Calculating NADCON Grids using GeoTools

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Abstract

Coordinate Reference Systems and their relations are core part of every GIS. When we try to combine data in various kinds of coordinate reference systems (CRS) we can run into problems and find that the data doesn't fit to each other precisely even if they should. This happens especially in the case when we are working with data in CRS that had been established long time before GPS become widely used and the relation to precise global system is not simple.

In many cases we have some CRS transformation definition available that can be used for that propose (e.g. Bursa Wolf), but not all transformation methods are able to deal with local deformation of geodetic network that are our data based on, so we still can not combine data precisely. One of the rarely used method that deals with such problem are methods based on grid like NADCON transformation.

During the 2007 and 2008 there has been few things newly implemented as part of GeoTools library that generally deal with the problem of building transformation method from known ground control points. One of the functionality of this contribution is focused on calculating the NADCON grids.

This paper is describing the way how to calculate NADCON grids from known ground control points (GCPs) using GeoTools library. Several algorithms how this grid can be calculated will be compared and the final results will be shown. Finally particular example of our experience with calculating such grid for transformation between CRS used in the Czech Republic and WGS84 will be described.

1. Algorithm of NADCON Transformation

Grid-based methods allow you to model the differences between the systems and are potentially the most accurate method. As a first step area of interest is divided into cells - the width and height of these cells depends on accuracy that we are exacting and distribution of GCPs and their differences. In this way we prepare the grid.

Then we calculate the shift in both axis (latitude and longitude) for all of the vertices of such cells (grid) from known differences at GCPs. Usually we are using some kind of interpolation method (e.g. inverse distance weighted).

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Finally when we want to transform a point of our interest we have to find the cell where such point is located and then calculate the shift in both directions from known shifts of cell vertices. NADCON algorithm is using linear interpolation in each axis direction (bilinear interpolation). When we choose proper parameters of generated grid according to distribution of GCPs we should be able to transform all source control points precisely on the target control points.

This method is well implemented in lot of GIS products, but the NADCON grid configuration files is available just for transformation for few Coordinate Reference Systems (usually in the US). The different values in decimal seconds are stored in two files: one for longitude and the other for latitude. The NADCON file header contains (in order) the number of columns, number of rows, number of z-values (always one), minimum longitude, cell size, minimum latitude, cell size, and not used.

Example of NADCON file:

```
NADCON EXTRACTED REGION                                    NADGRD
 167 198   1    12.89116     .01000    48.84586     .01000     .00000
   -2.843056   -2.848042   -2.853026   -2.858007   -2.862987   -2.867963
   -2.872938   -2.877910   -2.882880   -2.887848   -2.892814   -2.897777
   -2.902739   -2.907699   -2.912656   -2.917612   -2.922565   -2.927518
   -2.932468   -2.937416   -2.942364   -2.947309   -2.952254   -2.957196
   -2.962138   -2.967080   -2.972020   -2.976961   -2.981899   -2.986839
   -2.991778   -2.996718   -3.001658   -3.006598   -3.011541   -3.016483
   -3.021429   -3.026375   -3.031322   -3.036274   -3.041228   -3.046185
   -3.051145   -3.056108   -3.061075   -3.066046   -3.071020   -3.075999
   -3.080983   -3.085971   -3.090962   -3.095960   -3.100963   -3.105970
    .
    .
    .
```

Such NADCON grid file can be stored in ASCII format or as a binary file as well. There is also a free software tool (NADGRD) that let users to convert these files from one format to another (more at [1]).

2. Use Case for NADCON Transformation

The most widely used transformation method is probably Bursa Wolf. This method can be accurate enough for global systems that are established on similar geodetic controls and that are not affected by local deformation. Such systems are usually those that are built by modern methods (GPS) the only difference is in geodetic datum.

When we would like to transform some old coordinate reference system based on old geodetic control to modern one (WGS-84) we usually have to deal with local differences that cannot be solved precisely by Bursa Wolf method. Such case can be solved by local transformation key for Bursa Wolf or by grid based method.

For example in the case of CRS used in the Czech republic S-JTSK (EPSG:2065) the Bursa Wolf method that is used in GIS has accuracy about 1m and so we can not use it for precise measurements and we can not for instance use engineering GPS measurements directly in our national CRS (we have to derive every time our own local transformation).

The distribution of differences between target points and transformed source points by Bursa Wolf method (in longitude direction) is on figure (2).

One of the possible solutions for such problem is to use some of the grid based method.

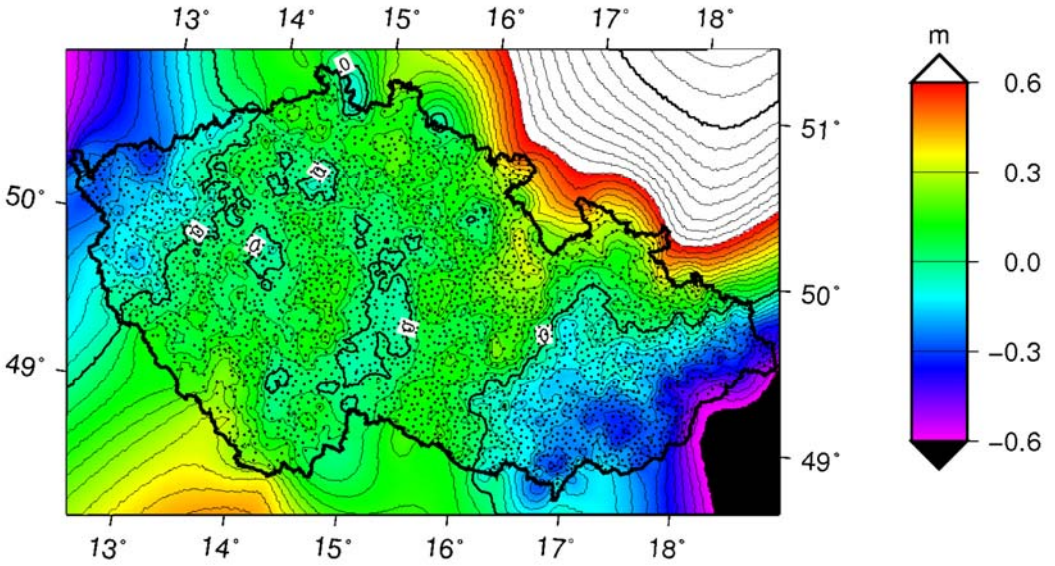

Figure 1. differnces in longlitude

3. Possibilities to Generate NADCON Grids With GeoTools

When trying to calculate our own grid file we have to choose few parameters:

- Height and width of grid cells - depending on the distribution of ground control points that are available and also on the accuracy that we are expecting from the transformation
- Interpolation method - the grid of shifts are calculated from GCPs by various kinds of methods (usually by some kind of interpolation).

The possibility to generate such files has been contributed to the GeoTools project this year (should become a part of GeoTools referencing module soon). The software can calculate the grid from known GCPs by various kinds of interpolation methods.

Java code example:

```
DirectPosition sDp = new DirectPosition2D();
DirectPosition tDp = new DirectPosition2D();

MappedPosition pos = new MappedPosition(sDp, tDp);
List<MappedPosition> mp = new ArrayList();
mp.add(pos);
.

.
NADCONBuilder builder = new NADCONBuilder(mp, dx, dy, env);
builder.writeDeltaFile(0, "/home/jezekjan/code/NADCON/vyber.laa");
builder.writeDeltaFile(1, "/home/jezekjan/code/NADCON/vyber.loa");
```

Figures (2), (3) and (4) shows the differences between three types of interpolation. Figure (2) shows also the source data and points that were transformed.

The GeoTools package enables you to calculate the NADCON files in ASCI format and also to generate another common GIS formats (geotiff). Such grid can be then analysed or classified by other GIS tools or process by GMT library for example (figure 2 is generated nearly directly from generated grid by GMT).

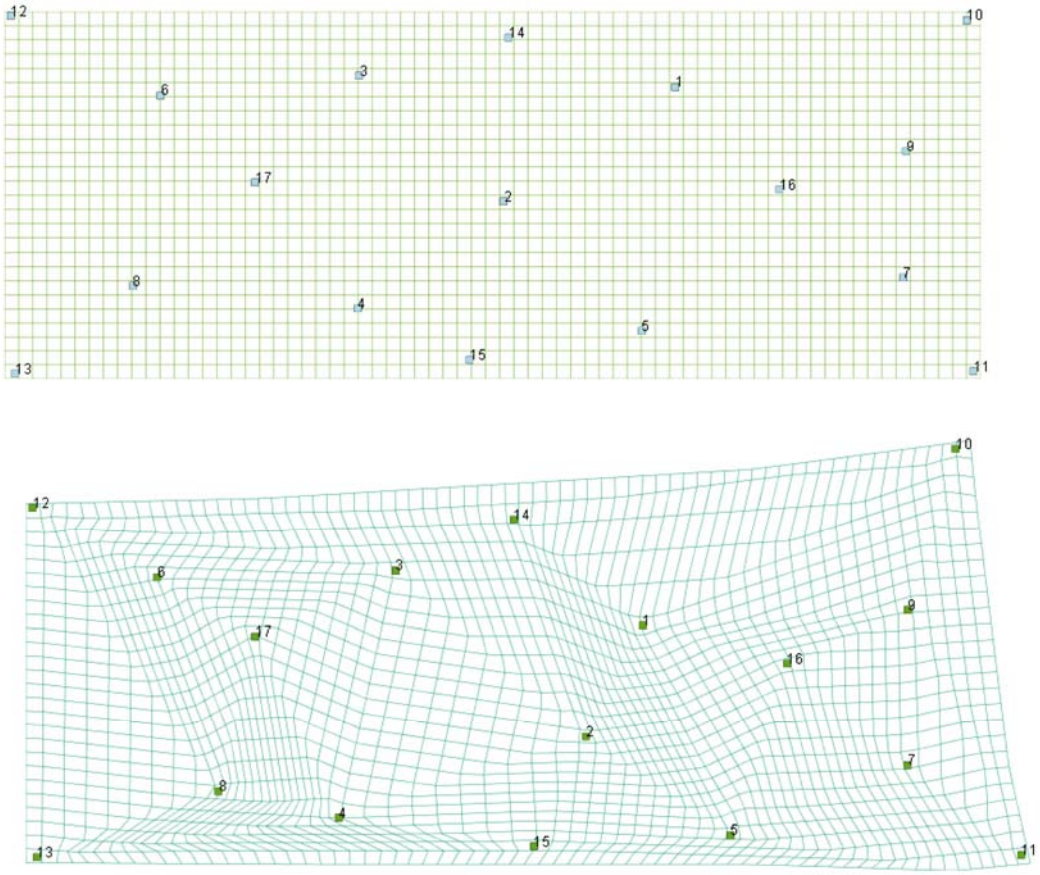

Figure 2. Rubber sheet interpolation

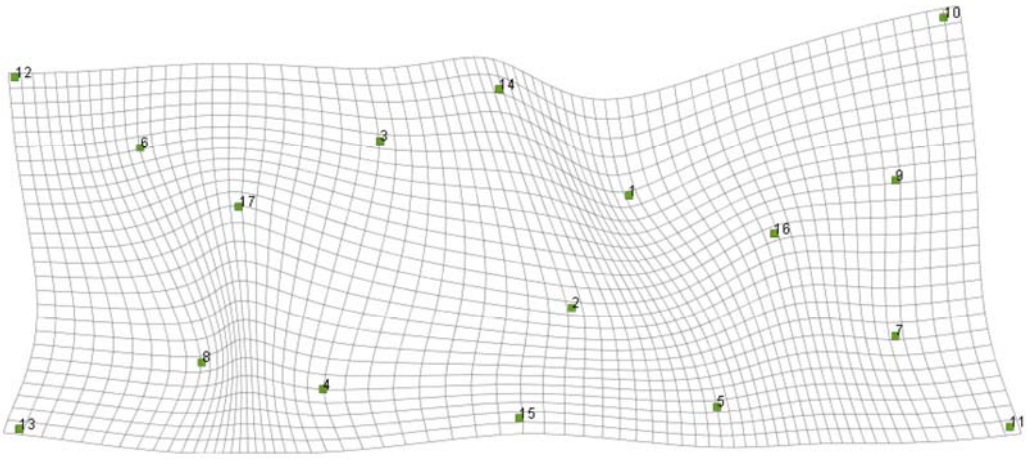

Figure 3. Inverse distance weighted interpolation

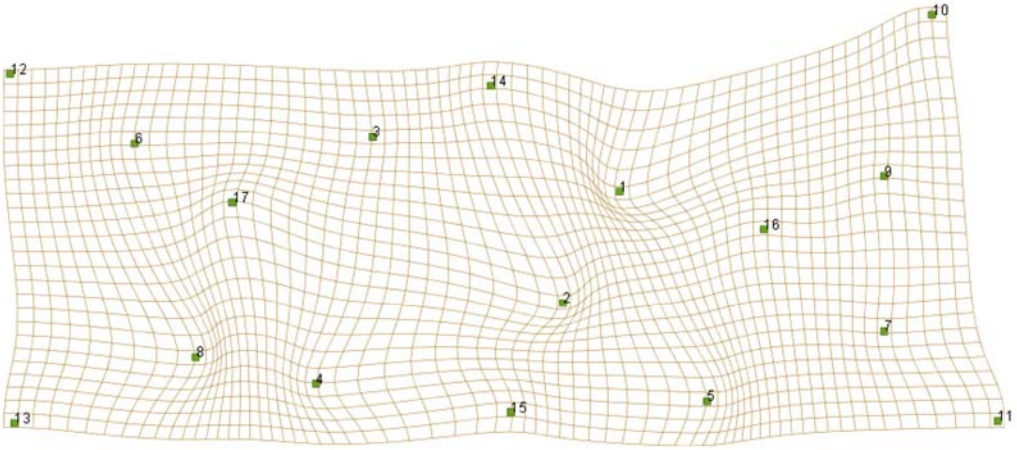

Figure 4. Thin plate spline interpolation

4. Example On System Used in Czech Republic

The NADCON transformation has been calculated for converting Czech national coordinate reference system (EPSG:4818) and WGS84 (EPSG:4326). The grid properties were:

- we used cca 3070 GCPs (directly measured in both systems)
- the grid cells were 0.01 degree high and width
- we used thin plate spline interpolation to generate this grid
- grid covers the whole area of the Czech Republic.

Calculated Root mean square error between transformed source points and target points was approximately 1 cm, which was required. The independent measurements shows the accuracy of about 1.5 cm (transforming newly measured data that we didn't count with during NADCON grid generation). To compare - the global transformation key for Bursa Wolf method (generated from same 3070 point) has accuracy of about one meter (see figure 2 that demonstrates the differences between transformed values by Bursa Wolf method and target coordinates).

5. Using Generated Grids

Generated grid files can be used in common GIS products that support such kind of method (Proj.4).

Another possibility is to use this grid files in ESRI ArcMap (you have to convert them to binary format at first using NADGRD software) - see figure (5). By making proper configuration you can transform data in whatever format you want (raster as well as vectors) according the functions of your favorite GIS.

6. Conclusion

In some cases we need to be able to work in GIS on high level of accuracy and to be able to fulfil the demands that are usually required from CAD systems and land surveyors tasks. Great progress of measurement technologies leads to the problem that widely used tools (differential GPS measurements, total stations) are much more precise that coordinate networks as such and that we often have to transform well measured data to old and not so accurate coordinate systems.

By calculating NADCON grid for such coordinate system we cat get unique and acceptable way to fix the transformation issue and to combine old and valuable data with actual and new high accurate measurements.

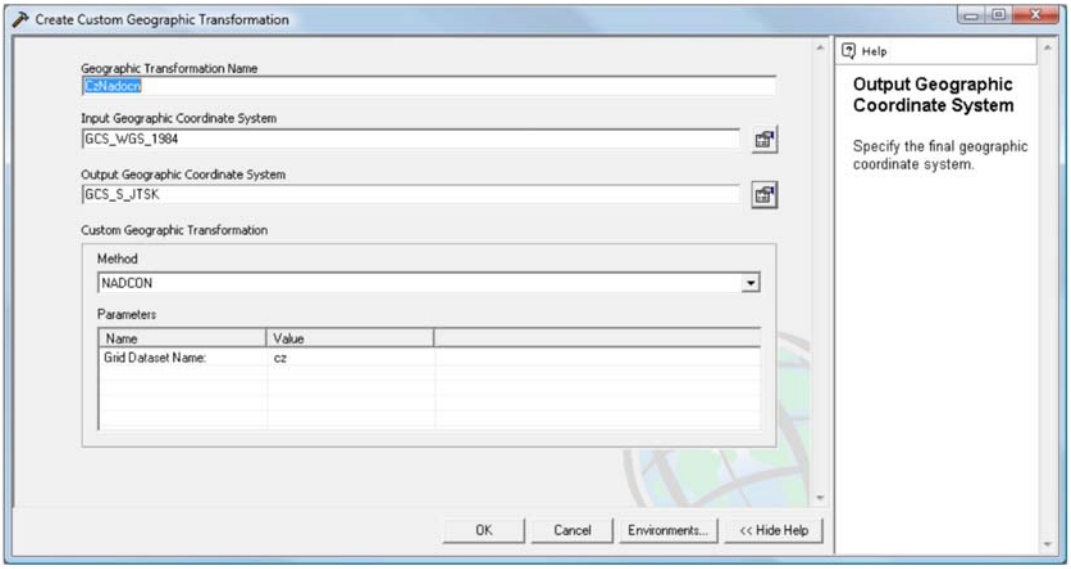

Figure 5. NADCON transformation in ArcMAP

References

[1] National Geodetic Surway home page: http://www.ngs.noaa.gov/PC_PROD/NADCON

[2] ArcGIS 9.2 Desktop Help: http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Grid-based_methods