

OPEN SOURCE GIS: TRANSFORMATION AMONG PARTICULAR COORDINATE SYSTEMS USED IN OUR TERRITORY USING SYSTEM PROJ

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Abstract:

At the department of mathematics started the grant, solving the www visualization and analyzing the open-cast mining activities and the reclamation development. Due to the long-term development prognoses of open source community software there was made a decision to develop strictly open source system. We solve transformation problem between coordinate systems applied in Czech Republic by the help of the freeware library PROJ.

The definitions of projections used in the PROJ system do not contain transformation parameters between various reference spheres (ellipsoids) and reference system ETRF-89 which is used for transition in transformation, therefor was the need to find the way how to find out these parameters and to use them in standard use in the programs using the PROJ library. Mapping server UMN MapServer and PostGIS (enhancement of relational database PostgreSQL enabling the use and manipulation of spatial objects).

Abstrakt:

Na katedře matematiky je řešen grant, jehož úkolem je vizualizace povrchové těžby a postupu rekultivačních prací pomocí www služeb. Vzhledem k předpokladu dlouhodobého vývoje open source software vyvíjíme systém používající striktně svobodný software. V současné době pomocí volně dostupné knihovny PROJ řešíme problém transformace mezi jednotlivými souřadnými systémy užitými na území České republiky.

Protože definice zobrazení použité v systému PROJ neobsahují parametry transformace mezi různými referenčními elipsoidy a referenčním elipsoidem ETRF-89, přes který se při každé transformaci přechází, bylo nutné najít způsob, jak tyto parametry zjistit a standardními prostředky využít v programech, které knihovnu PROJ používají. Tímto softwarem jsou mapový server UMN MapServer a PostGIS (nadstavba relační databáze PostgreSQL, umožňující ukládání prostorových objektů a manipulaci s nimi).

PROJ

The original program proj was developed by Gerald Evenden at the beginning of the eighties in the programming language Fortran for the purposes of the United States Geological Survey, where it served entirely for the calculations in the area of mathematical cartography and in itself was used only as single-purpose utility. The original source code was developed step by step and the next projections were gradually added. In the progress of time was rewritten to the C programming language and today is as a PROJ.4 is distributed under the MIT license as nearly all software created at the government organizations of the United States.

That gives the program practically the public domain status. Program package is maintained by Frank Warmerdam and was revised by him to the form of program library which allows to it the transparent use in various programs working with the spatial data. The original use as a standalone program remained, anyway the usability in the form of program library multiplies its potentials. In the applications with the support of PROJ library is possible to use simultaneously the data from different (supported) coordinate systems and the library supports the necessary transformation calculations to the coordinate system which is used for the work with the data.

All of the computations were performed in the PROJ package programs in the version 4.4.9. For the conversion of the coordinates from planar reference system to the geographic coordinates on the reference sphere is used the program proj or program invproj for the computations in reverse direction. For the transformations between particular systems is utilized the program cs2cs (cs for coordinate system). By reason that the finding and use of the transformation parameters among all of the reference spheres (ellipsoids), in the system PROJ is used one of the reference ellipsoids (ETRF-89) as a transitional and all the transformations are decomposed to two steps – the transformation from the source coordinate system to ETRF-89 and from ETRF-89 to the target coordinate system. However there is no public available authorized transformation parameters between Krassovsky reference ellipsoid (used as reference projection sphere for S-42 coordinate system) and ETRF-89.

PostGIS

This article should not only show the features and ways of use of PostGIS as a powerful tool for storing and manipulation of the geodata and the remotely network access to them in the frame of expected use by the subjects working with the geodata in the Czech Republic area [5], but as well the solution of the transformation among particular coordinate systems used in our area using the PROJ library.

Open source projects in the GIS area are monitoring the trends visible in the commercial systems. We can find here mainly desktop oriented systems (QGIS, GRASS) as well as the project aimed to the publication of spatially oriented data in the field of Internet/Intranet (e.g. UMN MapServer). Just like the commercial GIS there is an effort to divide the tools for storing the data and tools for processing them.

Scope of PostGIS

The OGC Simple Features Specifications for SQL standard defines the standard object types for GIS, the functions necessary for their manipulation and the set of database tables containing related metadata. From the reason of securing the data and their metadata consistency there are special procedures for the operations of creating or deleting the columns with the spatial objects.

PostGIS defines two tables containing metadata. The **geometry_columns** table with the information for particular tables (only those with the spatial objects) the necessary information about the type of geometry, object dimensions and used coordinate system using the identification number. The identification numbers are stored in the **spatial_ref_sys** table and their values are in accordance with the instruction of European Petroleum Survey Group (EPSG). Along with them are stored the definitions of the individual projections on the base of ESRI prj files and the principal information – the PROJ parameters for manipulation with the coordinate system. The EPSG instruction was selected because of its high elaboration level.

The way of treatment with the coordinate systems in the PostGIS environment

The principles of storing the geodata together with their metadata mentioned in the second paragraph allows to display together data from several coordinate systems. The transformation itself is solved using the functions of PROJ library with the transition over the reference space for which was chosen the reference system ETRS-89 (see [2]).

The PROJ program library solves the transition between different reference spheres using seven element Helmert transformation. This procedure gives acceptable results in the case of modern coordinate systems, but in the case of such heterogeneous coordinate systems such like S-JTSK and S-42 gives the results with as much as 5 meter absolute deviation. The alternative method to that one hereinbefore is for instance the evaluation of the increments of the spherical coordinates between two systems using conformal transformation of higher degree with the transformation key which was computed from the set of identical points. This algorithm is used for instance in the cartographic system MATKART [8].

The definition of JTSK coordinate system is not fully right and there was need to deal with the modification of the projection definition to get the proper results from the system.

First step was the minor modification of the PROJ source code (and subsequent recompilation) because by some oversight happened that the implementation of Krovak projection in PROJ remained somewhere on the half way between true Krovak ($X=-y$, $Y=-x$) and that one still usable in GIS (x,y). The signs were swapped, but the axes were not. The author of the patch is Radim Blazek, MEng. and the result after utilization of this patch is PROJ giving the coordinates usable for IIIrd quadrant of cartesian system of coordinates [4].

The results of transformations

The precision of the transformation among the coordinate systems S-JTSK, ETRF-89 and S-42 was examined on selected points of DOPNUL campaign [6,7]. The transformation was divided to four steps. We did the inverse Krovak projection [1] from the JTSK system to Bessel ellipsoid at first, then transformation to ETRF-89 ellipsoid and in consequence to Krassovsky ellipsoid. The last step was the application of the Gauss-Krüger conformal projection from Krassovsky ellipsoid in meridional zones [1] to the S-42 system.

PROJ allows the definition of those seven parameters of Helmert transformations between both reference ellipsoids and ETRF-89 system. The coefficients of rotation is necessary to set with plus sign (contrary to [3]).

In table 1 is presented the comparison of the system PROJ and Matkart when projecting from S-JTSK system to Bessel ellipsoid. The values of the geographic coordinates are not stated separately, because they are in both cases identical.

Point ID	Y[m]	X[m]	PROJ/Matkart φ Bessel	PROJ/Matkart λ Bessel
104	775279.26	1069759.49	49 48 34.219	14 01 33.620
119	768146.94	1155180.27	49 03 28.189	14 17 16.865
221	804332.20	1060930.08	49 51 01.361	13 36 31.077
404	702797.09	1042769.05	50 08 17.282	14 58 35.311
510	646145.87	1067707.23	49 58 42.610	15 48 16.950

Tab. 1: Latitude and longitude on the Bessel ellipsoid using PROJ and Matkart

Table 2 presents the values of latitude and longitude in the ETRF-89 (WGS-84) system enumerated using PROJ and Matkart. The values in second row of PROJ part are precisely determined by DOPNUL campaign. The results calculated using PROJ library differ from the DOPNUL campaign as far as in thousandths of seconds of arc. The results from Matkart differ already in tenths of seconds of arc.

Point ID	Proj φ ETRF-89	Proj λ ETRF-89	Matkart φ ETRF-89	Matkart λ ETRF-89
104	49 48 31.473 49 48 31.476	14 01 29.965 14 01 29.966	49 48 31.6	14 01 30.0
119	49 03 25.790 49 03 25.786	14 17 13.282 14 17 13.284	49 03 25.9	14 17 13.2
221	49 50 58.550 49 50 58.553	13 36 27.623 13 36 27.622	49 50 58.7	13 36 27.7
404	50 08 14.509 50 08 14.508	14 58 31.080 14 58 31.081	50 08 14.5	14 58 31.2
510	49 58 40.005 49 58 40.001	15 48 12.346 15 48 12.343	49 58 40.0	15 48 12.4

Tab. 2: Latitude and longitude in the ETRF-89 system calculated using PROJ and Matkart

Table 3 compares PROJ and Matkart when transforming the geographic coordinates from ellipsoid ETRF-89 to Krassovsky ellipsoid. The values of geographic coordinates. The values of geographic coordinates do not differ from each other significantly

In table 4 are compared the values of planar coordinates in the system S-42 using software PROJ and Matkart. The maximum difference of values, calculated by us in PROJ system in comparison with Matkart results, are about 2-3 meters for particular coordinates. Using PROJ library is possible to achieve a precision up to 1 decimeter. Rather big difference from Matkart is given by a lower precision of the program, using conformal transformation of only third degree.

Point ID	Proj φ Krassovsky	Proj λ Krassovsky	Matkart φ Krassovsky	Matkart λ Krassovsky
104	49 48 32.946	14 01 36.288	49 48 32.87	14 01 36.17
119	49 03 27.279	14 17 19.505	49 03 27.19	14 17 19.48
221	49 51 00.045	13 36 33.955	49 50 59.95	13 36 33.82
404	50 08 15.916	14 58 37.438	50 08 15.91	14 58 37.28
510	49 58 41.372	15 48 18.674	49 58 41.41	15 48 18.55

Tab. 3: The values of latitude and longitude on Krassovsky ellipsoid using PROJ and Matkart

Point ID	Proj X [m]	Proj Y [m]	Matkart X [m]	Matkart Y [m]
104	5520171.11	3429945.43	5520171.60	3429943.74
119	5436370.21	3448016.00	5436370.54	3448013.92
221	5525189.14	3399992.23	5525189.81	3399990.73
404	5556267.46	3498360.41	5556267.55	3498358.76
510	5538825.85	3557755.29	5538825.73	3557753.64

Tab. 4: The values of planar coordinates in S-42 system using PROJ and Matkart

Point ID	X [m] S-42	Y [m] S-42	Y [m] S-JTSK	X [m] S-JTSK
104	5520169 5520171.60	3429943 3429943.74	775280 775279.26	1069762 1069759.49
119	5436367 5436370.54	3448016 3448013.92	768146 768146.94	1155184 1155180.27
221	5525186 5525189.81	3399990 3399990.73	804334 804332.20	1060933 1060930.08
404	5556267 5556267.55	3498357 3498358.76	702799 702797.09	1042769 1042769.05
510	5538827 5538825.73	3557753 3557753.64	646147 646145.87	1067706 1067707.23

Tab. 5: Transformation in Matkart gives the precision only in meters

The idea about the overall precision of Matkart could be done on the base of table 5. In the first row are figured out the result values, when transforming directly from ellipsoid WGS-84 to S-42 system and in consequence directly to S-JTSK. Matkart itself rounds the resulting values only to meters. In the second row we present the values from subsequent steps (see Tab. 4), eventually in the case of S-JTSK the original values (see Tab. 1).

Conclusion

We hope that this article will inspire reader to try PostGIS and if he decide to use this system in any of his future projects, we will be glad if our findings in the field of coordinate systems will ease him his work.

This article was solved within the frame of project of Czech Science Foundation registered under the number 205/03/D155 with the name Tool for displaying the spatial data in the internet/intranet environment, and supported by the research proposal MSM 210000007 Complex innovation of technologies in geodesy and cartography as well.

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Important links

Open GIS Consortium Inc. <http://www.opengis.org>
European Petroleum Survey Group <http://www.ihsenergy.com/epsg/>
PostGIS <http://postgis.refraction.net>
UMN MapServer <http://mapserver.gis.umn.edu>
Description of patching the PROJ system <http://mpa.itc.it/radim/jtsk/>