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Conversion of Coordinates from Psuedo or Web Mercator to the Universal Transverse Mercator Minna Zone 32

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Abstract— *Coordinate transformation can be viewed as an important procedure which aims at converting data from one reference system to another using a set of control points measured in both systems. It is also the mathematical procedure to establish a geometrical relationship between a source coordinate system (local or image coordinate system) and a target coordinate system (world or object coordinate system). This procedure estimates the transformation parameters using a set of control points measured in the two coordinate systems. In this research the transformation parameters for Minna UTM zone 32 and Web Mercator or UTM World Wide were developed using a fit-for-purpose approach whereby coordinates in UTM Minna zone 32 are transformed to the Web Mercator and vice versa.*

Keywords— *Coordinate Transformation, Reference system, Web Mercator, Fit-for purpose, Parameters.*

I. INTRODUCTION

Attempts at coordinate transformation from one system to another have been made by many researchers. Among such researchers are Edoga (1979), Karney (2011) and Idowu (2012). In the cases mentioned above, their efforts were aimed at transforming coordinates from NTM i.e. Nigerian Transverse Mercator to the Universal Transverse Mercator using either analytical or numerical techniques. Such approaches were however tedious, rigorous and difficult to comprehend. Didigwu (2005) presented a simpler but fulfilling approach for the computation of three variables namely scale, rotation of axis and origin. Edan (2014) presented an easy to understand approach by transforming coordinates on Nigeria Transverse Mercator (NTM) to the Universal Transverse Mercator (UTM).

The use of the Google Earth Map and other online digital maps like Bing map, Openstreetmap, MapQuest, ESRI and a host of others have become a common place. All these online mapping platforms use the Web/Pseudo Mercator. The ability to transform the coordinates from one system to the other will be beneficial to users of these online mapping services to enable them establish relationship between these products and the projection system in use locally in Nigeria namely the UTM Minna zone 32.

Maps are basically a flat or planar representation of part or the earth's total surface. There is usually a problem in map making which is the impossibility to develop a surface with double curvature like the sphere or ellipsoid, onto a plane surface without distortion of same sort (Gregory, 1982). Many map projections are designed to maintain some properties of the ellipsoidal surface with minimal distortion. These are azimuthal, oblique, cylindrical and conformal projections. The Transverse Mercator is a conformal cylindrical one which can be visualized as a cylinder wrapped around the earth and oriented so that its axis is in the plane of the equator.

The UTM is a universally accepted projection system with application limited to between 84^o N and 80^{o}S. The polar areas are covered by the Universal polar stereographic projection (UPS). The UTM overlaps 30^o onto the UPS which extends from the poles to 83^o 30' N or 79^o 30'S respectively (DMATM 8353.2, 1989). The UTM has zones 6^o wide in longitude and uses a central scale factor of 0.9996.

However, the cylinder is often slightly smaller than the earth in radius and it intersects the earth along two ellipses equally spaced from and parallel to a central meridian of longitude (Uzodinma & Ezenwere 1993). The UTM is a universally accepted projection system based on the Transverse Mercator with more modifications (Idowu 2012).

Coordinate transformation can be defined as the process of establishing the relationship between coordinates systems in order to be able to convert points existing in one system to another. It can occur in a variety of methods depending upon the purpose for which the transformation is sought (Idowu 2012). Felus and Felus (2009) viewed it as an important procedure which aims at converting data from one reference system to another using a set of control points measured in both systems. They also defined it as the mathematical procedure to establish a geometrical relationship between a source coordinate system (local or image coordinate system) and a target coordinate system (world or object coordinate system). This procedure estimates the transformation parameters using a set of control points measured in the two coordinate systems. In this research the transformation parameters were developed using a fit-for-purpose approach whereby coordinates in UTM Minna zone 32 are transformed to the Web Mercator and vice versa.

The fit-for-purpose mathematical model

This is the easy to comprehend mathematical model presented in Oliver and Clendinning, (1979) involving only three variables out of which two were principally used here namely:

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I. $Swing\ (\theta)$ and
II. Scale ratio (m)

II. DATA ACQUISITION (METHODOLOGY)

The procedure adopted for acquiring the data was by reading the coordinate of points of interest (POIs) on the two datums of UTM Web Mercator and UTM Minna zone 32. Two 0SGoF pillars namely XSP 70 and YSP 11 located at the Secretariat of Igalamela/Odolu and School of Environmental Studies Federal Polytechnic Idah respectively were observed and the readings obtained showed differences in both datum. These differences were noted for a sufficiently large number of points and averaged. Table Below shows the readings on both.

EXTRACT OF GPS FIELD OBSERVATION

UTM MINNA 08 Z 31 – 33	**UTM WW**	**STATION**
E: 290233.268	290155.539	A
N: 814943.505	815067.484	
Z: 383.40	376.07	
E: 290247.055	290167.152	B
N: 8149914.062	815034.272	
Z: 377.49	375.70	
E: 290241.411	290170.460	C
N: 814909.939	815033.775	
Z: 385.87	373.16	
E: 290244.386	290170.832	D
N: 814909.714	815033.887	
Z: 383.89	3372.20	
E: 290244.284	290169.481	E
N: 814911.238	815033.976	
E: 290165.242	290087.008	F
N: 814893.453	815013.782	
Z: 389.40	379.50	
E: 290164.700	290087.008	G
N: 814893.403	815013.782	
Z: 389.40	379.50	
E: 290164.700	290087.008	H
N: 814893.403	8150013.782	
Z: 384.95	379.50	
E: 290165.146	290087.002	I
N: 814893.854	815012.307	
Z: 389.77	381.60	
E: 290165.029	290087.006	J
N: 814893.570	815013.045	
E: 290154.840	290083.769	K
N: 814929.457	815052.336	
Z: 380.14	369.95	
E: 290155.511	290079.082	L
N: 814932.012	815049.624	
Z: 380.77	370.68	
E: 290156.141	290077.776	M
N: 814932.656	815049.219	
Z: 371.92	368.43	
E: 290155.497	290080.209	N
N: 814931.375	815050.393	
E: 290233.268	290155.539	O
N: 814943.505	815067.484	
Z: 383.40	376.07	
E: 290233.581	290155.453	P
N: 814947.122	815066.592	
Z: 383.54	382.92	
E: 290235.339	290157.169	Q
N: 814950.306	815066.760	
Z: 378.40	384	
E: 256551.53	256472.33	R
N: 789118.69	789127	
E: 256553.72	256476.37	S
N: 789142.92	789262.48	
E: 249654.14	249653.82	T
N: 786729.36	789653.82	
Z: 88.793	69.64	
E: 259011.40	258936.92	U
N: 791886.78	792005.1	

III. DATA PRESENTATION

Two OSGoF control pillars namely XSP70 and YSP11 observed on both coordinate systems were analysed. The bearing and distance on both datums were found and there was a measure of precision. The differences of 1.06m and 0^0 6^0 44^{11} in distance and bearing respectively were observed.

The differences in northings and eastings on both datums were computed. From these, the bearings and distances between the two pillars on both datums were found.

As earlier noted the parameters required for this conversion were:

1 $Swing\ (\theta)$ and
2 Scale ratio (m)

The swing $(\theta) = \theta_2 - \theta_1$

Where $\theta_{2\,=}$ bearing in the second system coordinate
$\theta_{1\,=}$ bearing in the first system coordinate

The scale ratio (m) = s_2/s_1

where $s_{2\,=}$ bigger distance
$s_{1\,=}$ smaller distance

The second system bearing was then computed as $\theta_{2\,=}\,\theta_{1\,+}\,\theta$

Where $\theta_{1\,=}$ first system bearing and θ = swing

The second system distance was also computed as: ms_1

Where m = scale ratio and s_1 = first system bearing

These two parameters were used to re - compute the bearing θ_2 and distance S_2 in the second system to which conversion is sought and the bearing and distance in the second system were obtained as computed from their coordinate values with minor variation. Furthermore the scale ratio as computed tallied with the one given as example in the text cited which suggested that it was a constant. The research was able to establish that the scale ratio was actually a constant as evident from other works (e.g. Edan, *et al.* 2014).

The Easting and Northing in the second system were then computed using the formulae

$E = E_A + S_2\sin\theta_2$, where $E_A = \Delta E$ in the second system coordinate, S_2 and θ_2 are as explained and E is the transformed easting coordinate

$N = N_A + S_2\cos\theta_2$, where $N_A = \Delta N$ in the second system coordinate, S_2 and θ_2 are as explained and N is the transformed northing coordinate.

Where swing = $\theta = \theta_2 - \theta_1$

$$\text{Scale ratio} = m = \frac{S_2}{S_1} = \left[\frac{(\Delta E)^2 + (\Delta N)^2}{(\Delta e)^2 + (\Delta n)^2}\right]^{1/2}$$

Where $\theta_2 = \arctan\left(\frac{\Delta E}{\Delta N}\right)$ in the second system coordinate

$\theta_1 = \arctan\left(\frac{\Delta e}{\Delta n}\right)$

$\Delta E = E_B - E_A$, $\Delta N = N_B$ - NA

$\Delta e = e_B - e_A$, $\Delta n = n_B - n_A$

For every other point of the survey, the bearing and distance θ_1 and S_1 from XSP 70, YSP11 or from any other point of the survey that is transformed to the second system, is calculated from the local system coordinates. They are then transformed into corresponding quantities on the new system

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by simply adding θ to the bearing and multiplying the distance by m, i.e.
$\theta_2 = \theta_1 + \theta$
$S_2 = ms_1$

The new coordinate differences were computed using the new bearing and distance and applied to the second system coordinates of the point from which the first – system bearing and distance were computed.

In this case, $E_{XSP70} = \Delta_{EYSP11} + S_2 Sin\theta_2$
$N_{XSP70} = \Delta_{NYSP11} + S_2 Cos\theta_2$

In the reverse computation
$E_{XSP70} = \Delta_{EYSP11UTMWW} + S_2 Sin\theta_2$
$N_{XSP70} = \Delta_{NYSP11\ UTMWW} + S_2 Cos\theta_2$

In the reverse case, $E_A = \Delta E$ in the Minna UTM zone 32 and $N_A = \Delta N$ in the Minna UTM zone 32
The swing $\theta = \theta_1 - \theta_2 = -0^0\ 06^0\ 44^1$
The scale ratio = 1.000286325
$\theta_2 = \theta_1$ - 1.000286325

The differences in Easting and Northing were respectively – 0.03m and - 0.04m.

A reverse computation was done to convert from UTM Worldwide to UTM Minna Zone 32 following the same approach. This gave discrepancies of 0.01 and 0 in Easting and Northing respectively.

The conversion from UTM Worldwide to UTM Minna Zone 32 gave a better accuracy. This confirm that both systems are correct in their respective rights and conversion to UTM Minna Zone 32 is viable and can be upheld. The established difference in reading for respective stations mentioned in the methodology are realistic and inference made are tenable and upheld.

IV. Presentation of Results

The above is mathematically represented as follows:
Where swing = $\theta = \theta_2 - \theta_1$
Scale ratio = m = $\frac{S_2}{S_1} = \left[\frac{(\Delta E)^2 + (\Delta N)^2}{(\Delta e)^2 + (\Delta n)^2}\right]^{1/2}$
Where θ_2 = arc tan $\left(\frac{\Delta E}{\Delta N}\right)$ in the second system coordinate
θ_1 = arc tan $\left(\frac{\Delta e}{\Delta n}\right)$
$\Delta E = E_B - E_A$, $\Delta N = N_B$ - NA
$\Delta e = e_B - e_A$, $\Delta n = n_B - n_A$

For every other point of the survey, the bearing and distance θ_1 and S_1 from XSP 70, YSP11 or from any other point of the survey that is transformed to the second system, is calculated from the local system coordinates. They are then transformed into corresponding quantities on the new system by simply adding θ to the bearing and multiplying the distance by m, i.e.
$\theta_2 = \theta_1 + \theta$
$S_2 = ms_1$

The new coordinate differences were computed using the new bearing and distance and applied to the second system coordinates of the point from which the first – system bearing and distance were computed.

In this case, $E_{XSP70} = \Delta_{EYSP11} + S_2 Sin\theta_2$
$N_{XSP70} = \Delta_{NYSP11} + S_2 Cos\theta_2$

In the reverse computation
$E_{XSP70} = \Delta_{EYSP11UTMWW} + S_2 Sin\theta_2$
$N_{XSP70} = \Delta_{NYSP11\ UTMWW} + S_2 Cos\theta_2$

In the reverse case, $E_A = \Delta E$ in the Minna UTM zone 32 and $N_A = \Delta N$ in the Minna UTM zone 32
The swing $\theta = \theta_1 - \theta_2 = -0^0\ 06^0\ 44^1$
The scale ratio = 1.000286325
$\theta_2 = \theta_1$ - 1.000286325

V. Analysis of Results

The differences in Easting and Northing were respectively – 0.03m and - 0.04m.

A reverse computation was done to convert from UTM Worldwide to UTM Minna Zone 32 following the same approach. This gave discrepancies of 0.01 and 0 in Easting and Northing respectively.

The conversion from UTM Worldwide to UTM Minna Zone 32 gave a better accuracy.

VI. Conclusion

This confirm that both systems are correct in their respective rights and conversion to UTM Minna Zone 32 and vice versa is viable and should be upheld.

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