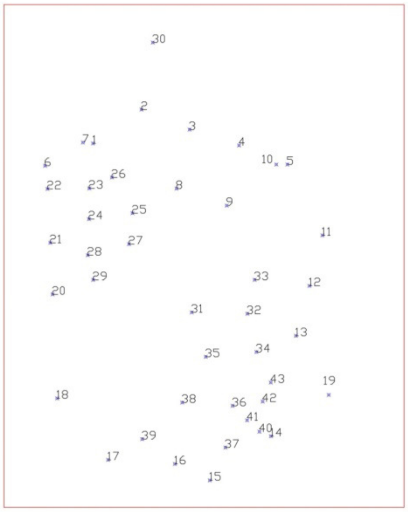


Fig. 1Position of 43 observed points in the study area

IV. RESULTS PRESANTATION

The result of the research are in a tabular and graphical forms as presented below:

Table 1: Total Station Data

Station	Northing (m)	Easting (m)	Height
1	1034093.483	225345.419	217.949
2	1034112.176	225358.468	218.363
3	1034130.672	225350.746	218.312
4	1034149.748	225344.636	218.221
5	1034168.357	225337.279	217.334
6	1034075.012	225336.800	217.666
7	1034089.593	225345.764	217.843
8	1034125.647	225327.996	217.747
9	1034144.988	225321.442	218.677
10	1034164.096	225337.279	218.009
11	1034181.838	225309.970	217.783
12	1034176.837	225290.504	217.563
13	1034171.627	225271.224	216.911
14	1034162.024	225232.534	216.055
15	1034138.481	225215.502	215.533

16	1034125.03	225221.819	215.555
17	1034099.296	225223.385	215.229
18	1034079.664	225247.106	215.744
19	1034678.687	225267.139	216.200
20	1034077.921	225287.197	216.532
21	1034077.030	225307.077	216.888
22	1034075.952	225327.875	217.222
23	1034092.037	225328.07	217.422
24	1034091.923	225316.261	217.321
25	1034108.693	225318.515	217.198
26	1034100.783	225332.302	217.562
27	1034107.344	225306.593	217.055
28	1034091.469	225302.31	216.919
29	1034093.544	225292.804	216.755
30	1034116.527	225384.31	216.644
31	1034131.503	225280.271	216.688
32	1034152.943	225279.732	216.955
33	1034155.729	225292.819	217.165
34	1034156.430	225264.98	216.643
35	1034136.914	225263.131	216.281
36	1034147.244	225244.233	216.088
37	1034144.464	225228.146	215.845
38	1034127.848	225245.508	216.011
39	1034112.434	225231.399	215.482
40	1034157.597	225234.255	216.771
41	1034152.846	225238.64	215.934
42	1034158.832	225245.881	216.380
43	1034161.960	225253.207	216.449
Standard Deviation			**0.888324**

Table 2: Spirit Level Data

Station	**height**
1	217.949
2	218.358
3	218.426
4	218.356
5	217.224
6	217.656

7	217.831
8	217.736
9	218.686
10	218.053
11	217.831
12	215.424
13	216.902
14	216.047
15	215.547
16	215.526
17	215.224
18	215.751
19	216.198
20	216.521
21	216.877
22	217.211
23	217.435
24	217.316
25	217.278
26	217.532
27	217.039
28	216.917
29	216.735
30	216.646
31	216.619
32	216.926
33	217.174
34	216.612
35	216.28
36	216.09
37	215.807
38	216.006
39	215.491
40	216.735
41	215.932
42	216.379
43	216.443
Standard Deviation	**0.906519**

Table 3: Difference between Total Station Heights and Spirit Level Heights

Station	Total station heights (H_{TS})	Spirit Level heights (H_{SLEVEL})	Difference (H_{TS}-H_{SLEVEL})
1	217.949	217.949	0
2	218.363	218.358	0.005
3	218.312	218.426	-0.114
4	218.221	218.356	-0.135
5	217.334	217.224	0.11
6	217.666	217.656	0.01
7	217.843	217.831	0.012
8	217.747	217.736	0.011
9	218.677	218.686	-0.009
10	218.009	218.053	-0.044
11	217.783	217.831	-0.048
12	215.563	215.424	0.139
13	216.911	216.902	0.009
14	216.055	216.047	0.008
15	215.533	215.547	-0.014
16	215.555	215.526	0.029
17	215.229	215.224	0.005
18	215.744	215.751	-0.007
19	216.200	216.198	0.002
20	216.532	216.521	0.011
21	216.888	216.877	0.011
22	217.222	217.211	0.011
23	217.422	217.435	-0.013
24	217.321	217.316	0.005
25	217.198	217.278	-0.08
26	217.562	217.532	0.03
27	217.055	217.039	0.016
28	216.919	216.917	0.002
29	216.755	216.735	0.02
30	216.644	216.646	-0.002
31	216.688	216.619	0.069
32	216.955	216.926	0.029
33	217.165	217.174	-0.009
34	216.643	216.612	0.031
35	216.281	216.28	0.001
36	216.088	216.09	-0.002
37	215.845	215.807	0.038
38	216.011	216.006	0.005
39	215.482	215.491	-0.009

40	216.771	216.735	0.036
41	215.934	215.932	0.002
42	216.38	216.379	0.001
43	216.449	216.443	0.006

Table 4: Statistical values for elevation difference of detailed points Total station and Spirit level.

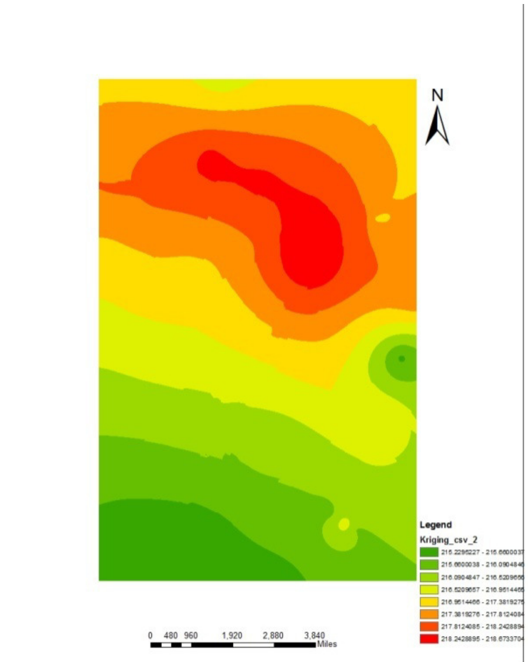
	Elevations (m)
Minimum	0.000
Maximum	0.139
SUM	0.178
Mean	0.00414
SD	0.045233
RMSE	0.000915

Table 5: Descriptive statistics

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Total Station	43	215.23	218.68	2.1686E2	0.88832
Spirit Level	43	215.22	218.69	2.1685E2	0.90652
n	43				

Table 6: Time expenditure for Total Station and spirit level

	Time Expenditure (min)	
	Total station	Spirit level
Preparation	20	20
Tripod setup	2	2
Centering	5	2
Heights measurement	62	78
Total	**89**	**102**



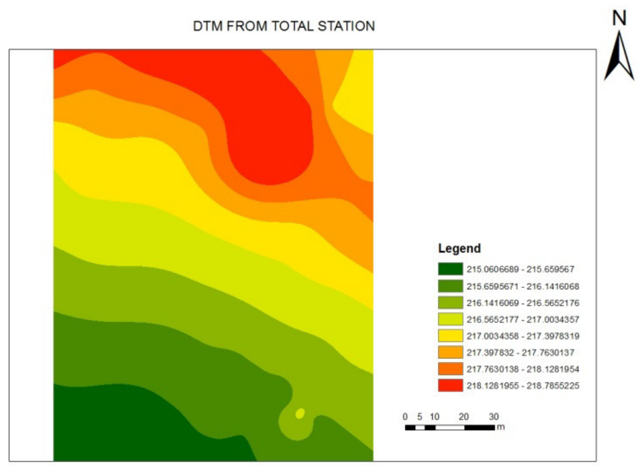


Figure 2: DTM generated from Spirit level dataFigure 3: DTM generated from total station data

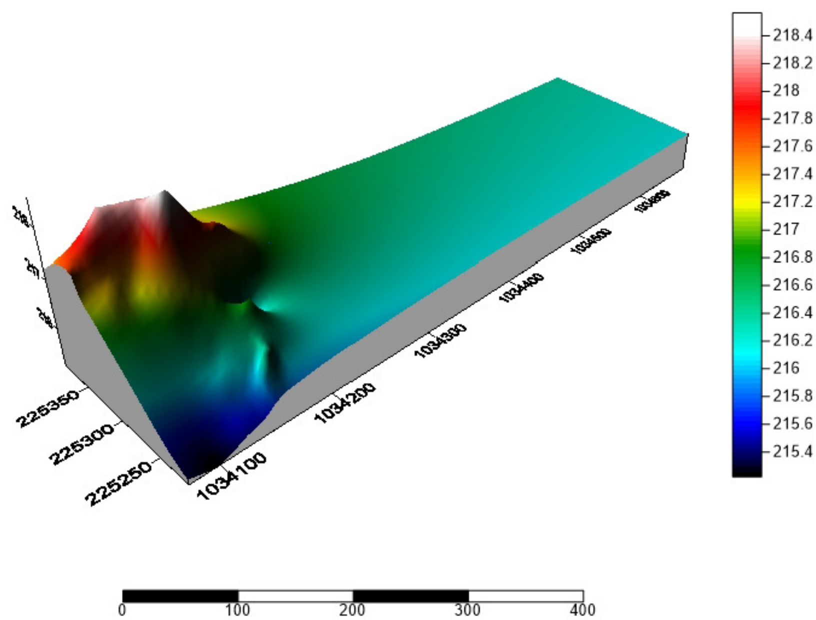


Figure 43D surface from Total Station

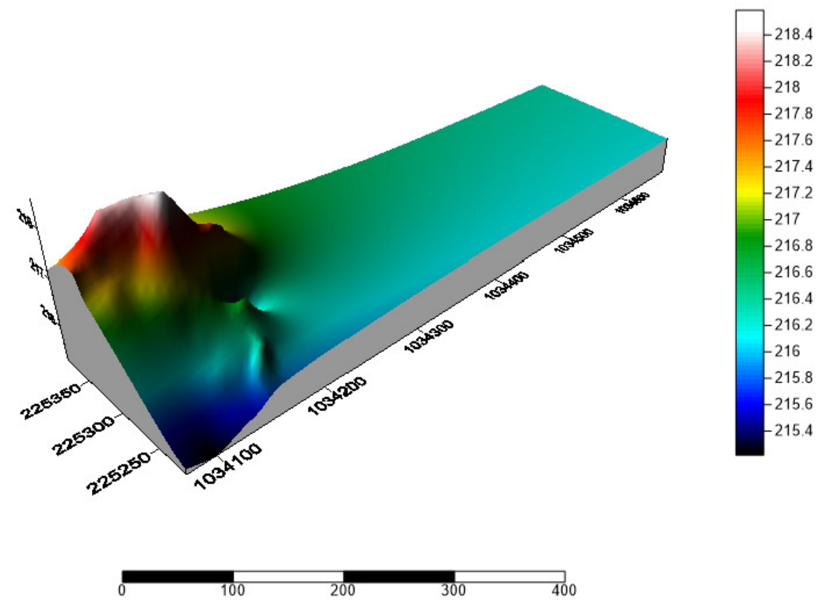


Figure 5: 3D surface from Spirit Level

V. ANALYSIS AND DISCUSSION OF RESULT

From the results obtained above, the total station observations gave a better accuracy with a minimum standard deviation of 0.888 compared to a sprit level observations which gave a standard deviation of 0.907. Thus, by comparing elevation obtained by both survey instruments, their measurement accuracy having been verified, it can be concluded that the measurements were accurate for a medium class project.The results from this study have confirmed the investigation of Julius, 2018 in comparing digital level and total station in Tanzania.It can also be deduced from figures 2 and 3 above, a close resemblance of the raster cells containing elevation values ranging from 215-216.5652. However, a clear discrepancy is shown in the remaining raster cells of the two instruments. This from the researchers' perspective is due to the heterogeneous nature of data generated from the two instruments at some points. The 3D surfaces show a clearer relatable model which infers that both instruments can be used for DEM creation.

In order to compare the cost (time expenditure) by using both survey instruments, effective time has been recorded throughout the measurement in sample. Effective time refers to the time needed to measure the required tasks without taking in to considering the delayed time due to unforeseen problems, effective time did not include the time for transportation of the instrument home base to field and vice versa or delayed time due to problems such as battery/power issues or incorrect readings. As indicated in Table 6, preparation time between Total station and spirit level was same. Each private company usually has its own internal expected preparation time and anticipated duration for preparation. Preparation in general terms includes scanning of the area by the team for a better understanding as to what method should be used, preparing the stocked pegs and other supporting equipment for the project. Tripod setup and centering for TS was the time expended for three setups of tripod in four sets of measurements. Thus, the required total time with TS was 89 minutes (1 hour 29 minutes). While the total time with spirit level is 102 minutes (1 hour 42 minutes). This shows that using total station for topographic project is more efficient than using spirit level- up to 7% faster. Moreover, to conduct this project using TS needs less team members (10% more efficient) compared with spirit level with 3 or 5 team members.

VI. SUMMARY:

This study is concerned with a comparison between total station and spirit level in generating Digital Terrain Model (DTM). The main concern is to assess the performance of total station instrument and digital spirit levels in executing levelling for DTM generation, vertical control in topographic surveys and for route engineering projects. The levelling operation was done and X,Y,Z coordinates of the same points was obtained using total station instrument. The spirit level heights were reduced using rise and fall method in order to obtain the reduced levels of the established stations. Descriptive statistic was adopted in comparing the two instruments. Total station gave a minimum height of 215.23m, and a maximum of 218.68m, while Spirit Level gave a minimum height of 215.22m and a maximum of 218.69m, this indicates that both instruments gave a very close results hence both total station and spirit level can be used in executing levelling for DTM, however, statistically, the total station observations gave a better accuracy with a minimum standard deviation of 0.888 compared to a sprit level observations which gave a standard deviation of 0.907. Thus, by comparing elevation obtained by both survey instruments, their measurement accuracy having been verified, it can be concluded that the measurements were accurate for a medium class project DTM.

Time expenditure between total station and spirit level was also compared, the required total time to acquire data with TS was 89 minutes (1 hour 29 minutes), while the total time expended to acquire data with spirit level is 102 minutes (1 hour 42 minutes). This shows that using total station for topographic project is more efficient than using spirit level- up to 7% faster. Moreover, using TS needs less team members (10% more efficient) compared with spirit level with 3 to 5 team members.

VII. CONCLUSIONS

From the results obtained it is concluded that the study was done according to both total station leveling and spirit leveling procedures which has fulfilled the objective of the research. The mean, standard deviation and root mean square error of the difference between the two data sets are0.00414, 0.045233 and0.000915 respectively. Therefore both instruments i.e. total station and spirit level can be used in executing leveling for DTM control in topographic surveys and for route engineering projects.Referring to the tables of the analysis of the results, spirit level instrument is less precise than total station because it has maximum standard deviation. The main advantage of total station compared to spirit level is it's faster in data capture, shorter time and safer means of data processing and the ability of data storage and retrieval electronically, also the telescope can be tilted to sight a point which the spirit level lacks.

VIII. RECOMMENDATIONS

Based on the resultsobtained and the analysis made I hereby made recommendations as follows;

i. The results obtained is a good start in comparing the total station levelling and Spirit leveling for generating DTM. Thus, further researches be carried out on a larger area in order to check the accumulation of errors.

ii. If one has a choice to use either one of the instruments for generating DTM and provision of control points in engineering surveys, the total station should be preferred as it is more precise and faster.

iii. Survey organizations should be encouraged to use total station for generating DTM as it is more automated, thus reducing chances of making blunders (gross errors) that might occur during spirit leveling process.

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