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COORDINATE TRANSFORMATION FROM KARBALA 1979 AND WORLD GEODETIC SYSTEM 1984 TO IRAQI GEOSPATIAL REFERENCE SYSTEM

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Abstract: Nowadays, the transformation between coordinate systems is the major interested problems especially in Iraq. There are many coordinate systems used to produce maps and documentations due to different datums and spheroids. These coordinate systems are preferable to be unified in local countries. Thus, this paper deals with the transformation of coordinate systems of Karbala 1979 Polservice and World Geodetic System (WGS) 1984 to Iraqi Geospatial Reference System (IGRS). Accurate and well distributed control points are selected to cover the study area in Baghdad city, Iraq. Coordinate transformations are implemented using ArcGIS application mainly. Also, MATLAB software is used to convert geographic to map coordinates and vice versa by designing two MATLAB programs. The differences between the coordinate systems have been calculated. The results found that the discrepancies between Karbala 1979 Polservice and IGRS are about 278.6 m, -287.6 m, 0.01 second, and -11.2 second in northing, easting, latitude, and longitude, respectively. The WGS 1984 is superposed to IGRS and the distinction between them is negligible. The map coordinate differences between ArcGIS and MATLAB results are about -16 to 14 mm in northing and about -13 to 12 mm in easting, while the latitude and longitude differences are zero.

Keywords: *Coordinate Transformation, Datum, IGRS, Karbala 1979 Polservice, Spheroid, WGS 1984.*

1. Introduction

The geodetic networks in Iraq have been passed through different stages. The progression of these networks includes Nahrwan 1934, Nahrwan 1967, Karbala 1979 Polservice, and the modern geodetic network of Iraqi Geospatial Reference System (IGRS). Geodetic networks consist of many control points defined by a datum and a spheroid. Table 1 illustrates the geodetic datums and spheroids used in Iraq. A datum provides a frame of reference for measuring locations on the surface of the earth [1]. The geodetic networks of Nahrwan 1934 and Nahrwan 1967 which have been established by British are called the English networks. These networks are based on Clarke 1880 Royal Geographical Society (RGS) spheroid. All English networks as well as the gravity points are almost completely extinct [2]. The geodetic network of Karbala 1979 Polservice was established by Polish State Enterprise for geodesy and cartography based on Karbala 1979 Polservice datum and Clarke 1880 RGS spheroid. The Iraqi geodetic control networks established by British and Polish are

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limited, destroyed, and their data documentations are difficult to obtain.

The American Institution of National Geodetic Survey (NGS) developed the geodetic network in Iraq called the IGRS during the period between (2004) to (2005). The control surveys of IGRS are based on Global Positioning System (GPS). The default GPS observations are based on World Geodetic System 1984 (WGS 1984) datum and ellipsoid. Also, the WGS 1984 with Earth Gravitational Model (EGM 1996 or EGM 2008) is the vertical datum used in GPS receivers [3].

IGRS is a series of six GPS Continuously Operating Reference Stations (CORS) which are spread geographically throughout the Iraq country [4]. The origin of IGRS is the International Terrestrial Reference Frame (ITRF2000) at epoch (1997.0). The original IGRS established in 2005 comprised six CORS and sixty four High Accuracy Reference Network (HARN) points levelled in six southern provinces in Iraq [5]. Iraqi Ministry of Water Resource, State Commission on Survey installed seven CORS stations and continued establishing the HARN points for whole Iraq provinces [6]. HARN points have been established relative to the CORS network forming the IGRS control network [6]. HARN is like a first order survey control network, while IGRS is a three dimensional coordinate system.

Nevertheless, up to the current IGRS, which was established with the help of the US and British Armies, the geographic coordinate reference systems were two dimensional, i.e. they excluded height information [7]. In most works, the geographic coordinates are measured and then transformed to map coordinates [8]. Universal Transverse Mercator (UTM) map projection is used for obtaining map coordinates. Each UTM zone has a false northing in the northern hemisphere: (0 m) and a false easting for every zone: (500000 m) [9]. A translational shift must be applied to convert coordinates from one datum to another. This situation is further complicated because the horizontal shifts are different for graticule and grid coordinates [10].

Table 1. Geodetic datums and spheroids in Iraq

Datum	Spheroid
Nahrwan 1934	Clarke 1880 RGS
Nahrwan 1967	Clarke 1880 RGS
European 1950	International 1924
Karbala 1979 Polservice	Clarke 1880 RGS
WGS 1984	WGS 1984
IGRS	GRS 1980

2. Study Objective and Software Used

The main objective of this study is to convert the commonly used coordinate systems in Iraq (karbala 1979 Polservice and WGS 1984) to IGRS using ArcGIS Desktop 10.8, and then develop equations that can be used to convert the karbala 1979 Polservice geographic and map coordinate systems to IGRS and vice versa within the study area. The coordinate transformations are done with the Project tool in ArcGIS software. In addition, two MATLAB programs are built using MATLAB software version 7.8.0.347 (R2009a) to convert the geographic coordinates to map coordinates and vice versa. The satellite image and control points are obtained from google earth pro 7.1.8.3036 build date 2017.

3. Study Area and Data Collection

The study area is placed in Baghdad city along the river of Tigris in Iraq. It is expanded from (33° 10′ 50″ N) to (33° 26′ 40″ N) latitude and from (44° 08′ 00″ E) to (44° 36′ 50″ E) longitude. The study area has been chosen because Baghdad city is the capital of Iraq and it meets the requirement of the research that represented by the possibility of reconnaissance the locations of points in the field. Fig.1 shows the location of Baghdad city on the map of Iraq and exhibits Baghdad map as well as the chosen control points (CPs). The map scale on the computer display is (1:250000) as shown in Fig.1. Twenty control points are scattered and distributed covering the whole region. The original data of satellite image and control points have been obtained from the google earth pro. The coordinate system of these data is according to WGS 1984 datum and spheroid. This coordinate system has been modified to IGRS datum and GRS 1980 spheroid using ArcGIS application.

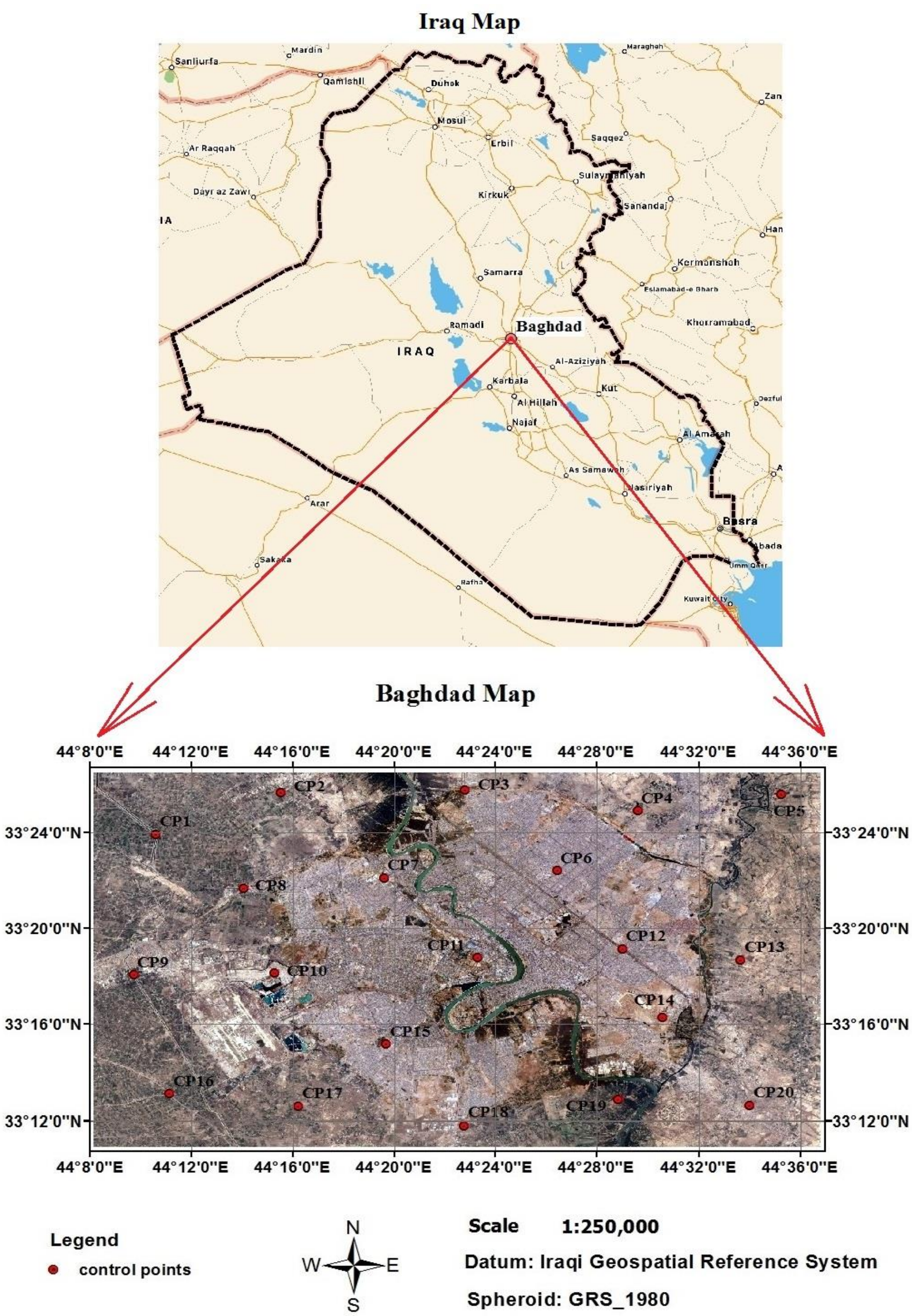

Figure 1. Study area and selected control points

4. Design of MATLAB Programs for Coordinate Transformations

Coordinate transformations are implemented by designing two MATLAB programs. The first program is used for the transformation of geographic coordinates [Latitude (Phi) and Longitude (Lambda)] to map coordinates [Northing (N) and Easting (E)] as shown in Fig. 2, while the second program is used for the inverse transformation of map coordinates to geographic coordinates as shown in Fig. 3. The adopted transformation equations are found in Snyder [11]. The designed programs are listed in Appendix-A.

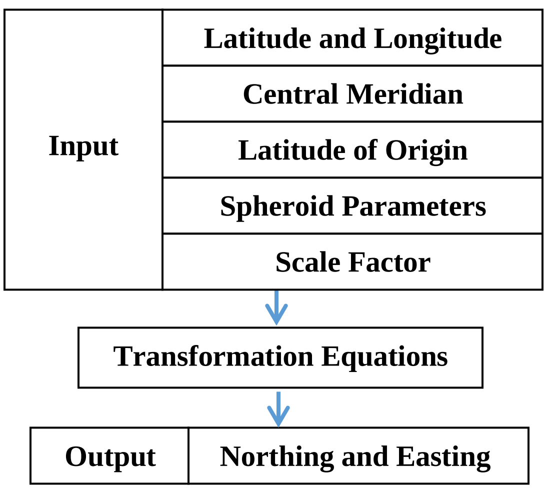

Figure 2. Transformation of latitude and longitude to northing and easting

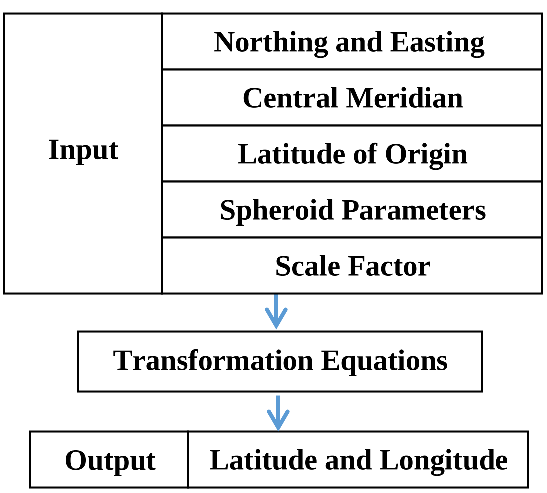

Figure 3. Transformation of northing and easting to latitude and longitude

5. Implementation and Results

The commonly available three coordinate systems in Iraq are Karbala 1979 Polservice, WGS 1984, and IGRS. The spheroidal parameters differences between Karbala 1979 Polservice and IGRS datum and between WGS 1984 and IGRS datum are calculated in Table 2 and Table 3, respectively. The source data include satellite image and twenty control points obtained from google earth pro. These data are based on the geographic coordinate system of WGS 1984.

Table 2. Spheroidal differences between Karbala 1979 Polservice and IGRS datum

Datum	Karbala 1979 Polservice	IGRS	Differences
Spheroid	Clarke 1880 RGS	GRS 1980	
Semi-major Axis (m)	6378249.145	6378137.0	−112.145
Semi-minor Axis (m)	6356514.869549776	6356752.314140356	237.44459058
Inverse Flattening (m)	293.465	298.257222101	4.792222101
Eccentricity Square (e^2)	0.00680351128	0.00669438002	−0.00010913126

Table 3. Spheroidal differences between WGS 1984 and IGRS datum

Datum	WGS 1984	IGRS	Differences
Spheroid	WGS 1984	GRS 1980	
Semi-major Axis (m)	6378137.0	6378137.0	0
Semi-minor Axis (m)	6356752.314245179	6356752.314140356	−0.000104823
Inverse Flattening (m)	298.257223563	298.257222101	−0.000001462
Eccentricity Square(e^2)	0.00669437999	0.00669438002	0.00000000003

By using ArcGIS application, the satellite image has been georeferenced to WGS 1984 coordinate system. Then, the WGS 1984 geographic coordinate system has been transformed to the two coordinate systems: Karbala 1979 Polservice and IGRS. Thus, three coordinate systems are available WGS 1984, Karbala 1979 Polservice, and IGRS. The geographic coordinates of Karbala 1979 Polservice and IGRS are listed in Tables 4(a) and 4(b), respectively, while the latitude differences (DLat.) and longitude differences (DLong.) between these two coordinate systems are listed in Table 4(c). The mean of latitude and longitude differences between Karbala 1979 Polservice and IGRS are 0.01 second and −11.2 second, respectively, in the study area.

Table 4(a). Karbala 1979 Polservice geographic coordinates

CP	Latitude Karbala 1979			Longitude Karbala 1979		
	deg	min	sec	deg	min	sec
CP1	33	23	57.486	44	10	47.967
CP2	33	25	40.614	44	15	43.309
CP3	33	25	47.921	44	22	59.273
CP4	33	24	56.024	44	29	48.253
CP5	33	25	37.625	44	35	27.916
CP6	33	22	25.944	44	26	37.533
CP7	33	22	8.054	44	19	46.525
CP8	33	21	40.642	44	14	14.616
CP9	33	18	4.414	44	9	55.758
CP10	33	18	9.510	44	15	26.752
CP11	33	18	47.440	44	23	28.833
CP12	33	19	10.082	44	29	11.123
CP13	33	18	42.133	44	33	51.503
CP14	33	16	17.452	44	30	45.802
CP15	33	15	11.714	44	19	51.249
CP16	33	13	7.095	44	11	18.642
CP17	33	12	36.548	44	16	23.574
CP18	33	11	48.908	44	22	56.794
CP19	33	12	53.024	44	29	1.067
CP20	33	12	38.554	44	34	11.240

Table 4 (b). IGRS geographic coordinates

CP	Latitude IGRS			Longitude IGRS		
	deg	min	sec	deg	min	sec
CP1	33	23	57.468	44	10	36.730
CP2	33	25	40.598	44	15	32.078
CP3	33	25	47.917	44	22	48.057
CP4	33	24	56.032	44	29	37.053
CP5	33	25	37.640	44	35	16.727
CP6	33	22	25.953	44	26	26.332
CP7	33	22	8.054	44	19	35.311
CP8	33	21	40.634	44	14	3.391
CP9	33	18	4.409	44	9	44.532
CP10	33	18	9.513	44	15	15.537
CP11	33	18	47.453	44	23	17.633
CP12	33	19	10.104	44	28	59.934
CP13	33	18	42.163	44	33	40.325
CP14	33	16	17.483	44	30	34.622
CP15	33	15	11.731	44	19	40.050
CP16	33	13	7.105	44	11	7.430
CP17	33	12	36.567	44	16	12.373
CP18	33	11	48.939	44	22	45.608
CP19	33	12	53.061	44	28	49.892
CP20	33	12	38.600	44	34	0.076

Table 4(c). Geographic coordinate differences between Karbala 1979 Polservice and IGRS in second

CP	D Lat.	D Long.	CP	D Lat.	D Long.
CP1	−0.018	−11.237	**CP11**	0.013	−11.200
CP2	−0.016	−11.231	**CP12**	0.022	−11.189
CP3	−0.004	−11.216	**CP13**	0.030	−11.178
CP4	0.008	−11.200	**CP14**	0.031	−11.180
CP5	0.015	−11.189	**CP15**	0.017	−11.199
CP6	0.009	−11.201	**CP16**	0.010	−11.212
CP7	0.000	−11.214	**CP17**	0.019	−11.201
CP8	−0.008	−11.225	**CP18**	0.031	−11.186
CP9	−0.005	−11.226	**CP19**	0.037	−11.175
CP10	0.003	−11.215	**CP20**	0.046	−11.164
Mean DLat.		0.012	**Mean DLong.**		−11.202

The transformations between the coordinate systems have been implemented using the Project tool in ArcGIS. Also, the Project tool has been used to convert between geographic and map coordinate systems. The geographic coordinates of Karbala 1979 Polservice datum with Clarke 1880 RGS spheroid, WGS 1984 datum with WGS 1984 spheroid, and IGRS datum with GRS 1980 spheroid are projected to UTM zone 38 north. The map coordinates of Karbala 1979 Polservice and IGRS are listed in Tables 5(a) and 5(b), respectively, while the northing differences (DN) and easting differences (DE) between these two coordinate systems are listed in Table 5(c).

Table 5(a). Karbala 1979 Polservice map coordinates using ArcGIS

CP	Northing (m)	Easting (m)
CP1	3695578.491	423741.423
CP2	3698697.321	431393.572
CP3	3698849.034	442653.430
CP4	3697193.956	453207.048
CP5	3698436.614	461984.808
CP6	3692597.211	448256.467
CP7	3692108.820	437632.357
CP8	3691323.622	429048.958
CP9	3684715.915	422305.624
CP10	3684808.182	430866.977
CP11	3685895.511	443341.117
CP12	3686545.185	452195.542
CP13	3685651.505	459441.496
CP14	3681217.294	454618.749
CP15	3679286.609	437672.193
CP16	3675542.895	424378.084
CP17	3674544.122	432265.157
CP18	3673011.656	442436.457
CP19	3674934.971	451878.131
CP20	3674453.047	459905.755

Table 5(b). IGRS map coordinates using ArcGIS

CP	Northing (m)	Easting (m)
CP1	3695857.112	423453.746
CP2	3698975.944	431105.901
CP3	3699127.657	442365.769
CP4	3697472.578	452919.396
CP5	3698715.237	461697.162
CP6	3692875.829	447968.810
CP7	3692387.438	437344.692
CP8	3691602.239	428761.285
CP9	3684994.526	422017.946
CP10	3685086.794	430579.306
CP11	3686174.124	443053.456
CP12	3686823.798	451907.889
CP13	3685930.117	459153.849
CP14	3681495.903	454331.097
CP15	3679565.216	437384.528
CP16	3675821.499	424090.408
CP17	3674822.725	431977.487
CP18	3673290.258	442148.796
CP19	3675213.575	451590.477
CP20	3674731.650	459618.108

Table 5(c). Map coordinate differences between Karbala 1979 and IGRS using ArcGIS in meters

CP	DN	DE	CP	DN	DE
CP1	278.621	−287.677	**CP11**	278.613	−287.661
CP2	278.623	−287.671	**CP12**	278.613	−287.653
CP3	278.623	−287.661	**CP13**	278.612	−287.647
CP4	278.622	−287.652	**CP14**	278.609	−287.652
CP5	278.623	−287.646	**CP15**	278.607	−287.665
CP6	278.618	−287.657	**CP16**	278.604	−287.676
CP7	278.618	−287.665	**CP17**	278.603	−287.670
CP8	278.617	−287.673	**CP18**	278.602	−287.661
CP9	278.611	−287.678	**CP19**	278.604	−287.654
CP10	278.612	−287.671	**CP20**	278.603	−287.647
Mean DN	278.613 m		**Mean DE**	−287.662 m	

On the other hand, the first program designed by MATLAB is used to transform the geographic coordinates obtained by ArcGIS to map coordinates. The resulted Karbala 1979 Polservice and IGRS map coordinates are listed in Tables 6(a) and 6(b), respectively, while the differences between these two coordinate systems are listed in Table 6(c). The results of using ArcGIS and MATLAB show that the mean of northing and easting differences between Karbala 1979 Polservice and IGRS coordinate systems are about 278.6 m and −287.6 m, respectively, in the study area. Also, the second program designed by MATLAB is used to convert the map coordinates to geographic coordinates. The resulted geographic coordinates coincide with ArcGIS results.

Table 6(a). Karbala 1979 Polservice map coordinates using MATLAB

CP	Northing (m)	Easting (m)
CP1	3695578.482	423741.430
CP2	3698697.330	431393.575
CP3	3698849.023	442653.439
CP4	3697193.940	453207.051
CP5	3698436.608	461984.809
CP6	3692597.205	448256.469
CP7	3692108.810	437632.344
CP8	3691323.628	429048.970
CP9	3684715.928	422305.630
CP10	3684808.176	430866.970
CP11	3685895.523	443341.119
CP12	3686545.180	452195.541
CP13	3685651.499	459441.496
CP14	3681217.283	454618.760
CP15	3679286.613	437672.189
CP16	3675542.882	424378.072
CP17	3674544.127	432265.149
CP18	3673011.645	442436.464
CP19	3674934.973	451878.126
CP20	3674453.042	459905.755

Table 6(b). IGRS map coordinates using MATLAB

CP	Northing (m)	Easting (m)
CP1	3695857.117	423453.752
CP2	3698975.934	431105.890
CP3	3699127.669	442365.769
CP4	3697472.571	452919.389
CP5	3698715.247	461697.172
CP6	3692875.815	447968.810
CP7	3692387.437	437344.691
CP8	3691602.229	428761.296
CP9	3684994.534	422017.956
CP10	3685086.779	430579.298
CP11	3686174.112	443053.450
CP12	3686823.812	451907.878
CP13	3685930.125	459153.847
CP14	3681495.891	454331.089
CP15	3679565.205	437384.537
CP16	3675821.487	424090.414
CP17	3674822.733	431977.484
CP18	3673290.254	442148.802
CP19	3675213.572	451590.489
CP20	3674731.661	459618.117

Table 6(c). Map coordinate differences between Karbala 1979 and IGRS using MATLAB in meters

CP	DN	DE	CP	DN	DE
CP1	278.635	−287.678	**CP11**	278.589	−287.669
CP2	278.604	−287.685	**CP12**	278.632	−287.663
CP3	278.646	−287.670	**CP13**	278.626	−287.649
CP4	278.631	−287.662	**CP14**	278.608	−287.671
CP5	278.639	−287.637	**CP15**	278.592	−287.652
CP6	278.610	−287.659	**CP16**	278.605	−287.658
CP7	278.627	−287.653	**CP17**	278.606	−287.665
CP8	278.601	−287.674	**CP18**	278.609	−287.662
CP9	278.606	−287.674	**CP19**	278.599	−287.637
CP10	278.603	−287.672	**CP20**	278.619	−287.638
Mean DN	278.614 m		**Mean DE**	−287.661 m	

In Baghdad city, the relationships between Karbala 1979 Polservice and IGRS for both geographic and map coordinate systems have been concluded from the differences in latitudes, longitudes, northings and eastings, as illustrated in Equation 1, Equation 2, Equation 3, and Equation 4. These equations can be used to convert the coordinate systems of Karbala 1979 Polservice to IGRS and vice versa within the study area in Baghdad, Iraq. Figure 4, Figure 5, Figure 6 and Figure 7 show latitude, longitude, northing and easing differences between Karbala 1979 Polservice and IGRS coordinate systems, respectively.

For both Karbala 1979 Polservice and IGRS, the map coordinate differences between ArcGIS and MATLAB results are about (− 16 mm to 14 mm) in northing and about (− 13 mm to 12 mm) in easting as represented in Figure 8, Figure 9, Figure 10, and Figure 11. The latitude differences and longitude differences between ArcGIS and MATLAB results are equal to zero. In addition, the WGS 1984 is approximately superposed to IGRS and the distinctions between them are negligible within the accuracy limits of coordinate conversion.

$$Latitude_{IGRS} = Latitude_{Karbala\ 1979} + 0.01_{sec} \quad (1)$$

$$Longitude_{IGRS} = Longitude_{Karbala\ 1979} - 11.2_{sec} \quad (2)$$

$$North_{IGRS} = North_{Karbala\ 1979} + 278.6_{m} \quad (3)$$

$$East_{IGRS} = East_{Karbala\ 1979} - 287.6_{m} \quad (4)$$

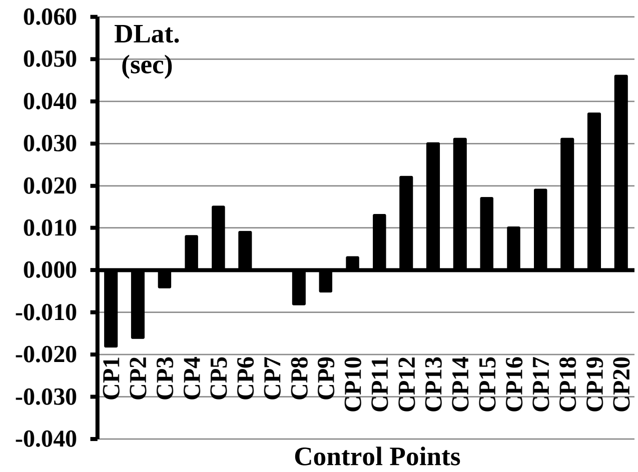

Figure 4. Latitude differences between Karbala 1979 Polservice and IGRS

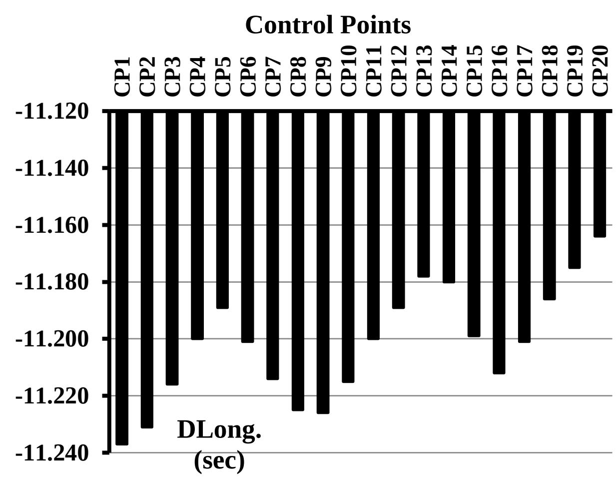

Figure 5. Longitude differences between Karbala 1979 Polservice and IGRS

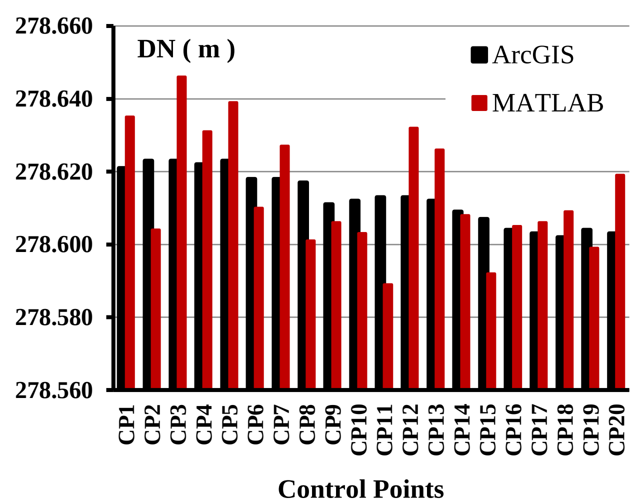

Figure 6. Northing differences between Karbala 1979 Polservice and IGRS

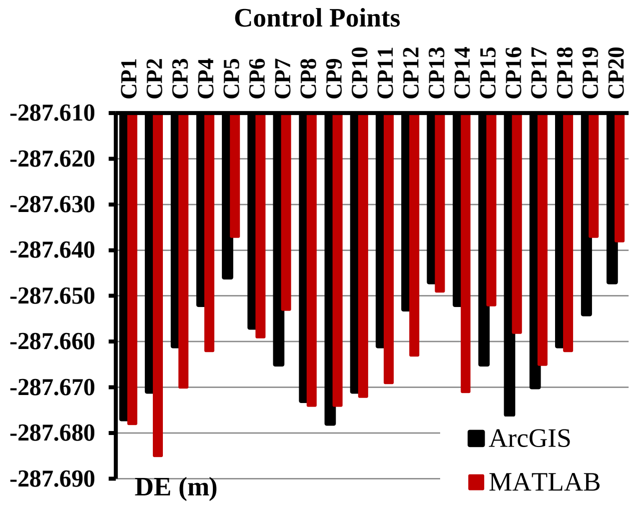

Figure 7. Easting differences between Karbala 1979 Polservice and IGRS

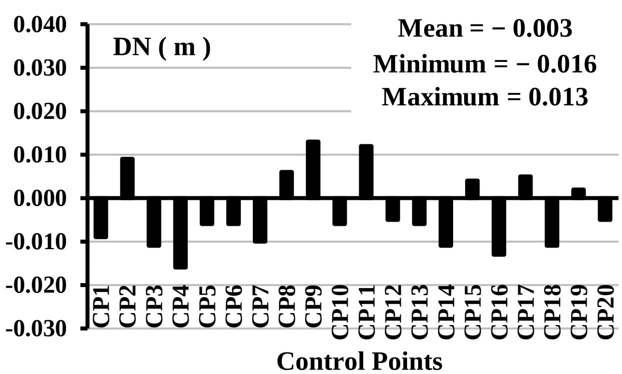

Figure 8. Karbala 1979 Polservice northing differences between ArcGIS and MATLAB results

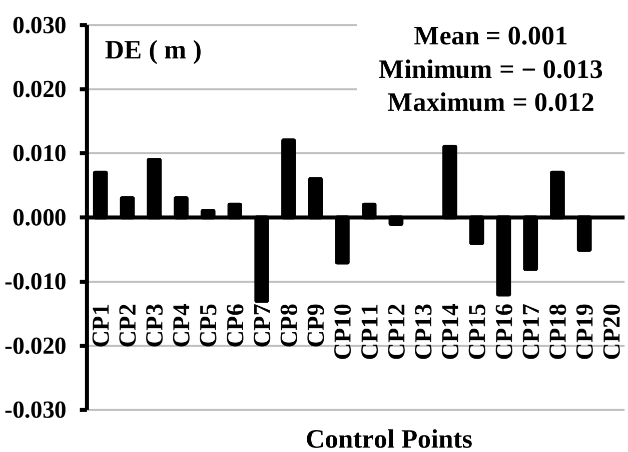

Figure 9. Karbala 1979 Polservice easting differences between ArcGIS and MATLAB results

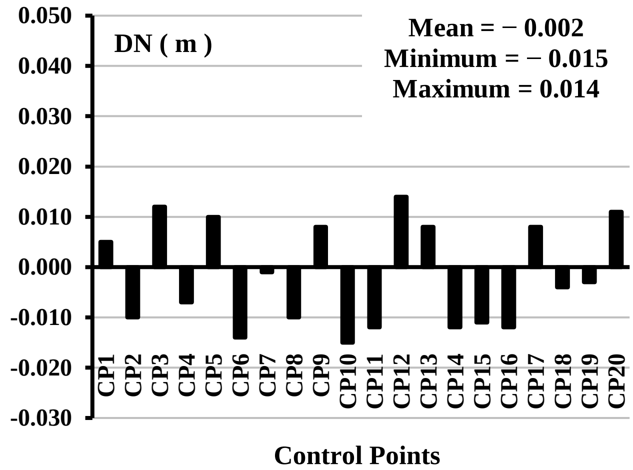

Figure 10. IGRS northing differences between ArcGIS and MATLAB results

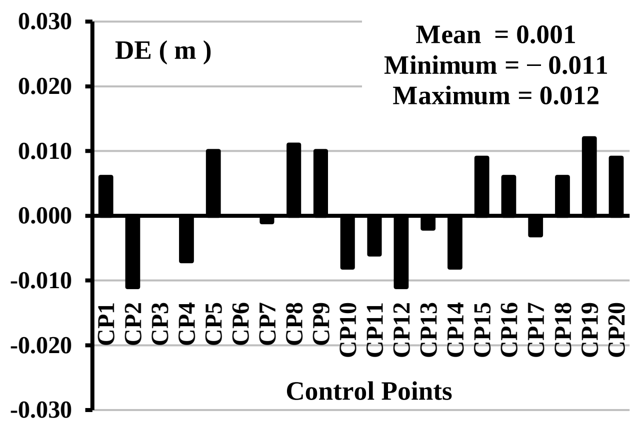

Figure 11. IGRS easting differences between ArcGIS and MATLAB results

6. Conclusions

1. ArcGIS application is capable of implementing different coordinate transformations. The accuracy of these transformations is adequate for most map production and updating in addition to the facility and rapidity in execution. ArcGIS can provide and save all types of geodatabases flexible for updating and printing in different scales, projections, and coordinate systems.
2. The coordinate discrepancies between Karbala 1979 Polservice and IGRS are about

278.6 m, − 287.6 m, 0.01 second, and − 11.2 second in northing, easting, latitude, and longitude, respectively. The distinction between WGS 1984 and IGRS coordinates are negligible. The WGS 1984 is equivalent to IGRS within the accuracy limits of coordinate conversion.

3. For both Karbala 1979 Polservice and IGRS, the differences in map coordinates between ArcGIS and MATLAB results are about (−16 mm to 14 mm) in northing and about (−13 mm to 12 mm) in easting. Also, the latitude differences and longitude differences between ArcGIS and MATLAB results are equal to zero.

7. Recommendation

There are different coordinate systems used in Iraq resulted from different geodetic networks. Some of these geodetic networks such as Nahrwan 1934 and Nahrwan 1967 are completely cancelled in Iraq. Others like Karbala 1979 Polservice network is still used in some projects. The user should take into account coordinate discrepancies before the work. Up to date, some of available maps and documents in Iraq offices and departments have been printed in Karbala 1979 Polservice with Clarke 1880 RGS coordinate system. These maps must be updated and adopted a uniform coordinate system such as IGRS.

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Conflict of interest

The author confirm that the publication of this article causes no conflict of interest.

8. References

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Appendix – A

The first program and the second program designed by MATLAB are illustrated in Fig. A-1 and Fig. A-2, respectively.

```
%This Program transforms Phi,Lambda
%into N,E using UTM Projection
clear;clc;
LD=input('lambda in degree= ');
LM=input('lambda in minute= ');
LS=input('lambda in second= ');
LAM=LD+LM/60+LS/3600;
LAM=LAM*pi/180;
LDo=input('lambdao in degree= ');
LMo=input('lambdao in minute= ');
LSo=input('lambdao in second= ');
LAMo=LDo+LMo/60+LSo/3600;
LAMo=LAMo*pi/180;
PD=input('Phi in degree= ');
PM=input('Phi in minute= ');
PS=input('Phi in second= ');
Phi=PD+PM/60+PS/3600;
Phi=Phi*pi/180;
PDo=input('Phio in degree= ');
PMo=input('Phio in minute= ');
PSo=input('Phio in second= ');
Phio=PDo+PMo/60+PSo/3600;
Phio=Phio*pi/180;
a=input('Semimajor axis= ');
e2=input('eccentricity square= ');
Ko=0.9996;
e4=e2*e2;e6=e4*e2;ep2=e2/(1-e2);
N=a/(1-e2*(sin(Phi))^2)^.5;
T=(tan(Phi))^2;C=ep2*(cos(Phi))^2;
A=(LAM-LAMo)*cos(Phi);
a1=1-e2/4-3*e4/64-5*e6/256;
a2=3*e2/8+3*e4/32+45*e6/1024;
a3=15*e4/256+45*e6/1024;
a4=35*e6/3072;
M=a*((a1*Phi)-(a2*sin(2*Phi))+ …
(a3*sin(4*Phi))-(a4*sin(6*Phi)));
Mo=a*((a1*Phio)-(a2*sin(2*Phio))+ …
(a3*sin(4*Phio))-(a4*sin(6*Phio)));
if (Phi == -pi/2)|(Phi == pi/2)
X=0;Y=Ko*(M-Mo);K=Ko;
else
XX=Ko*N*(A+(1-T+C)*(A^3)/6+ …
(5-18*T+T^2+72*C-58*ep2)*(A^5)/120);
X=XX+500000
Y=Ko*(M-Mo+N*tan(Phi)*((A^2)/2+ …
(5-T+9*C+4*C^2)*(A^4)/24+(61-58*T+ …
T^2+600*C-330*ep2)*(A^6)/720))
K=Ko*(1+(1+C)*(A^2)/2+(5-4*T+42*C+ …
13*C^2-28*ep2)*(A^4)/24+(61-148*T+ …
16*T^2)*(A^6)/720);
end
```

Figure A-1. Program listing for the transformation of latitude and longitude to northing and easting

```
%This Program transforms N,E into
%Phi, Lambda using UTM Projection
clear;clc;
LDo=input('lambdao in degree= ');
LMo=input('lambdao in minute= ');
LSo=input('lambdao in second= ');
LAMo=LDo+LMo/60+LSo/3600;
LAMo=LAMo*pi/180;
PDo=input('Phio in degree= ');
PMo=input('Phio in minute= ');
PSo=input('Phio in second= ');
Phio=PDo+PMo/60+PSo/3600;
Phio=Phio*pi/180;
a=input('Semimajor axis= ');
e2=input('eccentricity square= ');
Ko=0.9996;
x=input('x-value= ');
y=input('y-value= ');
x=x-500000;e4=e2*e2;
e6=e4*e2;ep2=e2/(1-e2);
e1=(1-(1-e2)^.5)/(1+(1-e2)^.5);
a1=1-e2/4-3*e4/64-5*e6/256;
a2=3*e2/8+3*e4/32+45*e6/1024;
a3=15*e4/256+45*e6/1024;
a4=35*e6/3072;
Mo=a*((a1*Phio)-(a2*sin(2*Phio))+ …
(a3*sin(4*Phio))-(a4*sin(6*Phio)));
M=Mo+y/Ko;
u=M/(a*(1-e2/4-3*e4/64-5*e6/256));
u1=3*e1/2-27*(e1^3) /32;
u2=21*(e1^2)/16-55*(e1^4)/32;
u3=151*(e1^3)/96;
u4=1097*(e1^4)/512;
Phi1=u+u1*sin(2*u)+u2*sin(4*u)+ …
u3*sin(6*u)+u4*sin(8*u);
C1=ep2*(cos(Phi1))^2;T1=(tan(Phi1))^2;
N1=a/(1-e2*(sin(Phi1))^2)^.5;
R1=a*(1-e2)/(1-e2*(sin(Phi1))^2)^1.5;
D=x/(N1*Ko);
Phi=Phi1-(N1*tan(Phi1)/R1)*((D^2)/2 …
-(5+3*T1+10*C1-4*C1^2-9*ep2)*(D^4)/ …
24+(61+90*T1+298*C1+45*T1^2-252*ep2 …
-3*C1^2)*(D^6)/720);
LAM=LAMo+(D-(1+2*T1+C1)*(D^3)/6+(5- …
2*C1+28*T1-3*C1^2+8*ep2+24*T1^2)* …
(D^5)/120)/cos(Phi1);LAM=LAM*180/pi;
RLD=fix(LAM)
l1=LAM-RLD;l2=l1*60;RLM=fix(l2)
l1=l2-RLM;RLS=l1*60
Phi=Phi*180/pi;RPD=fix(Phi)
l1=Phi-RPD;l2=l1*60;RPM=fix(l2)
l1=l2-RPM;RPS=l1*60
```

Figure A-2. Program listing for the transformation of northing and easting to latitude and longitude