Datum Transformation with the Minimum Curvature Surface Interpolation Approach

Dr. Abbas Zedan Khalaf
Building and construction Engineering Department, University of Technology/Baghdad.
Email: khalaf1955@yahoo.com
Ghydaa A. Abdul-Rehman
Building and construction Engineering Department, University of Technology/Baghdad.
Email: Ghydaa_80@yahoo.com

Received on:29/10/2014 & Accepted on:11/6/2015

Abstract

This paper investigates main and important problem related to coordinates systems of Iraq. Maps of Iraq referenced to a local geodetic system while the technique oflocation observation and map production use the world geodetic system (WGS84) as a base reference datum. So, it has become necessary to find an algorithm to convert between Iraq local geodetic system (Karbala79) and world geodetic system (WGS84) simply because the (WGS84) is adopted globally and all of GPS and GNSS use that datum to calculate positions .

The idea of this paper came to create a mathematical model that relates between old and new datums by programing new software with matlab that perform the conversion with low coast, accurate and rapid procedure. In this paper modern approach was used to convert between (Karbala79) and (WGS84) it is:-

Minimum curvature surface interpolation via geodetic coordinates approach, this approach was used in USA by National Geodetic Survey (NGS) and it is requires a set of common points of two different datums. Computer software (IRAQCON) were developed with matlab 2013.

Precision of (0.03) meters in ΔE and (0.02) meters in ΔN were obtained from this approach when converted between datums, represent very precise result. Furthermore, field tests were done for this approach in ThiQar city. The tests were accomplished sucsussfly. It can be recommended forconversion system and production large scale maps for Iraq.

This work aims to develop and evaluate the best fit mathematical model of the existing control network system of Iraq to the WGS84 system

Keywords: minimum curvature interpolation ▪ international terrestrial reference frame (ITRF) ▪ EPOCH▪geodetic datum▪ world geodetic system (WGS).

التحويل بين المراجع الجيوديسية بأستخدام طريقة
((Minimum Curvature Interpolation))

الخلاصة

هذا البحث يتناول دراسة مشكلة رئيسية ومهمه هي التحويل بين الشبكات في العراق . وبما ان الخرائط الوطنية العراقية تعتمد على مرجع جيوديسي محلي لنظام الاحداثيات ومع التقدم الحاصل

في برامجيات وأجهزة قياس الاحداثيات من جهة وتطور ألاساليب الخاصة بإنتاج الخرائط من جهة اخرى أصبح من الضروري إيجاد حل للتحويل بين النظام المحلي للشبكة الجيوديسية العراقية والمسمى (Karbala79) والنظام الجيوديسي العالمي (world geodetic system -WGS84) علما ان النظام ألاخير أصبح معتمد عالميا كونه النظام ألرئيسي الذي تعمل عليه أجهزة ال GPS و GNSS .
لذا جاءت فكرة هذا البحث والتي تتمثل بانشاء موديل رياضي يربط بين الانظمة المحليه والنظام العالمي بواسطه برنامج Matlab وبإسلوب برمجي سريع ودقيق واقتصادي ، وهذا الاسلوب يتطلب توفير مجموعة من النقاط معلومة الاحداثيات بنظامين مرجعيين مختلفين .
في بحثنا هذا تم أستخدم اسلوب (minimum curvature surface interpolation) الذي يعتمد على الاحداثيات الجغرافية وهذا الاسلوب تم العمل به لاول مرة في الولايات المتحدة الاميركيه من قبل هيئة المساحه الجيوديسية (National Geodetic Survey –NGS) فتم بناء برنامج يدعى (IRAQCON) تمت برمجته بواسطة اللغة البرمجية Matlab 2013 .
كانت الدقة التي حصلنا عليها من هذا الاسلوب كالتالي :-

$\Delta E = 0.03$ meters , $\Delta N = 0.02$ meters

حيث كانت نتائج دقيقة جدا بالاضافة الى ذلك تم عمل رصد حقلي في محافظة ذي قار واثبتت الفحوصات نجاح هذا الاسلوب لذلك نوصي باستخدام هذا الاسلوب لانتاج وتحديث الخرائط في العراق.

INTRODUCTION

The application of minimum curvature is described as it applies to the transformation of positional data between various geodetic datums.

In this paper a datum transformation method represented by " IRAQCON" program is used for the first time in Iraq. This method was used by National Geodetic Survey (NGS) to produce NADCON, a computer program to convert data between the North American Datum of 1927 (NAD 27) and the North American Datum of 1983 (NAD 83). It should be noted that the method is quite applicable to transform between any other geodetic data, however, two different coordinate values referenced to those geodetic system and represent the exact same point on the surface of the Earth are required. The actual differences between coordinate values are modeled; no knowledge of datum origins or ellipsoidal parameters are required. The application of minimum curvature within this context is new and somewhat innovative. IRAQCON is sufficiently accurate for mapping at a scale of (1:200) or smaller, which is ideal for Geographic Information Systems (GIS), which originated in the national mapping agency of Canada and was subsequently adopted in Australia, New Zealand and then several other countries; and used in Great Britain [1].

The shift or offsets between (Karbala 79) and (WGS84) arise from the difference in the assumed coordinate systems as well as the difference in approach taken in calculation of coordinate values. Figure (1) shows the magnitude of the shifts between these datums. Several approaches are employed for the transformation of data from Karbala to WGS84. All rely upon knowing the exact differences at a number of existing control points.

The transformation can be accomplished in curvilinear (geodetic) coordinates depending on the following equations:

$$\varphi_{system2} = \varphi_{system1} + \delta\varphi \quad (1)$$

$$\lambda_{system2} = \lambda_{system1} + \delta\lambda$$

Where

φ $system1$,φ $system2$ are the latitudes of the common point referenced to the current and target geodetic system.

λ $system1$, λ $system2$ are the longitudes of the common point referenced to the current and target geodetic system.

$\delta\varphi$, $\delta\lambda$ are the geodetic shift between the tow systems

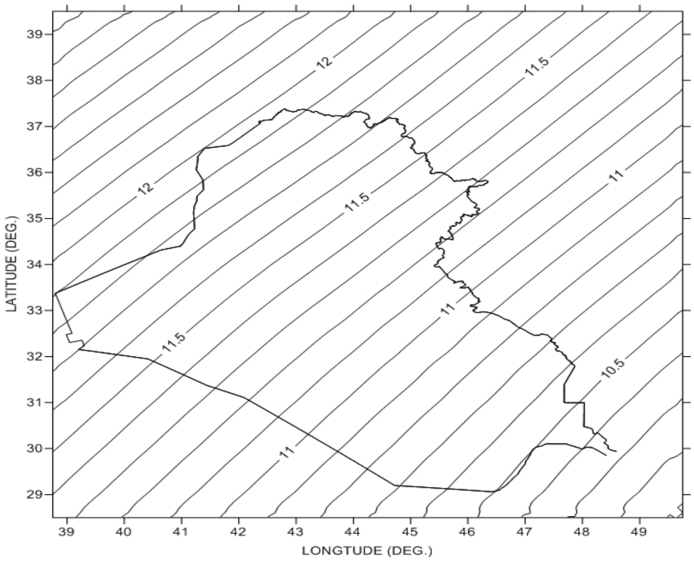

Figure (1): magnitude of total shift between Karbala79 and WGS84 datums in (second).

IRAQCON in General

To achieve the most accurate transformation methods an intuitive method was developed (IRAQCON) by utilizing some points of first order horizontal control data. They represent the best available data associated with the establishment of Karbala datum. IRAQCON can be used to transform data between all Iraq geodetic networks. As a condition to satisfy this transformation, coordinates of common points in both datums must be known. In essence, a gridded data set of standard datum shifts has been prepared and a simple interpolation routine provides estimates of values at non-nodal points. The preparation of the gridded values was the difficult aspect. In summary, (IRAQCON) is two-step process (1) the development of gridded data sets-essentially the δφ and δλvalues of equation (1) ,and (2) the estimation to non-nodal points by using interpolation based on the grids.

Definition of IRAQCON

IRAQCON applies a standard method to calculate mathematical transformations between horizontal geodetic datums. IRAQCON transforms coordinate values between any other two geodetic datums in Iraq for which grids are available. It convertsthe coordinates of geodetic point from one system to another by using a pair of text files containing sets of coordinate points. The conversion result are shown in main screen for IRAQCON or saved as text file in case of multiple points are converted. The location of original and converted points are shown on two types of map selected by theuser: Google map or a satellite image background. This program can perform two way conversions, from old (Karbala) to new (WGS84) datum and vice versa. In addition to convert others data formats such as shapefiles and raster image.

Modeling of IRAQCON Grids with Minimum Curvature

The first-step process to transferring data by IRAQCON is developed of gridded data sets-essentially the $\delta\varphi$ and $\delta\lambda$ of equation (1). The gridded data sets are prepared using a technique known as "minimum curvature interpolation" [2]; [3]. This approach mathematically minimizes the total curvature, or rate of bending, associated with a smooth surface describing the shift values between datums. A total of two gridded data sets are required for the complete computation of a transformation: One for latitude shifts and another for longitude shifts. Thus, two mathematical surfaces must be prepared for Iraq.

Minimum curvature interpolation was used within mechanical engineering applications, geophysics, and the mathematics of finite differences. The differential equations pertaining to the deformation or bending of plates form the basis for the method [2]. Minimum curvature program has been developed to interpolate grid surfaces.

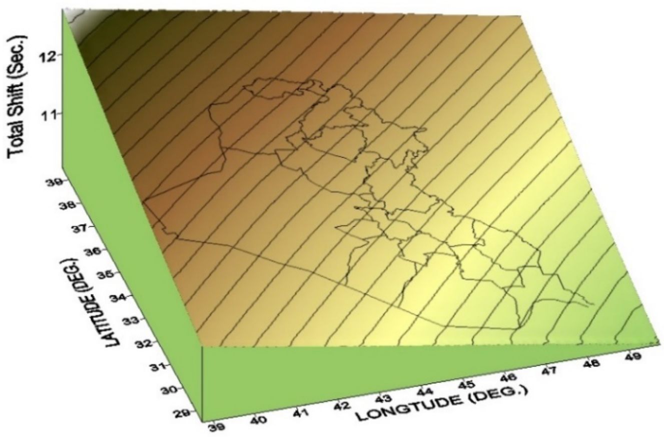

Figure (2): Three dimensional perspective and contour map for Iraq

Each point on the earth surface can be represented by deferent pairs of geodetic coordinates according to the reference geodetic system. In essence, there are two sources for the differences in the point coordinates, the first is the conformal mapping between different ellipsoids and the second resultsfromthe different observation methods, accuracy and technologies which have been used to build those datums. The second source, which can be called distortion, is not particularly well understood but completely recognized as existing. The first source results in differences which are smoothly varying over the Earth as shown in figure (2), the curvature of the differences being continuous. The second may results in highly location-dependent differences, but usually confined within specific regions and of lower amplitude than the first source. Smoothness may or may not be evident with differences resulting from the second source.

It is instructive to compare a surface of gridded datum shift values to plate theory in mechanical engineering. Consider a large thin sheet (thickness much less than either lateral dimension); with point forces acting perpendicular to the sheet (see figure3).

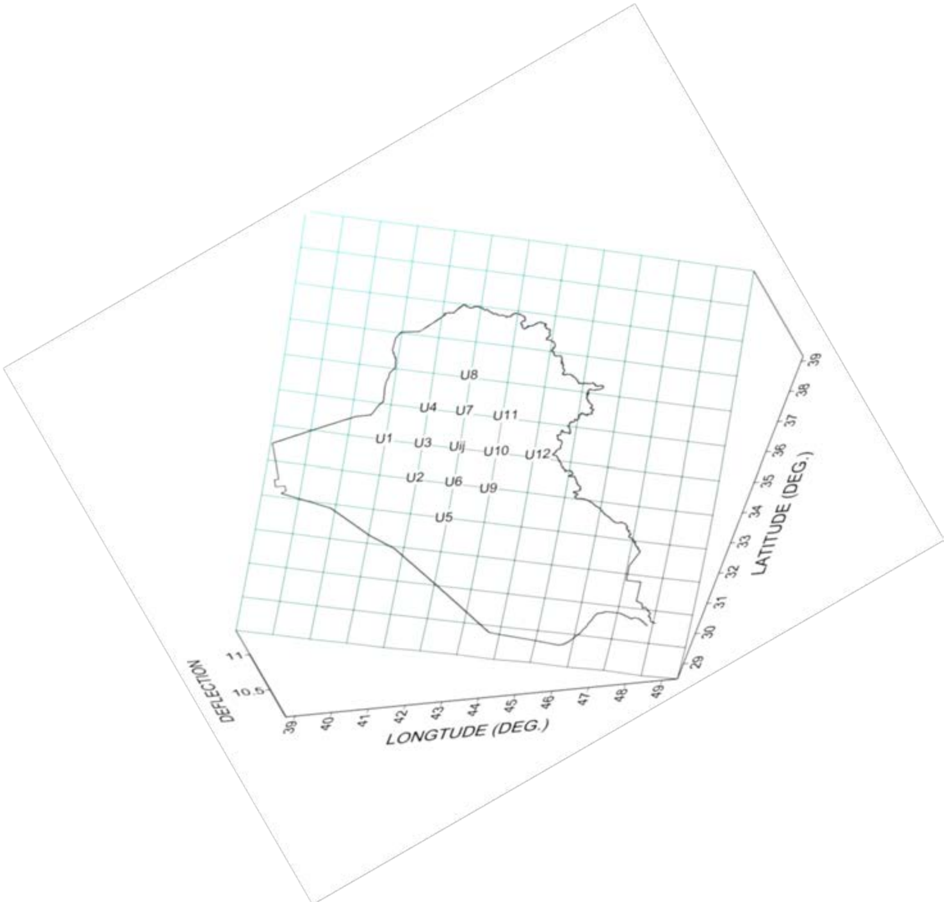

Figure (3): deflections of minimum curvature derived surface with node locations as represented in eq. (7).

Shear and tensional/compressional forces are not present. Bending or deformation occurs, with the magnitude of deformation at each point source dependent or constrained by the force applied at the point. Deformation away from the point sources would be dependent upon close forces, with smooth bending between points evident unless the forces exceed some threshold and actually "crimp" or puncture the plate. The datum values at station locations would be equivalent to the point forces and the smooth bending being representative of the variation of shift values that depend upon location. Smoothness of both the thin sheet and the surface describing the shift values is highly desirable, provided discontinuities or punctures are to be avoided.The biharmonic partial differential equation describing the deformation of the plate is given by:

$$\frac{\partial^4 w}{\partial x^4} + \frac{2\,\partial^4 w}{\partial x^2\,\partial y^2} + \frac{\partial^4 w}{\partial y^4} = \frac{P}{D} \text{OrD } \nabla^4 w = P \qquad \ldots (2)$$

Where: D is a scale factor dependent upon the material, known as the flexural rigidity, P the force, and w the normal displacement of the sheet.
Note that a solution to this differential equation is a third-order polynomial in two space variables. Continuity is of course a condition of solution, requiring that the deformation at point forces equals that resulting from the force at the point. Mathematically,

$$u(x_m, y_m) = w_m$$

Where u(x,y) is the displacement at point m.
Consider curvature, C_{ij}, at a point (x_i, y_i) on a grid of unit spacing as:-

$$C_{ij} = \frac{\partial^2 u_{ij}}{\partial x^2} + \frac{\partial^2 u_{ij}}{\partial y^2} = u_{i+1,j} + u_{i-1,j} + u_{i,j+1} + u_{i,j-1} - 4u_{ij} \qquad \ldots(3)$$

The discrete total squared curvature can then be defined as

$$C = \sum_{i=1}^{i} \sum_{j=1}^{j} (C_{ij})^2$$

Note that the curvature, C, is a function of the values on the grid, uij, and its neighboring points. The accuracy of the estimate of total curvature, C, is dependent upon the total number of neighbors one is able or willing to consider. Quite often, depending upon the density and distribution of data, one may only have to sum over a small area surrounding the data, allowing values in sparse regions to be fixed by linear extrapolation or some other technique. Note that a minimum of three points is necessary to estimate curvature.
Minimization of the discrete total curvature, eq. (3), differentiating with respect to each grid point and setting the result to zero, yields

$$4C_{ij} = C_{i+1,j} + C_{i-1,j} + C_{i,j+1} + C_{i,j-1} \qquad \ldots(4)$$

This difference equation of curvature can be used through substitution of eq. (3), to solve for the estimates u_{ij}. In general, this leads to a new difference equation in terms of the grid estimates, u_{ij}.

$$u_{i+2,j} + u_{i,j+2} + u_{i-2,j} + u_{i,j-2} + 2\,(u_{i+1,j+1} + u_{i-1,j+1} + u_{i+1,j-1} + u_{i-1,j-1}) - 8\,(u_{i+1,j} + u_{i-1,j} + u_{i,j-1} + u_{i,j+1}) + 20\,u_{ij} = 0 \qquad \ldots(5)$$

Modification of the above for various locations, for example along the edges of the grid, is necessary due to numerical differentiation, the free-edge boundary conditions, and the finite dimensions of the surface. The following provides a summary of the requisite difference equations. For completeness, they appear below. Note that there are exactly as many of these equations to solve as there are nodal or grid points [2].

Normal or general situation

Away from edges and observations, the difference equation is equation (5).

Edge

For the edge j =1 and away from corners:

$$u_{i-2,j} + u_{i+2,j} + u_{i,j+2} + u_{i-1,j+1} + u_{i+1,j+1} - 4(u_{i-1,j} + u_{i,j+1} + u_{i+1,j}) + 7u_{ij} = 0 \quad ..(6)$$

One row from edge

For the row j =2 and away from corners, use

$$u_{i-2,j} + u_{i+2,j} + u_{i,j+2} + 2(u_{i-1,j+1} + u_{i+1,j+1}) + u_{i-1,j-1} + u_{i+1,j-1} - 8(u_{i-1,j} + u_{i,j+1} + u_{i+1,j}) - 4u_{i,j-1} + 19u_{ij} = 0 \quad ...(7)$$

The corners

For the corner i=1, j =1, use

$$2\,u_{ij} + u_{i,j+2} + u_{i+2,j} - 2(u_{i,j+1} + u_{i+1,j}) = 0 \quad ...(8)$$

Next to corner

For a grid point next to the corner and lying on a diagonal i=2, j =2, use

$$u_{i,j+2} + u_{i+2,j} + u_{i-1,j+1} + u_{i+1,j-1} + 2u_{i+1,j+1} - 8(u_{i,j+1} + u_{i+1,j}) - 4(u_{i,j-1} + u_{i-1,j}) + 18u_{ij} = 0 \quad ... (9)$$

Edges next to corner

For a grid point next to the corner point, which lies on the edge, i=2, j =1, use

$$u_{i,j+2} + u_{i+1,j+1} + u_{i+2,j} + u_{i-1,j+1} - 2\,u_{i-1,j} - 4(u_{i,j+1} + u_{i+1,j}) + 6u_{ij} = 0 \quad ...(10)$$

The original data, the datum shift values in this case, do not often coincide with the location of grid nodes. Curvature at a grid point in which original data are nearby can be defined as:-

$$C_{ij} = \sum_{k=1}^{4} b_k u_k - u_{ij} \sum_{k=1}^{5} b_k + b_k w_n \quad ...(11)$$

This expression can be used in eq. (4) from above to yield another difference equation in term of eq. (5). This can then be thought of as a special case, where data exist within a grid cell. w in eq. (11) represents the actual data values and b_k are internal weights applied to the surrounding grid points [2]. Equation (11) is the result of considering the data point as part of an irregular grid, together with the vertices of the regular grid surrounding the point. Two limitations need to be noted; the matrix yielding the weights becomes singular as data approach the grid location at uij, and the data must be close enough to the desired node so the approximations leading to eq. (11) remain valid.

All nodes in which data points located within a certain radius are set to the exact value of the data; while data outside a certain radius are ignored and the general curvature equation is used. For the purpose of this study the separation thresholds are 0.05 and 0.75 of the grid spacing. A threshold of 0.05 times the grid spacing guarantees that data located nearby will have the most influence on an estimate and that data farther away will not be as heavy an influence. This is also in agreement with the “boundary” condition, that grid nodes which coincide exactly with data points attempt to assume the value of the data points.

Let us now examine some of the practical aspects of the above discussion. Consider a matrix of grid locations shown in figure (3). Note that an estimate at an unknown grid location, u_{ij}, appearing in the center and away from the edges, can be defined by eq. (5) as:-

$$-\frac{1}{20}[u_1 + u_5 + u_8 + u_{12} + 2(u_2 + u_4 + u_9 + u_{11}) - 8(u_3 + u_6 + u_7 + u_{10})] = u_{ij} \quad ...(12)$$

Wher

e the subscripts are the same as shown in figure (3).

A similar relationship can be found for each point within this matrix grid. This set of equations can be solved, either through linear algebra or through iteration. Iteration accommodates a large amount of data without potentially unstable matrix inversion (e.g., singularities). However, iteration also requires that initial values of uij be provided. Theoretically, any initial values could be used (including zero).
Smoothness is assured by this method. For any data set (a minimum of four values are required) and a given grid interval, this method will determine the smoothest surface.

Polynomial Interpolation for the Grid

The data grids require interpolation to be useful. For this investigation, a locally fit polynomial is used in the interpolation, equivalent to a bilinear interpolation. Other methods may work; this method is simple and sufficiently accurate.

The polynomial surface, fit to the four surrounding nodal points, is defined as:-

$$Z=a+bx+cy+dxy \qquad \ldots(13)$$

Where

z: is the estimate shift at the unknown point,

x and y: are positional indices ,

a, b, c, and d: are coefficients of the polynomial equation.

This equation is solved by using index location based on the row and columnorganization of the grid. The grids are organized from minimum latitude to maximum latitude (e.g., rows) and from minimum longitude to maximum longitude (e.g., columns). In the above equation, x and y are defined as

$$x = \left[\frac{(long._{pt} - long._{min})}{dx} + 1\right] - j_{sw} \qquad \ldots(14)$$

And

$$y = \left[\frac{(lat._{pt} - lat._{min})}{dy} + 1\right] - i_{sw} \qquad \ldots(15)$$

Where $0 < x < 1$ and $0 < y < 1$

$lon._{pt}$ and $lat._{pt}$: represent the geodetic coordinates of the unknown point,

$long._{min}$, $lat._{min}$: represent the minimum coordinates for the overall grid,

dx, dy : are the grid intervals in each direction,

And j_{sw} , i_{sw} are the indices of the subgrid lower left (e.g., southwest) corner of the cell in which the unknown point resides[4].

The coefficients a, b, c, and d are functions of the shift values of the surrounding nodal points. Clockwise from the southwest corner of the cell, these values can be defined as t1, t2, t3, and t4. Within this scheme, the coefficients become[4]:

a = t1 …(16)

b = t3 – t1 …(17)

c = t2 –t1 … (18)

d = t4 -t3 -t2 + t1. … (19)

This interpolation is extremely fast, requiring few operations. In addition, given a grid of points sufficiently dense (e.g., dx and dy small) then this technique will work as well as more complicated approaches. The IRAQCON program that is produced by the researcher provides for the transparent application of the interpolation method outlined above. The program user merely has to ensure that the proper gridded data set resides in the same directory or storage area as the program. Latitude and longitudes provided by the user will be converted between datums via the program.

Several different file formats are allowed. The sorting of data, the selection of applicable cell as well as the selection of the appropriate grid files (e.g., area) are all done automatically. Hence, a user may easily transform multiple points from various distant areas. For example, a user could compile a list or file of several points in Iraq and transform all with a single effort [4].

The Basics of IRAQCON

IRAQCON provides geographic conversion. The new IRAQCON application products the following

•Provides a modern interface: this method includes “user-friendly” interface, making the conversion easier to use, more other methods, and therefore less prone to error .

•Supports two grid files: text document contain (number of common point, old latitude, old longitude, new latitude, new longitude) use to create grid files *.las ,*.los, which are a pair of binary files carrying the differences in coordinates for any list of common points of two datums.

•Accepts any valid geographic coordinate as long as it falls within a conversion grid. The new application accepts any valid geographic coordinate; it was written for use over all the earth. The IRAQCON would not accept coordinates with west longitude or south latitude**.**

•Allows user control of conversion grid selection: the application performs conversions based on the conversion type selected by the user.

- Provides datum conversions that are easily extensible: requiring only the additional new grids.
- Supports input and output data formats: maintains conversion of deferent formats, four formats are accepted :

-Single geographic point stated as a latitude/longitude pair of coordinates

• Degrees, minutes and seconds.

•Decimal values

•Degrees, Minutes

•UTM Pair of coordinates

- List Of points in Ascii file of *.txt or *.csv.

-Esri Shape File of points, Line or Polygon feature class.

-Raster image of *.TIFF format.

•Converts between datums: from old to new as well as from new to old. Such astransformations of coordinate values between Karbala 79 datum and International Terrestrial Reference Frame (ITRF00 (WGS84)) or from WGS84 to Karbala79.

• Shows the results on two types of map view: the user can select the results on either Iraq image or Iraq Google map.

•IRAQCON capability isexpanded: this property can be used to convert between old Iraqi datums in case of common points are available. Many conversion types such as conversion between old cadastral Iraqi mapswhich are based on another local datums. Moreover user can build a conversion types between old datums and any ITRF (International Terrestrial Reference System) epoch.

The Functions of IRAQCON

IRAQCON transforms latitude and longitude coordinate values between two geodetic coordinate systems known as “datums”. To do so, IRAQCON uses a pair of conversion grids that essentially provide a transformation “bridge” between the two datums. To perform the conversions, the IRAQCON application reads input coordinate data and uses an algorithm to calculate new coordinate values and shift offsets [5]. Results are displayed in seconds and meters with the new values are displayed. Each conversion requires the presence of conversion grids that are pairs of binary files (*.las, *.los) made up of a grid array of datum shift values plus spatial location and parameter information. Datum shifts for each input value are calculated based on an algorithm that interpolates the positional data using a minimum curvature function. IRAQCON conversions between datums are approximate values based on models of real data. The accuracy of the transformations should be viewed with some caution. This method introduces approximately 0.05 meter uncertainty within the country of Iraq [6].
IRAQCON cannot improve the accuracy of data. Stations that are originally third-order will not become first-order stations. IRAQCON is merely a tool for transforming coordinate values between datums.

Validation

To test Iraqcon results, seven points were selected to be observed and compare the results of observation with the results of Iraqcon output. All these points are located in the south of ThiQar province. The following table shows the state of each point.

Table (1): list of selected IRAQCON test.

Name	latitude	longitude	State	Location	EPOCH
34099	30.98434	46.65945	Observed in 2008 and exist now	ALFOHUD CITY	2008.7904
38009	30.88145	46.57552	Not observed in 2008 and exist now	ALGARMA	
38010	30.9122	46.65239	Not observed in 2008 and exist now	AL TAR	

All points that found exist and can be reached are observed by TOPCON GR3 GNSS receiver with a static observation method.

GNSS Observation.

According to the current shutdown of Iraq CORS stations, the observation of test points need a base point to be observed for not less than 4 hours to get a sufficient accuracy. For that reason a base point selected in GarmatBaniSaeed city and observed for more than five hours. The rinex file of base point observation is processed by OPUS website to get the accurate coordinate of base point.
According to the state of point that is shown in table (1) only three control points have been observed. The other points are either destroyed or could not be reached. The observed points are: 38009, 38010 and 34099. Each point is observed for more than 15 minutes. Topcon Tools software is used to process the observation data of these three points.

Since the base point referenced to ITRF08 the three observed points are referenced to the same frame. To compare the coordinates values of Iraqcon output with the observed values the ITRF and epoch for the observed and the converted values have to be same. ThiQar Province is selected to be a case study for testing results of IRAQCON conversion values. There are ten control points in ThiQar were observed in 2008 by State Commission on Survey. So the following steps were followed for testing process.

1- Ten control point rinex files were processed by OPUS to get the ITRF08 coordinates.
2- Using the coordinates values from step one to create a grid files and conversion type for ThiQar area. Note that all points are observed in 2008, so they can be assumed to have the same epoch (2008.5).
3- Using the conversion type from step two in Iraqcon, the test three points 38009, 38010 and 34099 are converted from Karbala 1979 to ITRF08. At this step we determine the ITRF08 values for the observed and converted values.
4- The converted values were transformed to epoch 2014.6391 which is the time of observing test points. This step is carried out by using the following equations.

$$E_{2014} = E_{2008} + Vx * Ts \quad \ldots(20)$$

$$N_{2014} = N_{2008} + Vy * Ts \quad \ldots(21)$$

Where:
E_{2014}=Easting in epoch 2014.
E_{2008}=Easting in epoch 2008.
N_{2014}=Northing in epoch 2014.
N_{2008}=Northing in epoch 2008.
VE= Velocity of motion for test points in East direction.
VN= Velocity of motion for test points in North direction.
Ts=Time Separation between two observation dates.

Motion of points is caused by the tectonic movement of earth crest so, the velocity of near points can be very similar. However NGS provide velocity as well as detailed information for each CORS station. This information can be obtained from NGS Basrah CORS station from the following website:

http://www.ngs.noaa.gov/cgi-cors/corsage_2.prl?site=ISBS.

In this website the detailed information of Basrah CORS station can be found. It can be seen from this information that the velocity in northward is 0.0341 m/yr and in eastward is 0.0289 m/yr.

The following tables shows the comparison process of observed and converted data

Table (2): coordinates of test points in Karbalaa79 datum

Point name	Karblaa 79 Clarc1880			
	Geodetic (dd mm ss.ss)		UTM(m)	
34099	30º 59' 03.0599"	46º 39' 44.6681"	658745.35	3428770.15
38009	30º 52' 52.6349"	46 º 34' 42.5201"	650891.34	3417248.60

38010	30º 54' 43.3259"	46 º 39' 19.2358"	658189.51	3420763.12

Table (3): coordinates of test points in ITRF08 EPOCH 2008.5

Point name	ITRF08 From IRAQCON EPOCH 2008.5)			
	Geodetic (dd mm ss.ss)		UTM(m)	
34099	30º 59' 03.6422"	46 º 39' 34.0305"	658457.797	3429048.500
38009	30 º 52' 53.2270"	46 º 34' 31.8833"	650603.783	3417526.911
38010	30 º 54' 43.9194"	46 º 39' 08.6053"	657901.959	3421041.447

Table (4): coordinates of test points in ITRF08 EPOCH 2014

Point name	Velocity Of Techtonic Motion m/y		ITRF08 From IRAQCON EPOCH (2014.6391)	
	V_E	V_N	UTM(m)	
34099	0.0289	0.0341	658457.9744	3429048.709
38009	0.0289	0.0341	650603.9604	3417527.12
38010	0.0289	0.0341	657902.1364	3421041.656

Table (5): the deference between coordinates in same ITRF provides more accurate results.

ITRF08 Observed (EPOCH:2014.6391)				Deference between EPOCH08 and EPOCH2014		Deference in same EPOCH2014	
Geodetic(dd mm ss.ssss)		UTM(m)		ΔE(m)	ΔN(m)	ΔN(m)	ΔE(m)
30 59 03.64840	46 39 34.03740	658457.978	3429048.695	-0.181	-0.195	-0.004	0.014
30 52 53.23399	46 34 31.88795	650603.903	3417527.129	-0.120	-0.218	0.057	-0.009
30 54 43.92545	46 39 08.61114	657902.111	3421041.635	-0.152	-0.188	0.025	0.021
RMS				**0.15**	**0.20**	**0.04**	**0.02**

From table (2)-(5) it can be seen that ITRF type and EPOCH may influence the accuracy of conversion. So ITRF and EPOCH have to be considered in conversion calculation. For that reason the final step in this research was to determine the coordinate of all used control points to ITRF08 by processing there observations files with OPUS then use equations (20) and (21) to transfer these coordinates to EPOCH 2014. To avoid losing accuracy by converting geodetic to UTM coordinates and return them back to geodetic when creating grid files, geocentric coordinates (X, Y, Z) are used to calculate epoch 2014 coordinates. So the following equations are used instead of (20) and (21).

$$X_{2014}=X_{2008}+Vx * Ts \quad \ldots(22)$$

$$Y_{2014}=Y_{2008}+Vy * Ts \quad \ldots(23)$$

$$Z_{2014}=Z_{2008}+Vz * Ts \quad \ldots(24)$$

Where:

X_{2014}, Y_{2014} and Z_{2014} are geocentric coordinates epoch 2014.

X_{2008}, Y_{2008} and Z_{2008} are geocentric coordinates epoch 2008.
Vx, Vy, Vz are velocities of motion in X, Y and Z direction respectively.
Ts is the time separation between previous and present observation dates .
Note that all dates should be in decimal year format. For exampleTs = 2014.6391-2007.9462=6.6929.

The following steps of testing were applied to all control points which have available raw rinex files. Unfortunately some control points were observed for less than two hours, so they could not been processed in present time according to the current stop of all Iraq CORS stations. The following steps were used to find out the final accuracy of IRAQCON conversion.

1- All the available rinex files for control points are processed with OPUS website again to get the updated coordinates values referenced to ITRF08.
2- Using equation 5.13, 5.14 and 5.15 to transfer all geocentric coordinates to EPOCH 2014 and convert them back to geodetic format by using matlab function called cart2ell.m.
3- Creating a new grid and conversion type by using IRAQCON for all Iraq area.
4- Perform the conversion process for the three test point to find out the corresponding ITRF00 Epoch2014 coordinates .
5- Compare the converted with the observed coordinates.

Table (6): coordinates of test points in ITRF08 EPOCH 2014.6391

Point Name	ITRF08 From IRAQCON EPOCH 2014.6391)			
	Geodetic		UTM	
34099	30 59 03.6488	46 39 34.0369	658457.964	3429048.708
38009	30 52 53.2339	46 34 31.8895	650603.945	3417527.126
38010	30 54 43.9262	46 39 08.6116	657902.123	3421041.659

Table (7): the deference between coordinates in same ITRF and EPOCH

Point Name	ITRF08 Observed (EPOCH:2014.6391)				Deference of epoch 2014	
	Geodetic		UTM		ΔE(m)	ΔN(m)
34099	30 59 03.6484	46 39 34.0374	658457.978	3429048.695	-0.014	0.013
38009	30 52 53.2340	46 34 31.8879	650603.903	3417527.129	0.042	-0.003
38010	30 54 43.9254	46 39 08.6111	657902.111	3421041.635	0.012	0.024
RMS					**0.03**	**0.02**

CONCLUSIONS

- The issue of datum transformation from local to global (WGS84) coordinate systems is a real, persistent and serious problem in Iraq that requires pragmatic solutions. Therefore, this work aims to develop and evaluate the best fit mathematical model of the existing control network system of Iraq to the WGS84 system. From the applied method the following conclusions can be drawn:
- The approach "minimum curvature surface interpolation" via Geodetic Coordinates can be used for high precision geodetic projections in Iraq by using developed software (Iraqcon) simply because of obtaining high precision of (0.03) meter in ΔE and (0.02) meter in ΔN.

- To conclude, this approach (Datum Transformations via Geodetic Coordinates with the minimum curvature surface interpolation) represents the best fit mathematical model of the existing control network system of Iraq to the WGS84 system.

Results

This research results in producing standalone software to perform the geodetic conversion between the local geodetic datum Kerbalaa79 and the World Geodetic System WGS84 with feasible accuracy.

Refrences

[1]OGP Publication 373-7-2., (2013). Coordinate Conversions and Transformations including Formulas, Geomatics Guidance Note Number 7, part 2.

[2]Briggs, I. C., (1974). Machine contouring using minimum curvaturre, Geophysics, vol. 39, NO.1, pp.39_48.

[3]Webring, M., (1981). MINC: Agridding program based upon minimum curvature, U.S., Geological Survey Open File Report 81-1224, 41 pp.

[4]Warren T Dewhurst, Rockville, MD., (1990).THE APPLICATION OF MINIMUM CURVATURE IN THE TRANSFORMATION, NOAA Technical Memorandum NOS NGS-50.

[5]Ghosh, Sanjib K., (1979). "Analytical Photogrammetry", Pergamon Press, New York.

[6]Cindy Craig, (July 2010). NADCON v4.2, User Manual , National Geodetic Survey,Information Manufacturing Corporation.