Modern Geodetic Control in the Czech Republic Based on the Densification of EUREF Network

Jan KOSTELECKY and Jan PYTEL, Czech Republic

Key words: densification process, EUREF, the database of GPS observations, PostgreSQL, internet access to database.

SUMMARY

In the Czech Republic there was a process called ”GPS densification” from 1995 until 2003. The results (data) of this densification is a large number of the new densified stations and GPS observations. GPS observations from this densification are archived in the form of ”database” files of the observation vectors. These ”database” files are transformed into a main database. The database was created in 2003 based on PostgreSQL database and is written in C++ language. The paper covers basic information about the ”densification” process and the database software implementation.

This paper endeavors to demonstrate how to create geodetic project (database with www access) using free software only, released under GNU GPL license, or under similar licenses.

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1. Densification of EUREF in the Czech Republic

The densification process is reported and described in *(Kostelecky and Simek, 1993, 1995), (Simek and Kostelecky, 1994)* and *(Kostelecky et al., 1996, 1997, 1998, 1999, 2000, 2001).* The beginning of the ETRF89 in the Czech Republic dates back to 1991 (campaign EUREF-CS/H-91), followed by its exposure in 1991 - 1994 and implementation in 1995, *(Kostelecky, Dusatko, eds., 1998).* 174 sites of the national GPS reference network DOPNUL represent the national reference frame. The coordinates of the DOPNUL stations were determined by a combined processing based on the data from several national densification campaigns i.e.- NULRAD, CS-BRD-93 and DOPNUL, see Figure 1.

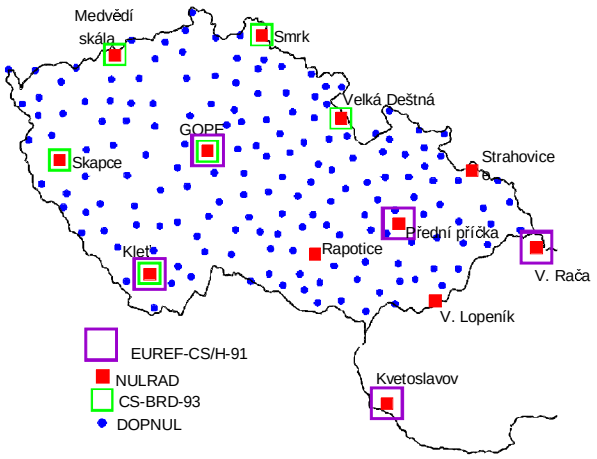

Figure 1

Since 1995 this national reference frame has been densified in two parallel ways. The first densification, carried out by the Land Survey Office, is called ”selective maintenance”. It is aimed for GPS user communities and based on the national GPS reference network DOPNUL. After the work is finished, the total number of the GPS stations will be 3,500. The final density will be 1 station per 24 km sq with an average spacing below 5 km. All these stations are identical with the triangulation stations of the national terrestrial triangulation network. They are equipped with a new monumentation and a special protection against damage. The end of 2003 determined app. 2,000 stations. Their coordinates are available in ETRF89 and in both the official national user system S-JTSK and an improved user system S-JTSK/95. The improved system S-JTSK/95 has been implemented in two variants. The first one is represented by the official user system S-JTSK. This is rectified only by the “precise” terrestrial system S-42/83. The second one is an amended version of the first

variant and created by incorporation of the available GPS observations. The standard deviation of the horizontal position is 3.9 cm. The differences between the amended version S-JTSK/95 and the original (still official) S-JTSK are represented by the horizontal standard deviation 11 cm.

Parallel to the "selective maintenance" the other large scale of the GPS based densification has been carried out since 1995. This is implemented by the regional cadastral offices (departments of cadastral mapping) under the title "Densification". The project will have been finished by the end of 2004. The selective maintanence is a process where the GPS campaigns are carried out within the existing triangulation network. Unlike the "selective maintenance", the primary densification establishes a large number of the new densified stations. The new stations include GPS observations. The total figure of the newly setted up stations is estimated over 30,000. At present, preliminary "ETRF89" geocentric coordinates tied to the national GPS reference network DOPNUL are being determined along with the plane coordinates of the national system S-JTSK. These coordinates are determined by a transformation process using local transformation formulas.

After the work is completed, a new graduate adjustment is supposed to get the final "ETRF89" coordinates. The adjustment is implemented within the regions. Software for the adjustment of the large geodetic networks has been developed at the Research Institute of Geodesy, Topography and Cartography. The software was produced on that purpose in 2000. A test process of 1,841 stations, determined by GPS fast static technique in South Bohemia region. was carried out in 2002. This subnetwork was tied into 10 stations of the DOPNUL network. The inner accuracy characterized by the r.m.s. errors is app. 1.4 cm for the horizontal components and for the up component it is 1.2 cm.

The data from both densifications are *archived in the form of "database" files* of the observation vectors, described bellow. Within the near future we suppose

- reobservation and reprocessing of the DOPNUL network
- reprocessing of the "selective maintenance" densified network in one block using archived vectors connected to the DOPNUL network
- reprocessing of the network created within the frame of the "Densification" project. This happens by computing one block for each region using the vectors connected to the stations of the "selective maintenance".

Information about stations (coordinates, sketches, etc.) is collected in ORACLE type database maintained by the Land Survey Office in Prague. The internet access into this database has already started in December 2003.

2. The Database of GPS Observations

As mentioned above, the data from both densifications processes are archived in the form of "database" files of the observation vectors. This form is not (of course) suitable for the common/final users. Hence it follows demand to create database of GPS observations (observation vectors achieved from densification process) and internet (www) access to the database. GPS data is to be stored in relational database system PostgreSQL. The database will serve as:

- revision of observations
- archive of observations
- provision of free access of observations for all possible users.

2.1 The GPS Observations Data Model

Each item (line) of "data" files represents one vector with this information:
- campaign number
- project number
- epoch of observation
- pair of stations
- coordinate differences dx, dy, dz in [m]
- name of coordinate system
- name of fieldworker
- code of used software
- code of used efemerid.

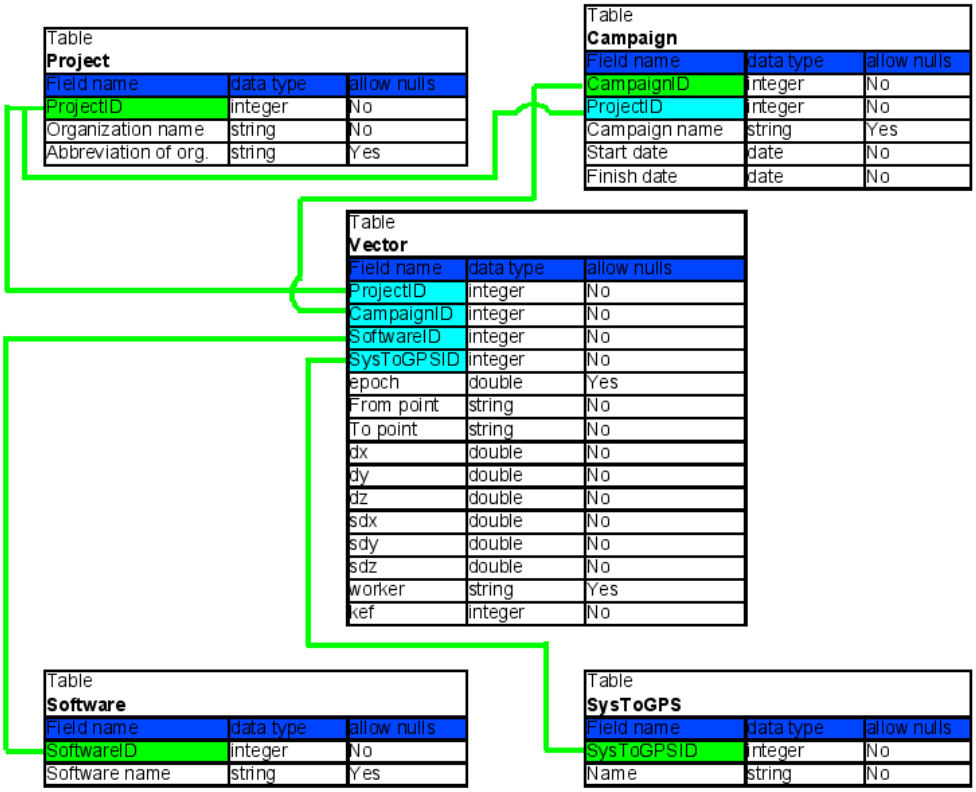

Figure 2

Firstly, data model must be created. Data are to be stored in relational database managing system. This system will enable to manage data stored in relations. Relation is essentially a mathematical term for table. Each table is a named collection of rows. Each row of a given table has the same set of named columns, and each column is of a specific data type. Tables are grouped into databases.

The data model, see Figure 2, consists of four tables. The tables are interconnected by using foreign keys:

- table *Project* - general information concerning projects
- table *Campaign* - cover data about campaigns
- table *SysToGPS* - list data including coordinate systems entity
- table *Software* - list data including software entity
- table *Vector* - main table, including observed vector data.

After scheme of data model is completed, then appropriate relation database management system is chosen. Objectives required:

- release under GNU GPL license, or under similar license
- enable to run on GNU / Linux operating system
- support for SQL 92 and (optimally) for SQL 99
- foreign keys
- transactional integrity.

The chosen object-relational database management system PostgreSQL. PostgreSQL is an object-relational database management system (ORDBMS) based on POSTGRES 4.2. The database has been developed at the University of California at Berkeley Computer Science Department.

PostgreSQL fulfils all ours requirements and provides with many other useful features such as triggers, multiversion concurrency control, etc. For more information about PostgreSQL see

http://www.postgresql.org.

2.2 Internet Access to the Database of GPS Observations Via www

For creating access to the database via http protocol, we have used only C++ libraries released under GNU General Public License. The whole project is written in C++ language and is available for OS GNU/Linux (the main platform on which this project is being developed). We have decided to get rid of www-like languages (like PHP) from the project, owing to possibility to run the project everywhere. The project is based on the two libraries:

- *library Gowl* is a small C++ object library for creating CGI and is released under GNU GPL license. The project Gowl has started at the Department of Mapping and Cartography, faculty of Civil Engineering, Czech Technical University in Prague about 2000. More information about this project are available
  http://gama.fsv.cvut.cz/~pytel/gowl
- *library libpgxx* is a C++ frontend (API) to PostgreSQL and is released under the BSD license. This library contains Standard Template Library (STL)-conformant interface and makes extensive use of C++ language features such as exceptions, templates, and strings. Further information about this library can be found at either of web pages:
  http://pqxx.tk/
  http://gborg.postgresql.org/projects/libpqxx

Final www interface, CGI scripts, is consist of pure C++ programs which are using both of previous libraries. CGI scripts generate html pages which are valid XHTML 1.0 (XHTML is a reformulation of HTML 4.0 in XML 1.0. XHTML is a language for building web pages that has recently been proposed as a W3C Recommendation). One of the main advantages of generating XHTML pages is accessibility via cell phones. In particular while operators working outside, they can obtain data through mobile connection instantly.

WWW interface can be found on homepage
http://www.vugtk.cz/gpsdb.

For working with GPS observations (vectors) www interface offers next possibilities:

- viewing/editing/adding/deleting of GPS observations
- create XML input data format (selected observations) for program GNU Gama
- browsing GPS campaign.

To change (deleting, editing) data in database it is necessary to know and use a password.

WWW interface is very intuitive and simple to use, see Figure 3 and 4. Because of using of database system PostgreSQL is possible to find appropriate observations by using a regular expression. "Regular expression" is a pattern, which denotes a class of alternative observations to select, possibly infinitely many. For example, the percent sign % is used to represent any possible character (number, letter, etc.).

3. CONCLUSIONS

Using language C++ (with libraries Gowl and libpqxx) instead of pure ”web” languages like PHP decreases requirements on software equipment dramatically. The database system and any support programs are released under the GNU General Public License (GPL). Although this database application is tailored to the specific Czech needs, it is a Free Software and it is available to the whole FIG community.

The database of GPS observations has internet access on homepage
http://www.vugtk.cz/gpsdb.

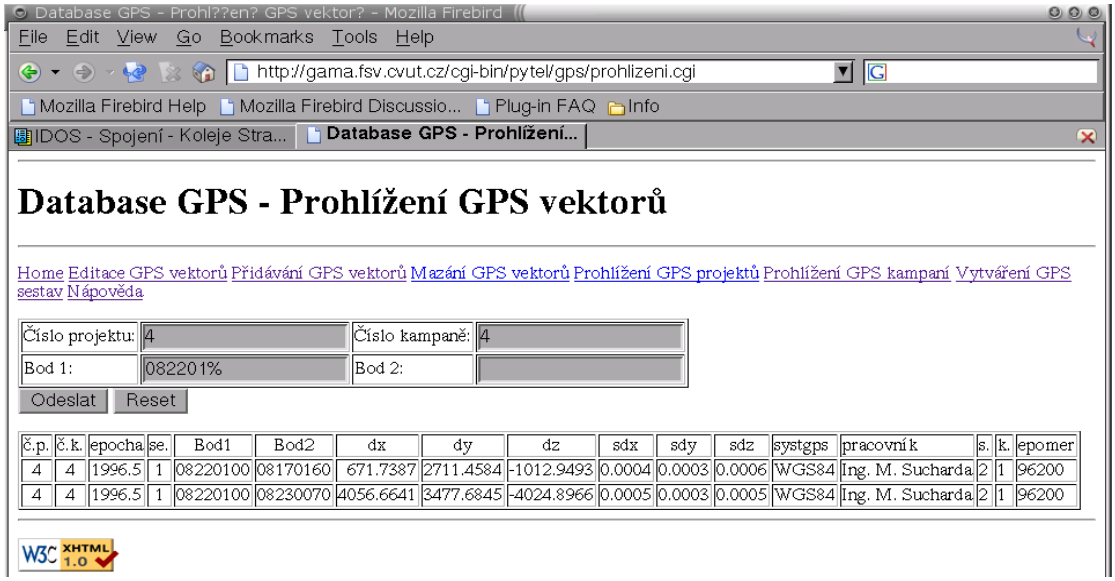

Figure 3: Viewing of observations

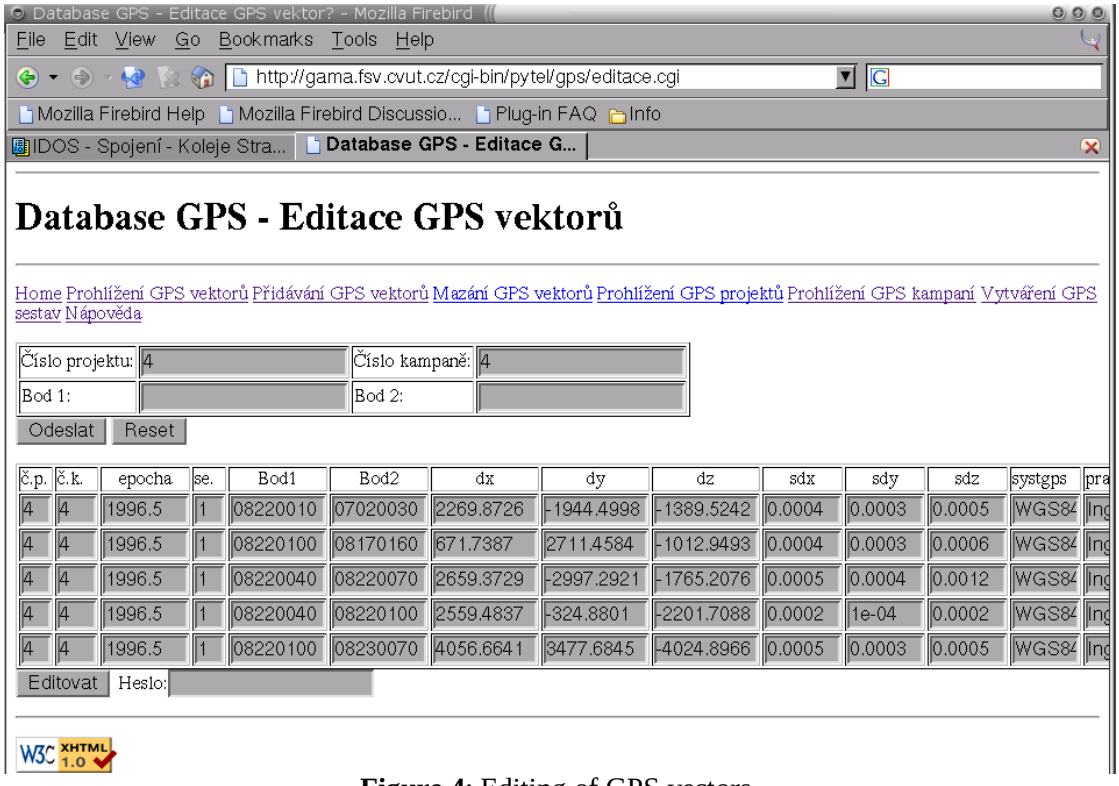

Figure 4: Editing of GPS vectors

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BIOGRAPHICAL NOTES

Jan Kostelecky is professor of geodesy from 1997, working at the Department of Advanced Geodesy, Faculty of Civil Engineering,Czech Technical University in Prague. Since 1970 research worker at Research Institute of Geodesy, Topography and Cartography, Zdiby, at present vice director of the Institute. He is working in geodetical astronomy, space geodesy, geodynamics and geodetic control. Author of more then 150 scientific papers, co-author of the two Space Geodesy monographies.

Jan Pytel is a PhD student of Ales Cepek. His research is focussed on geodetic observations and deformation analysis. Jan Pytel published several papers and intensively works in the field of Free Software development (he is author of free geodetic adjusment project Rocinante)

CONTACTS

Jan Kostelecky
Department of Advanced Geodesy, Faculty of Civil Engineering, Czech TU Prague
Thakurova 7, 166 29 Praha
CZECH REPUBLIC
Tel. + 420 2 2435 4797
Fax + 420 2 2435 4343
Email: kost@fsv.cvut.cz

Jan Pytel
Department of Mapping and Cartography, Faculty of Civil Engineering, Czech TU Prague
Thakurova 7, 166 29 Praha
CZECH REPUBLIC
Tel. + 420 2 2435 4647
Fax + 420 2 2435 5419
Email: pytel@gama.fsv.cvut.cz
Web site: http://gama.fsv.cvut.cz/~pytel