Software development & validation for Geodetic Datum Transformations

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Abstract

A common problem faced by most countries is the estimation of precise transformation parameters between their national geodetic datum, and the World Geodetic System 1984 (WGS84) global datum, used by the Global Positioning System (GPS). In this study, a coordinate transformation package has been developed for this purpose, under UNIX environment, using the C programming language. It is capable of estimating the seven transformation parameters between any two geodetic datums, and transforming geodetic coordinates from one geodetic datum to another. The software offers the option to transform the coordinates of a single point interactively, or to transform the coordinates of any number of points, listed in an input file. It is primarily designed to perform the seven parameter Helmert transformation from WGS84 / EURopean REference Frame (EUREF) to EOV (Hungarian National Frame), in Cartesian coordinates. It uses a database of geodetic points, for which the Cartesian coordinates are known in both the systems. The program uses the principle of least square adjustment, to estimate the transformation parameters. This work has been carried out at the FOMI Satellite Geodetic Observatory, Penc, Hungary. However, the software can also transform coordinates between any other geodetic datums, provided that the necessary database of points is available. The details of the software, and results obtained using test data, are presented in this paper. This software can also been used for the estimation of transformation parameters in the Bhuj and Koyna regions where GPS surveys for earthquake studies are quite frequent.

Introduction

A common problem faced by most countries is the estimation of precise transformation parameters between their national geodetic datum, and the World Geodetic System 1984 (WGS84) global datum, used by the Global Positioning System (GPS). In this study, a coordinate transformation package has been developed for this purpose, under UNIX environment, using the C programming language.

Transformation parameters

There can be considerable difference in positions of the local ellipsoidal datum and the global datum, sometimes up to several hundred meters. So a country like India may require a lot of datums for accurate transformation of coordinates from the local datum to the global one and the vice-versa. A country like Hungary, on the other hand uses just one datum, HD-72. With the increasing exchange of geographic information local and globally, positions need to be available in terns of both a local and global datums. The process of mathematically converting positions from one datum to the other is known as datum transformation. Datum transformation parameters define functional relationship between two reference frames. The GPS derived coordinates (which are with respect to the global datum), and the local terrestrial coordinates (which are relative to the local datum of the region) of the lumped points may be processed together using an appropriate transformation model. This forms the required set of database for calculating the result, which would be a set of quantities termed as transformations parameters which could be used for converting coordinates from one datum to the other and vice-versa. The combination of data sets from two or more different sources is purely a matter of adjustment and the technique used in this case is “least square adjustment”. Since cartographers work with projections

systems, in general, the transformation from one projection system to any other projection system can be performed as it follows:

1) From projections system1 to its corresponding datum, say datum1
2) From datum1 to one of Global reference frames (Say to WGS-84]
3) From global reference frame to the Datum of interest. Say datum2,
4) From Datum2 to the projection system in goal.

The first and last steps are easily solved using the appropriate formulae

We are interested in solving steps 2 and 3, which is accomplished using this software. The method is as follows:

Formula for transformation:

$$\begin{vmatrix} X_{Global} \\ Y_{Global} \\ Z_{Global} \end{vmatrix} = \begin{vmatrix} dX \\ dY \\ dZ \end{vmatrix} + (1 + k) \times \begin{vmatrix} 1 & E_Z & E_Y \\ -E_Z & 1 & E_X \\ E_Y & -E_X & 1 \end{vmatrix} \times \begin{vmatrix} X_{HD-72} \\ Y_{HD-72} \\ Z_{HD-72} \end{vmatrix}$$

where

X_{Global} , Y_{Global} , Z_{Global} - *the coordinates in system WGS-84 (Global Datum)*

dX , dY , dZ - *origin difference between the two systems (translational parameters),*

k - *scale difference between the two systems,*

E_X , E_Y , E_Z - *rotation around the **X, Y, Z** axis*

X_{HD-72} , Y_{HD-72} , Z_{HD-72} - *coordinates in the HD-72 system(Local Datum)*

Source of Information : *Joó, I. et al., 1985; Ádám, J., 1987; Official communications (Ádám, J. and Borza, T.); Gubler, E. et al. (eds), 1992; Gubler, E. et al. (eds), 1993; (see Chapter 8).*

The software

The software requires a Database of points with the coordinates known in both the reference systems. It then calculates the coordinates of the points required in the local coordinate system, given the coordinates of the point in the WGS 84 system. The points used for estimating the transformation parameters, which vary from region to region, for the point/points in question, are chosen by the program by calculating the distances of the point from all the points given in the database and then choosing all the points which are within a range of 20 Km. The program is user friendly and lets the user know if there are no points within a range of 20 Km. A minimum of 3 points has to be lie within the range, else the program won't proceed, since the method used is the "Least Square Adjustment". There are seven transformation parameters to be estimated. the principle used is least square adjustment. The utility of the software simply put, is because of the fact that one can't perform the complex and huge matrix operations without a computer. The matrix used can be of the order of 100*100 depending on the number of points in the vicinity of the point of interest. The program can take input interactively one after the other, or take input from some user defined file.in the applicable format

Results

The work in Hungary involved a huge database of 1150 points surveyed all over the country, with modern GPS instruments and Terrestrial Geodetic techniques, the later being collected painstakingly over the years. The coordinates of some points at the international borders, which were measured with respect to the GPS instruments and transformed approximately into the local coordinates, were falling into the neighboring country. So it called for a program which could accurately measure the seven Transformation parameters and hence the

coordinates in the local datum too, given the GPS coordinates of the point of interest. Since the database is confidential, only the sample results are given here.

SAMPLE DATABASE OF POINTS

Point	GPS coordinates		
	X	Y	Z
Pili	4082873.474	1454082.764	4664021.508
Penc	4052392.820	1417750.672	4701415.990
Tisz	4052457.444	1518221.640	4669885.105

Point	Local coordinates		
	X	Y	Z
Pili	4082870.524	1454084.764	4664020.878
Penc	4052388.355	1417749.104	4701410.778
Tisz	4052453.964	1518220.270	4669888.242

The results given by the program were very accurate which were tested by giving one of the same points as the input, and the output was as expected, with a difference of few centimeters.

The output for the point- Penc was as follows :

X = 4052388.378
Y = 1417749.100
Z = 4701410.756

Unfortunately, the limited database of points in Bhuj, acted as a bottleneck in trying to work out results with the program on points of interest in the region. GPS coordinates of the points in the region are readily available, but the local coordinates are not.

Conclusion

The software can transform coordinates accurately between any two geodetic datum's, provided the necessary database of points is available. The software can be put to use more effectively if its made into an executable file, so that it doesn't require the user to reach for a computer, or compile and run the program each time he wishes to transform coordinates. Unfortunately. the C-programming language has a shortcoming in this regard, in that the program is compiler dependant. So it's executable file from an Unix environment can't be used elsewhere.

References

1) Joó I.-Ádám J.-Czobor Á.-Mihály Sz., 1985: Improvement of the Hungarian National Geodetic Control Network by Satellite Doppler Positioning.
Proceedings of FIG Study Groups 5B and 5C, July 1985, München.

2) Sz. Mihaly,1995: Description directory of the Hungarian Geodetic Reference, © FÖMI, 1995, Budapest,

3) Joó, I. et al., 1985; Ádám, J., 1987; Official communications (Ádám, J. and Borza, T.); Gubler, E. et al. (eds), 1992; Gubler, E. et al. (eds), 1993; (see Chapter 8).

4) Singh S.K, Coordinate transformation between everest and WGS – 84 datums – A parametric approach. Geodetic & Research Branch, Survey of India, Dehradun-2002