Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 4(2): 156-161
© Scholarlink Research Institute Journals, 2013 (ISSN: 2141-7016)
jeteas.scholarlinkresearch.org

Satlevel Collocation Model for Production of Contour Map of Yanbu Industrial City, Saudi Arabia

[1,2]K. F. Aleem

[1]Department of Geomatics Engineering Technology,
Yanbu Industrial College, Yanbu Industrial City, Saudi Arabia.

[2]Surveying and Geoinformatics Programme,
Abubakar Tafawa Balewa University, Bauchi Nigeria.

Abstract
Contour map serves a lot of purposes to the map users as it's depict the three dimensional configuration of the area under study. Data acquisition for the production of such maps has been tedious, expensive and time consuming. There is need for simple and quick method of producing these maps. "Satlevel" Collocation is a method of geoid determination in which the ellipsoidal height from any satellite based system is combined with orthometric height from geodetic levelling to model the geoid. Geoid determinations using integration of geodetic levelling and Global Navigation Satellite System (GNSS), which enables the geoid to be determined in patches, are taking over from the empirical geoid determination. Geoid so determined can be applied with ellipsoidal height to get orthometric height which height users always prefer. The Orthometric height can then be used for production of contour map. In this work, "Satlevel" Collocation model along with the user's interactive computer program "Orthometric Height on Fly", were used to generate orthometric heights in Yanbu Industrial city. The generated data was used to produce the contour map of the study area using SURFER software. This method enables production of contour map from "Satlevel" Collocation predicted orthometric height from GNSS observations without going through all the processes of data acquisition by levelling, when the initial geoidal coefficients have been determined. There is no significant difference between the new map and the one from the acquired data. This method can be extended to other parts of Saudi Arabia and the world at large.

Keywords: contour map, geoid, "satlevel" Collocation and SURFER.

INTRODUCTION

A contour map is made up of contour lines and depicts the configuration of any portion of the earth surface. A contour line is an imaginary line drawn on the map to connect points with the same elevation or height on, above or below the earth surface. Historically, Different types of maps were produced for the Kingdom by the foreign agencies, educational institutions and governments. The maps includes but not limited to the following:

Historical city maps of Mecca, Al-Madinah and Riyadh from Western Arabia and the Red Sea were produced by the Naval Intelligence Division of the Great Britain in 1946; while those of Dhahran, Jeddah and Riyadh were produced by the United States of America (U.S) Department of State 1983 and 1986. Furthermore, the shaded relief map of Saudi Arabia was produced in 1974, reviewed in 1991 and 2003 by the United States Central Intelligence Agency (CIA). Thematic map from CIA Atlas of the Middle East was produced in 1993. Topographical maps which include contour were produced as part of Operation Navigational chart series by U.S. Defence Mapping Agency Aerospace Centre. In the recent time, U.S. National Imagery and Mapping Agency have produced the topographical maps of Saudi Arabia in a scale of 1:250,000 (PCL, 2012).

Presently, the Ministry of Municipal and Rural Affairs (MOMRA) is currently handling mapping and mapping related activities in the Kingdom (Bariz, 2012). MOMRA has concluded the production of geodetic controls for the whole Kingdom. Apart from production of controls and maps in different scales for the Kingdom, different maps were produced depending on the need and purposes by agencies such as the General Commission for Survey (GCS). King Abdulaziz City for Science and Technology (KACST), Saudi Geological Survey, Companies like the Saudi Aramco, Schlumpberger Consulting Engineers Inc., Educational Institutions such as King Saud University, King Abdulaziz University, Yanbu Industrial Colleges and others with Geomatics and Geospatial Information System (GIS) related disciplines.

In Yanbu Industrial City, the Urban Planning Department of the Royal Commission for Jubail and

yanbu, Royal Commission at Yanbu is currently handling all issues of Survey and mapping under the Survey section that comprises of CAD (Computer Assisted Drafting) and GIS (Geographic Information System) sections. The Department produces different types of maps, which include topographical map that contained the contours either as a direct labour or contracts to reputable mapping companies.

The contour maps, like most complex ones, are designed using index contours. Contour lines are shown in brown colour with the value of height written on it. The height is typical measured with reference to a known Datum. The datum usually adopted is the geoid, because of its relationship with ocean which is available worldwide making it to be natural (Aleem, 2011; Williams, 2012 & Aleem, 2013).

The geoid is the surface which coincides with that surface to which the oceans would conform over the entire earth, if free to adjust to the combined effect of the earth's mass attraction (gravitation) and the centrifugal force of the Earth's rotation. Specifically, it is an equipotential surface, meaning that it is a surface on which the gravitational potential energy has the same value everywhere with respect to gravity. The geoid surface is irregular, but considerably smoother than earth's physical surface. Sea level, if undisturbed by tides, currents and weather, would assume a surface equal to the geoid when the observation is carried out for a numbers of years, usually 18.61years.

Determination of the geoid has been one of major challenges of geodesists. Gravity data have been used in the past with stokes integration and other approaches. These methods are time consuming, expensive and laborious. GNSS provide WGS‟84 ellipsoidal heights and when compared with orthometric height, from geodetic levelling, allows for the computation of the geoid, or the geoid-ellipsoid separation in the region of the survey (Aleem, 1996; Olaleye et al, 2010; Aleem et al, 2011). These height differences were used to derive the geoidal models called “Satlevel” collocation model (Aleem, 2013).

The geoid model will give geoidal undulation at every point of observation. This can be substituted with the ellipsoidal height from GNSS observation to get the orthometric height has given in Equation 1:

$$H = h - N \quad (1)$$

Where:

H = Orthometric height
h = Ellipsoidal height
N = geoidal undulation

From the above Equation 1 orthometric height can be computed, which can be plotted on the map as spot heights. The spot heights can be interpolated to produce the contours.

Interpolation of Contour

Interpolations of contours are often done by rough estimate. The procedure is to first plot all the available spot heights on the map and estimate the point for the contour. However, a more accurate but time consuming method used to be adopted is to use the formula (Aleem, 2011):

$$PC = \frac{D}{Z} i \quad (2)$$

Where:

PC is distance to the point of contour
D is the distance between two spot heights
Z is the difference between the two spot heights
i is the difference between the contour and one of the Spot heights.

Distance PC will then be scaled and marked on the map, which are later connected to form the contour.

SIGNIFICANCE

Contour maps are effective for displaying the landscape of a space. Contour lines that are spaced closer together show a very steep landscape. In contrast, those contour lines spaced farther apart identify a landscape that is flatter with a gentler slope. In addition, valleys are shows with upward V curved lines and ridges are depicted with downward V lines. Therefore, “contour lines bring together on a map physical dimensions such as mountains, sea and elevated ground levels” (Boehike 2012) This study is significant because its reduces the rigour of data acquisition each time the contour map of the area is to be produced, when the geoidal coefficients have been determined. The use of software developed by the author “orthometric height on fly” will enhance the productivity.

CONTOUR MAP SOFTWARE

There are different types of software in the market for production of contour, digital terrain and three dimensional surface model of any part of the world. This study used Surfer software.

Surfer: Surfer is a contouring and 3D surface mapping software package from Golden Software Incorporation can transform random surveying data, using interpolation, into continuous curved face contours. Surfer’s sophisticated interpolation engine transforms your XYZ data into publication-quality maps. It is provided with eighteen different gridding/trend surface algorithms. The methods were grouped into smoothing and exact interpolators. Smoothing interpolators are: Inverse Distance to a Power, Kriging, Polynomial Regression, Radial Basis Function, Modified Shepard's Method, Local Polynomial, Moving Average; while the exact interpolators are: Inverse Distance to a Power, Kriging, Nearest Neighbour, Radial Basis Function, Modified Shepard's Method, Triangulation with Linear Interpolation, and Natural Neighbour. Any of

these interpolation methods can be used to approximate the geoid in an area, if adequate data are available. Surfer provides more gridding methods and more control over gridding parameters. Recent edition has added conversion and combination of maps with different coordinate systems (Golden Software, 2012 and Aleem, 2013).

3DField: 3DField is a contouring surface plotting and 3D data program that runs under Microsoft Windows NT/XP/Vista/7. 3DField converts the data into contour maps and surface plots. It creates a 3D map or a contour chart from the scattered points, numerical arrays or other data set. All aspects of 2D or 3D maps can be customized to produce the exact presentation desired (Galouchko, 2012).

Other Contour Map Software: Other Contour Map Software includes: Garmin Baseman, mapviewer, Contour storyteller, Function Grapher, Auto plotter, Visual data, Filter test, AutoDEM Li Contour and several other software are available for production of contour map. Any of these software can also be used for the production of Contour map of the study area.

STATEMENT OF PROBLEM

Obtaining orthometric height data for production of contour map with existing method of geodetic levelling is time consuming, expensive and difficult in some terrains. Data acquisition for orthometric height is labour intensive over long distances and the field procedures are tedious and prone to human and other errors. This research provides alternative and simple method of obtaining orthometric height for production of contour map with the use of geodetic coordinates from Global Positioning System.

AIMS AND OBJECTIVES

The aim is to produce contour map of the study area from data generated using "Satlevel" Collocation Model and Surfer software.

The objectives are:

1. To acquire data for ellipsoidal and orthometric heights of the study area.
2. To compute geoidal coefficients of the "Satlevel" Collocation Model in the study area using Least squares adjustment.
3. To generate data for production of contour map from GNSS observation.
4. To plot the contour map of the study area using surfer software.

SCOPE AND LIMITATIONS OF THE STUDY

The following are the limitations of this research**:**

1. Automatic level was used to obtain orthometric height as against the use of digital or geodetic level.
2. The readings were taken to 3 places of decimal as against 5 places of decimal required by specification for geodetic levelling.
3. Since the study area is a coastal city, the orthometric correction was assumed to be negligible and therefore neglected.
4. Outliers were not removed from the observations.

THE STUDY AREA

The study was carried out in Yanbu Industrial City (popularly known as 'Yanbu Al-Sina'iya' in Arabic which literarily means Industrial Yanbu) in Madina Province of Saudi Arabia. The city was established around 1975, located on the Coast of Red Sea about 350km North of Jeddah. The geodetic coordinates of a point in the city are as follows: Latitude $23^0$59'57.840"N (23.9994) and longitude $38^0$13'39.000"E (38.2275)

Figure 1: Map of Saudi Arabia showing the location of Yanbu Industrial city

Yanbu Industrial City has a section called the Royal Commission (RC). Its residents are mostly expatriates mostly from Europe, America, and other Western Countries. RC Yanbu Existing Area is about 185 km² and the expansion Area is about 420 km². The industrial developed land is estimated to be 3240 Hectares (RCJY, 2012).

Figure 2: The Existing and land use Map of Yanbu Industrial City. Source: RCJY (2012)

The presence of industries such as the oil refineries, plastics facility and several other petrochemical plants in the existing and expansion of Yanbu Industrial City will require detailed map and updating of the existing map of which contours have a prominent role to play. Contour maps will also enhance monitoring of the existing structures. Therefore, a quick and fast method such the use of "Satlevel" collocation model will minimise the rigour of data collection of the existing method.

METHODOLOGY

Materials and Data

The equipment needed for the exercise are:
GNSS receiver and its accessories to acquire data for ellipsoidal height
Level and its accessories to acquire data for orthometric height
Computer and its accessories for computation and analysis
Surfer software for plotting the contour
Any software or program that can be used to implement least square adjustment.

In this exercise Microsoft Office excel was used for all computations, However Aleem, (2013) has developed computer program for all the procedures "Orthometric Height on Fly" which was used to validate the results.

Data Acquisition

Levelling operation was carried out to obtain data for orthometric height while more data were collected from the survey section of Urban department of Royal Commission. Data for a total of six hundred and thirty (630) points were covered.
GNSS observation was carried out to acquire data for geodetic coordinates which includes the geodetic latitude, geodetic longitude and ellipsoidal height.
Other relevant data such constant for the referenced ellipsoid were collected from various literatures and INTERNET websites for data analysis and processing.

Data Processing

Levelling reduction was done; the reduced levels were assumed to be the orthometric height of each of the points. GNSS observation was processed to get the three dimensional coordinates. These are the geodetic latitude (ϕ), geodetic longitude (λ) and ellipsoidal height (h), which were used in "Satevel" collocation model.

"Satlevel" Collocation Model

"Satlevel" Collocation model was developed by Aleem, (2013), who gave the detailed explanation of the derivation. The model is of the form:

$$N_i = N_L + A_1\left(\cos^3\phi_i\cos\lambda_i + \sin^2\phi_i\cos\phi_i\cos\lambda_i + \cos^3\lambda_i\cos\phi_i + \sin^2\lambda_i\cos\phi_i\cos\lambda\right) + A_2\left(\cos^3\phi_i\sin\lambda_i + \sin^2\phi_i\cos\phi_i\sin\lambda_i + \cos^2\lambda_i\cos\phi_i\sin\lambda_i + \sin^3\lambda_i\cos\phi_i\right) + A_3\left(\cos^2\phi_i\sin\phi_i + \sin^3\phi_i + \cos^2\lambda_i\sin\phi_i + \sin^2\lambda_i\sin\phi_i\right) + r_i \quad (3$$

Where:

N_L is the long wavelength part of the geoid undulation in the area.

A_1, A_2 and A_3 are the geoidal coefficients which are unknown coefficients to be determined.

ϕ and λ are the WGS '84 geodetic coordinates (Latitudes and Longitudes)

r_i is residue at an observation point.

One hundred and fifteen (115) points were randomly selected and used to obtain the "Satlevel" Collocation geodal coefficients of the study area. The "Satlevel" collocation geoidal coefficients of the area were computed using least squares adjustment observation equation method. The "satlevel" collocation model geoidal coefficients were used to compute the geoidal undulation of each point in the area, which were connected to get the geoidal surface.

The geoidal undulations and Ellipsoidal heights obtained from the result of GNSS observations were used in Equation 1 to get the "Satlevel Collocation orthometric height of the area.

The orthometric heights generated from "Satlevel" collocation model and the geodetic coordinates of the area were plotted into contour map using Surfer software. The orthometric heights acquired using geodetic levelling method and the geodetic coordinates of the area were plotted into contour map using Surfer software.

RESULTS AND DISCUSSIONS

The data used for this research were used to plot chart (Figure 3):

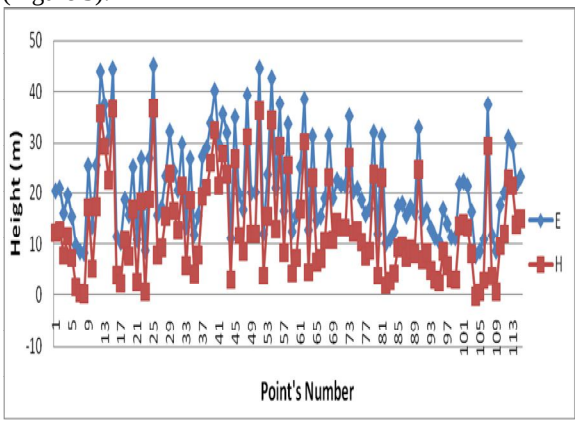


Figure 3: Orthometric and Ellipsoidal Heights of part of Yanbu Industrial City

The values of the geoidal coefficients computed using least square adjustment observation equation method as follows:

N_L=7.85995128
A_1=0.36447485
A_2=-0.5309024
A_3=0.15167311

The results of the "satlevel" collocation geoidal undulations were plotted into chart to form the geoidal surface (Figure 4):

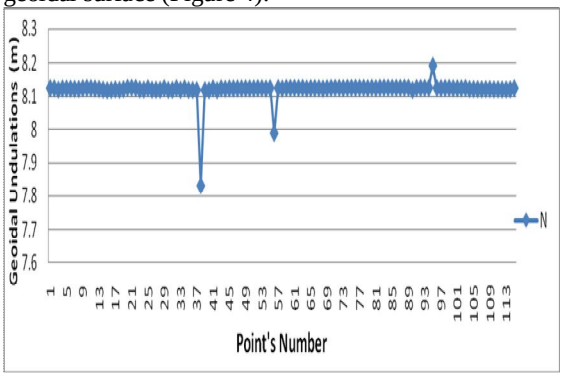


Figure 4: Geoidal Surface of parts of Yanbu Industrial City

The results of the "satlevel" collocation orthometric height were plotted into chart (Figure 5):

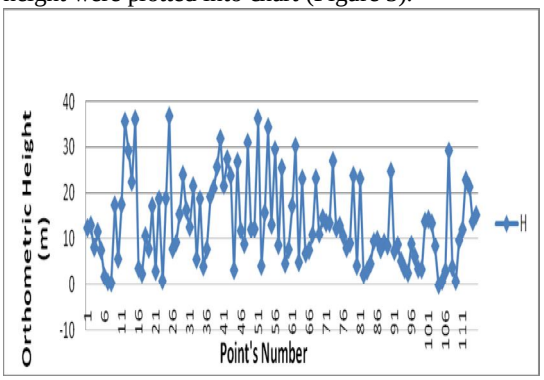


Figure 5: Orthometric Heights of parts of Yanbu Industrial city

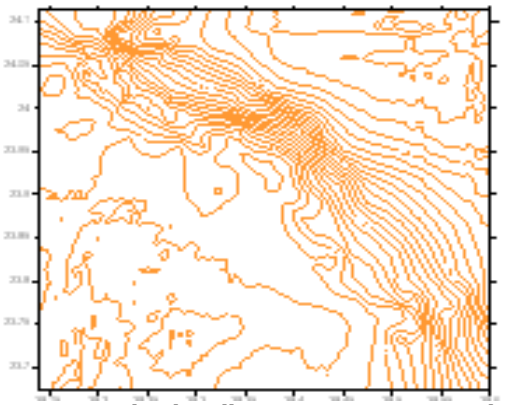
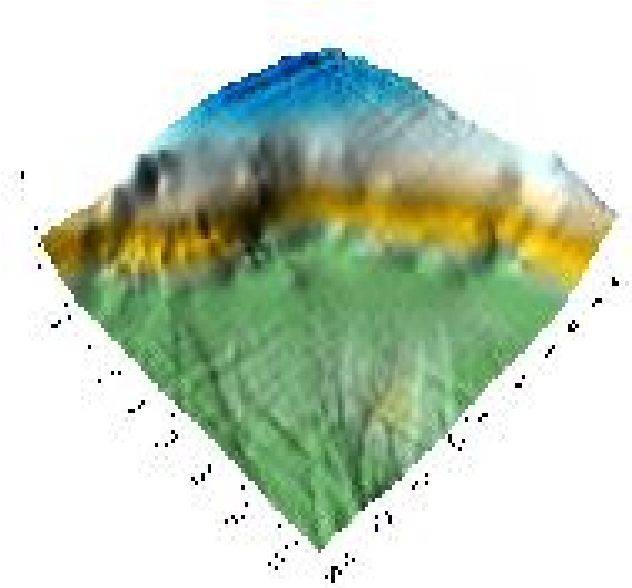


Figure 6: "Satlevel" collocation Contour Map and 3D Surface Model of parts of Yanbu Industrial City



The contour map from levelling method (Figure 7)

DISCUSSIONS

One of the components of GPS geodetic coordinates is the ellipsoidal. The processed results of the geodetic levelling were used as the orthometric height without the application of orthometric correction. Orthometric Height Correction is the small correction needed to be applied to the observed elevation difference along a given line of précised levelling so as to get the orthometric height. It is a function of gravity and related to latitude, longitude and height of any chosen point. Hence it should be computed and applied to get the geopotential number that is equal in a particular locality. The popular notion is that orthometric correction is very small especially in low elevation area and it is always neglected. (Heiskanen and Moritz 1967; Aleem. 2013): since Yanbu Industrial City is a coastal city, the correction is equally assumed to be small and therefore neglected.

In this chart shown in Figure 3, ellipsoidal and orthometric height of the selected 115 points follow the same pattern is an indication that the two are true representation of the same terrain.

Figure 4 shows the geoidal surface of Yanbu Industrial City. In this chart, the geoidal Undulations of 3 of the points were outrageous, which is an indication that there were presences of outliers in the observations. These observations which were more than 3 standard deviations were removed to produce a smoother geoidal surface (Heliani et al, 2004). The selected 115 points were used to generate the geoidal coefficients, using least squares observation equation method. These geoidal coefficients were used to compute the "satlevel" geoidal undulation for each of the 630 points. The "satlevel" geoidal undulations

were applied in Equation 1 to get the "satlevel" orthometric heights. The satlevel orthometric and acquired orthometric heights were used to produce the contour map and 3D surface modelling of the area (Figures 6 and 7 respectively)

CONCLUSION AND RECOMMENDATION

CONCLUSION

In this study, levelled heights were established along with GPS observation in some parts of Yanbu Industrial city to model the geoid in the study area. We have coordinated some of the points collocated with both GNSS and levelling in the area. 'Satlevel" Collocation Model was used to obtain the geoidal coefficients, which were used to compute the geoidal undulation for each of the points. Ellipsoidal heights from GNSS observation were used to calculate the orthometric heights, and used to plot the contour with surfer software. The map compared favourably with the one plotted from the acquired data using the conventional levelling procedures.

RECOMMENDATIONS

The area of coverage needs to be extended and more data should be acquired to improve the results**.**

Contracts for the production of maps should be awarded to the Institutions of Higher learning in the Kingdom. This will enable the participating staff to acquire more experience, so as to improve the qualities of graduates for future challenges.

A local geoid model for Saudi Arabia is hereby recommended to commence.

REFERENCES

Aleem, K. F. 1996. GPS and Remote Sensing of Environment, The Graduate Surveyors. Journal of NISS University of Nigeria, Enugu Campus. 12: (1) 24 – 29

Aleem, K. F. 2011. Drafting and Mapping (GET 102), Lecture Notes, Department of Geomatics Engineering Technologies, Yanbu Industrial College, Kingdom of Saudi Arabia. UNPUBLISHED.

Aleem, K. F. 2013. Adaptation of a Global Orthometric to a Local Height Datum Using "Satlevel" Collocation Model". A PhD Thesis, University of Lagos. Nigeria.

Aleem, K. F., J. B. Olaleye, O. T. Badejo and J. O. Olusina 2011. A Combination of Ellipsoidal Height from Satellite Method and Orthometric Height for Geoid Modelling. publication of the International Global Navigation Satellites Society IGNSS . http://ignss.org/Conferences/PastPapers/2011ConferencePastPapers/2011PeerReviewedPapers/tabid/108/Default.aspx

Baris Uz 2012. MOMRA Mapping Reference Framework. Geo tech Briefly. GeoTech Quarterly Volume 1 Issue 1 http://www.ags-group.com/gq/v1i1/?f=Z2VvdGVjaGJyaWVmbHlhLnBocA==

Boehlke J. 2012. What Do Topographic Maps Show? Online Article accessed on the 12th November, 2012 http://www.ehow.com/about_4614538_what-do-topographic-maps-show.html

Galouchko V. 2012. Contour Map Software 3DField http://field.hypermart.net/

Golden Software, Inc 2012. "Surfer 11: Powerful Contouring, Gridding, and 3D Surface Mapping Software for Scientists and Engineers". Online Article 12 November 2012 http://www.goldensoftware.com/products/surfer/surfer.shtml

Heliani, L. S., Y. Fukuda, and S. Takemoto 2004. Simulation of the Indonesian Land Gravity Data using a Digital Terrain Model Data, Earth Planets Space Journal, 56(1): 15–24

Heiskanen, W.A., and H. Moritz. 1967. Physical geodesy. San Francisco, California: W.H. Freeman and Co.

Olaleye, J. B., K. F. Aleem, J. O. Olusina and O. E. Abiodun 2010. Establishment of an Empirical Geoid Model for a small Geographic Area: A case study of Port Harcourt, Nigeria, Surveying and Land Information Science. 70(1): 39-48 http://www.ingentaconnect.com/content/nsps/salis/2010/ 00000070/00000001/art00006

Perry-Castañeda Library (PCL) 2012. Map Collection. University of Texas. http://www.lib.utexas.edu/maps/saudi_arabia.html

Royal Commission for Jubail and Yanbu (RCJY), Royal Commission at Yanbu 2012. Annual Report of the Strategic Planning & Investment Development Division Economic Planning Department. https://eservices.rcyanbu.gov.sa/Doc/YanbuIndustrialCityEconomicReview.pdf

Williams N. A., 2012. What Does a Contour Map Show? | eHow.com Online Article accessed on the 12th October, 2012 http://www.ehow.com/about_5465398_contour-map-show.html#ixzz2Can9xwzp