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ELD79-LGD2006 Transformation Techniques Implementation and Accuracy Comparison in Tripoli Area, Libya

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Abstract**—**During the last decade, Libya established a new Geodetic Datum called Libyan Geodetic Datum 2006 (LGD 2006) by using GPS, whereas the ground traversing method was used to establish the last Libyan datum which was called the Europe Libyan Datum 79 (ELD79). The current research paper introduces ELD79 to LGD2006 coordinate transformation technique, the accurate comparison of transformation between multiple regression equations and the three – parameters model (Bursa-Wolf). The results had been obtained show that the overall accuracy of stepwise multi regression equations is better than that can be determined by using Bursa-Wolf transformation model.

Keywords**—**Geodetic datum, horizontal control points, traditional similarity transformation model, unconventional transformation techniques.

I. Introduction

THE first datum of Libya, defined for geodetic network and mapping, is ELD79 based on Hayford International Ellipsoid 1924 (a = 6378388, f =1/297). In the1980's, Libya established Doppler network, which was initially defined in the WGS-72 datum and then in the International Terrestrial Reference Frame 2000 (ITRF00) datum.

Later, Surveying Department of Libya SDL introduced LGD2006, again based on Hayford International ellipsoid 1924 (a = 6378388, f = 1/297), for this purpose some of 61 stations were GPS surveyed in 2006 and tied to IGS stations (Epoch: 2006.3822). Thus, precise coordination, were determined in the ITRF00 datum, based on GRS80 ellipsoid (a=6378137.0 m, f=1/298.25722101) [8]. Libya's datum information is illustrated in Table I. Fig. 1 shows the distribution of the first order control points [8] (the main geodetic control points in LGD2006 datum). The issue of datum transformation of control points, coordination of the old geodetic datum ELD79 to the new geodetic datum LGD2006, is a crucial dilemma. The transformation will help GPS users to utilize with the ELD79 control points for their works. Also it can transfer almost of the surveying works e.g. maps which made before 2006 from old datum to new one. The origin of one coordination system is assumed to be offset from the other, the axes of one coordinate system are assumed to be parallel with respect to the other, and the two systems are assumed to have no different scales.

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The most widely used traditional methods are Bursa-Wolf and Molodensky-Badekas transformations. Regarding these traditional methods, it is impossible to make uniform transformation for the whole area of the country because the attainable accuracy is not sufficient [6]. Furthermore, the traditional methods do not take into account the systematic errors existing in the national geodetic networks [2]. With Multiple Regression Equations better results could be obtained.

TABLE I
Libyan Horizontal and Vertical Datum

Datum type	Name	Description	Reference
Horizontal datum	ELD79/LG D2006	Haford international 1924 a=6378388,f=1/297	SDL Datum report
Vertical Datum		Mean Sea Level of Mediterranean Sea (MSL)	SDL Datum report
Horizontal Datum	ITRF00	GRS80 (a=6378137, f=1/298.25722101)	SDL Datum report
Vertical Datum		Mean Sea Level of Mediterranean Sea (MSL)	SDL Datum report

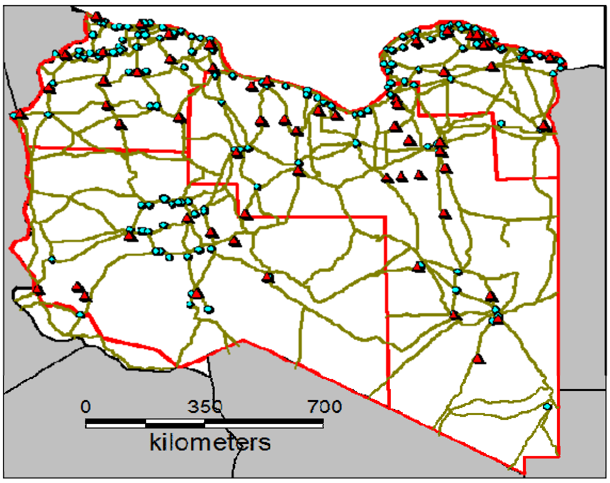

Fig. 1 The main geodetic control points in LGD2006

II. Datum Transformation Techniques

A. Traditional Similarity Transformation Model

There are several transformation models such as Bursa-Wolf, Molodensky-Badekas, Veis Model, Thomson-Krakiwsky Model, Helmert Similarity Transformation and

Affine transformation. They are also called similarity or seven-parameter transformations. Each of these models could be used to determine parameters necessary to convert data in a geodetic datum into another datum and vice versa.

Generally, the similarity transformation model is based on 7 parameter; three translation parameters (dx, dy, and dz), three rotation parameters (ωx, ωy, and ωz), and a parameter (s) for the scale difference between two systems. Three –parameters Bursa-Wolf model [5], [3] are used in this research because the relationship between LGD2006 and ELD79 is based on 3 parameters (dx, dy, and dz). This model simply applies three-dimensional origin shift, with little regard to any scale changes or rotations. Therefore, it is coarse, but also extremely simple to implement. The Cartesian coordination of the initial datum are simply added to the origin shift, and then converted to curvilinear coordinates on the new datum. In vector form, this can be as follows [9]:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_W = \begin{bmatrix} X_0 \\ Y_0 \\ Z_0 \end{bmatrix} + \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_A \tag{1}$$

B. Unconventional Transformation Techniques

The stepwise multiple regression technique [4] is the other technique used to determine the transformation parameters between ELD79 datum and LGD200 datum. This technique is based on modeling the differences Δϕ, Δ λ and Δh between two geodetic systems.

The general form of the stepwise multiple regression equation for datum transformation is [1]:

$$\Delta\phi = A_0 + A_1\phi + a_2\lambda + A_3\phi_2 + A_4\phi\lambda + A_5\lambda_2 + \cdots + A_{99}\phi_9\lambda_9 \tag{2}$$

where:

$A_0, A_1, \ldots, A_{99}$ = coefficients determined in the development
ϕ, λ = geodetic latitude and geodetic longitude (in degrees), Respectively, of the computation point

Similar equations are obtained for Δλ and Δh by replacing Δϕ in the left portion of (2) by Δλ and Δh, respectively.

The first step of the procedure produces a constant and a variable. The procedure then sequentially adds one variable at a time to the equation and the variable that provides the greatest improvement in fitting the coordinate difference. After a variable had been added, all variables previously incorporated into the equation are tested , if one is no longer significant, it is removed. Each addition or removal of a variable is called a "step". This stepwise addition or removal of variables ensures that only significant variables are retained in the final equation.

III. Data Used and Results

Precise geodetic coordinates of 30 first-order geodetic stations known in both ELD79 and LGD2006 geodetic datum , (all these 30 first-order geodetic stations known are located in zone 7 ,which extend from 12°E to 14°E) ,have been used in this investigation and four stations have been considered as check points , that haven't been used in the processing stage. These coordinates are the most accurate database available in Surveying Department of Libya SDL for this zone. The following are the results obtained by using two methods, three-parameters Bursa-Wolf model and stepwise multiple regression equations.

A. Results of the Three –Parameters (Bursa-Wolf) Model

The final results by using the first method of transformation technique (the three-parameter) Bursa-Wolf model for ELD79-LGD2006 transformation are:

$$\Delta X = +\,94.2048 \tag{3}$$

$$\Delta Y = +\,11.4361 \tag{4}$$

$$\Delta Z = -\,149.582 \tag{5}$$

B. Results of Stepwise Multiple Regression Technique

The final stepwise multiple regression formulas for transforming coordinates from the ELD79 to the LGD2006 system, (formula for Δh is excluded in this research) are:

$$\Delta\phi'' = 6.255 + 3.532E^{-17}\lambda_{79}^{13} - 8.091E^{-21}\phi_{79}^{13} - 7.187E^{-5}\phi_{79}^{2}\lambda_{79} + 1.831E^{-15}\phi_{79}^{9}\lambda_{79} - 7.088E^{-21}\phi^{12}\lambda \tag{6}$$

$$\Delta\lambda'' = -0.060698 + 2.719E^{-7}\phi_{79}^{2}\lambda_{79}^{3} - 7.503E^{-17}\phi_{79}^{5}\lambda_{79}^{7} \tag{7}$$

where Δϕ" and Δλ" are obtained in arc of seconds, while ϕ and λ are the ELD79 coordinates in degrees.

Substitute the values of Δϕ" and Δλ" From (6) and (7) in the next equations to LGD2006 Geographic coordinates (latitude and longitude). The equations are:

$$\phi_{LGD\ 2006} = \phi_{ELD\ 79} + \Delta\phi'' \tag{8}$$

$$\lambda_{LGD\ 2006} = \lambda_{ELD\ 79} + \Delta\lambda'' \tag{9}$$

IV. Comparison of Both Techniques

Four check points have been utilized to compare the validity of results which obtained from both transformation techniques. The coordinates of these stations have been computed through the final model for each technique , that are (three-parameter) Bursa-Wolf model and stepwise multiple regression approach. Then the transformed coordinates are be compared with the corresponding coordinates. The obtained results are presented in Tables II-V.

TABLE II
ACCURACY OF REGRESSION TECHNIQUE OVER CHECK POINTS

Station	ϕ " observed	ϕ " computed	Δ ϕ "(observed – computed)
1	14.32532	14.32545	-0.00013
2	2.39311	2.39649	-0.00338
3	21.3932	21.40995	-0.01675
4	47.38372	47.38908	-0.00536
Mean			0.006405
			0.1978 m

TABLE III
ACCURACY OF REGRESSION TECHNIQUE OVER CHECK POINTS

Station	λ " observed	λ " computed	Δλ"(observed – computed)
1	31.19265	31.20389	-0.01124
2	0.11685	0.12208	-0.00523
3	9.62358	9.61789	0.00569
4	20.61447	20.61293	0.00154
Mean			0.005925
			0.1830 m

TABLE IV
ACCURACY OF BURSA-WOLF MODEL OVER CHECK POINTS

Station	ϕ " observed	ϕ " computed	Δ ϕ "(observed – computed)
1	14.32532	14.32691	-0.00159
2	2.39311	2.39105	0.00206
3	21.3932	21.40546	-0.01226
4	47.38372	47.41510	-0.03138
Mean			0.0118225
			0.3651 m

TABLE V
ACCURACY OF BURSA-WOLF MODEL OVER CHECK POINTS

Station	λ " observed	λ " computed	Δλ"(observed – computed)
1	31.19265	31.21484	-0.02219
2	0.11685	0.1265	-0.00965
3	9.62358	9.60709	0.01649
4	20.61447	20.54543	0.06904
Mean			0.0293425
			0.9062 m

From Tables II and III, it can be seen that the overall accuracy of the developed multiple regression datum transformation technique is in the order of approximately 20cm in latitude and 7cm in longitude. Whereas the results obtained by using (three parameter) Bursa-Wolf model as illustrated in Table IV and V, show the accuracy found, is 33cm in latitude and 41cm in longitude. That means the developed multiple regression datum transformation technique is more accurate than the traditional similarity datum transformation technique. The reason for that is the disability of the similarity transformation models to represent the distortion existing in the old local geodetic networks. The same situation happens for several national and regional coordinate systems all over the world [1].

V. SURVEYING DEPARTMENT OF LIBYA TRANSFORMATION PARAMETERS

SDL utilized 29 control points over the country to produce transformation parameters between ELD79 and LGD2006 [7]. Those points have their coordinates in both datums.

For transformation parameters determination, the three-parameter Bursa-Wolf model has been used. The final transformation parameters are as follows:

$$\Delta X = +\,92.5515 \tag{10}$$

$$\Delta Y = +\,10.8194 \tag{11}$$

$$\Delta Z = -\,149.8852 \tag{12}$$

Using the same check points to compare the results that obtained from this study (only three-parameter Buras-Wolf model) and SDL transformation parameters, these results are presented in Table VI and VII.

TABLE VI
ACCURACY OF SDL TRANSFORMATION PARAMETERS OVER CHECK POINTS

Station	ϕ " observed	ϕ " computed	Δ ϕ "(observed – computed)
1	14.32532	14.34868	-0.02336
2	2.39311	2.41219	-0.01908
3	21.3932	21.42559	-0.03239
4	47.38372	47.43164	-0.04792
Mean			0.0306875
			0.9478 m

TABLE VII
ACCURACY OF SDL TRANSFORMATION PARAMETERS OVER CHECK POINTS

Station	λ " observed	λ " computed	Δ λ "(observed – computed)
1	31.19265	31.20602	-0.01337
2	0.11685	0.11749	-0.00064
3	9.62358	9.59761	0.02597
4	20.61447	20.53649	0.07798
Mean			0.02949
			0.9108 m

From Table VI and VII, it can be seen that the accuracy is less than that found in Table IV and V. It was 95cm in latitude ad 70cm in longitude. The reason is that SDL utilized only 29 points distributed over the whole country to produce the transformation parameters.

VI. CONCLUSION

The coordinate transformation from ELD79 to the LGD2006 is currently an important issue in Libya. The obtained results show that the accuracy of stepwise multiple regression technique is better than the accuracy of traditional transformation technique. Consequently, it is recommended to be applied by using all available geodetic station, with a national coverage, to come up with an accurate set of regression equations to transform ELD79 coordinates into LGD2006 coordinates system. Also the results obtained show that the SDL transformation parameters isn't accurate comparing with transformation parameters that obtained from this study.

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