CROPOS - on-line transformation services

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Abstract. CROPOS (CROatian Positioning System) has been established at the end of 2008 and in that way was enabled to users a simpler, precise and more cost-effective determining of point coordinates on the entire state territory. In last 32 months of operating, CRO-POS was used in performing many geodetic and cadastral tasks and therefore is successfully implemented new geodetic reference system HTRS96. Till now in total 372 companies were registered with more than 500 licenses for RTK CROPOS service usage. In order to make possible to the users to determine the coordinates in real-time field measurements in old Croatian State Coordinate System HDKS and in new terrestrial reference system HTRS96 as well as to determine orthometric heights in the old vertical reference system based on Trieste tide gauge and the new vertical reference system HVRS71, the unique T7D transformation model and HRG2009 new geoid model were developed and integrated in the CROPOS system with the Trimble Transformation Generator software. In the first part of paper the computation concept of the T7D unique transformation model and HRG2009 geoid model will be given and in the second part integration of model grids and new on-line transformation services into the system.

Keywords. CROPOS, SGA, HTRS96, HDKS, HVRS71, unique transformation model

T7D, geoid model HRG2009, on-line transformation services, TTG

1 Introduction

CROPOS is a national network of permanent reference GNNS-stations of the Republic of Croatia providing to the users the determination of positions in real-time on the entire territory of the Republic of Croatia, and it consists of 30 reference GNNS-stations covering the whole area of the Republic of Croatia, and of a control centre for processing and distribution of data in Zagreb [Marjanović and Link, 2009].

CROPOS stations are distributed at the distance of about 70 km, and they consists of surveying (GNSS antenna Trimble Zephyr II Geodetic, GNSS receiver Trimble NetR5) and ITC equipment. The control centre is placed in the data centre of the State Geodetic Administration, and it consists of computer equipment (Hewlett Packard) and communication equipment (Cisco). Trimble GPS Net software is used for continuous administration and monitoring of the system, network adjustment, computation and distribution of correction parameters. In order to increase the quality and reliability of data in border areas of neighbour countries the data exchange agreements were signed in June 2009 with the Republic Hungary, the Republic Slovenia and Republic Montenegro, so that there are now 43 reference GNSS stations included into the CROPOS networking solution and computation of correction parameters (Figure 1).



Fig. 1: CROPOS network

2 Reference systems in the Republic of Croatia

According to the Decree on Defining the Official Geodetic Datums and Horizontal Map Projections of the Republic of Croatia published in 2004 [Official Gazette, 2004], the Croatian Terrestrial Reference System was defined as a new positional system HTRS96 – Croatian realisation of ETRS89 (GRS80, ellipsoid heights) [Bašić, 2000; Lapaine, 2000]. The old Croatian coordinate system HDKS (Bessel, orthometric height) is still being used in practice until the complete transfer to the new reference system.

The new vertical system of the Republic of Croatia – HVRS71 is determined by the geoid datum defined by the mean sea level for the epoch 1971.5 on five tide gauges distributed along the Adriatic coast (Dubrovnik, Split, Bakar, Rovinj and Kopar) [Feil and Rožić, 2000]. Just as it is the case with the positional datum, the old vertical reference system defined by the tide gauge in Trieste as its original point is still used.

Referring to the above mentioned, the following reference coordinate systems and coordinates are used in the Republic of Croatia:

- ETRF00 (R05), 1989.0 (ETRS89) Ellipsoid GRS80; φ , λ , h (X, Y, Z); Ellipsoidal height: h,
- HTRS96/TM Ellipsoid GRS80; N, E, H(Transverse-Mercator projection); Orthometric height: H = h-N (HVRS71),
- HDKS Ellipsoid Bessel; y, x, H (Gauss-Krüger projection); Orthometric height: H = h-N (Trieste).

3 Transformation problem

Today's problem in every day works is transformation of coordinates between geodetic datums while we need transformation parameters for that process because geodetic datums are defined on different reference ellipsoids as well as transition from ellipsoid heights to orthometric heights by means of geoid undulations (Figure 2).

ETRS89 (φ, λ, h)	→ H = h - N
	Transformation
	parameters (7)
	Transformation
	GRS80 > Bessel
	HDKS

Fig. 2: ETRS89 > Transformation process between geodetic datums

For geodetic applications local transformation is suitable for smaller areas, but in the border of two areas we can have coordinate shifts even up to 20 cm because of inhomogeneity of trigonometric network and selection of different trigonometric points used for computations of transformation parameters. The solution is to apply global transformation model which is valid on state level. Because of requested accuracy only GRID transformation model is appropriate and therefore new transformation model was developed (Table 1).

Table 1: Transformation solutions

Transformation method	Accuracy
Molodensky	5 m
3D - 7 parameters	1 m
GRID	0.1 - 0.3 m

4 Development of geoid model

The system CROPOS generates a set of ellipsoid coordinates (φ , λ) together with the ellipsoid height h in ETRF00(R05) system coinciding with ETRS89 system, i.e. the Croatian official reference system – HTRS96. In practical usage we need orthometric heights instead of ellipsoid heights, and they are obtained if the geoid undulation N is known, in other words, we should know the relation between the surfaces of geoid and ellipsoid. For that purpose a new significantly improved geoid model HRG2009 was developed in collaboration with the Faculty of Geodesy in Zagreb at the end of 2009 [Bašić, 2001, 2009].

The following has been taken into consideration in the calculation of new geoid model:

- point values of free-air anomalies (over 30000),
- geoid undulations obtained on the basis of precise levelling and GNSS measurements (495 points),

- geoid undulations obtained from satellite altimetry in the area of the Adriatic Sea (400 points),
- global geopotential model EGM2008.

The final result is a reliable gooid model relating to the new official vertical system with standard deviation of ± 0.03 m referring to internal accuracy. The external accuracy with standard deviation of ± 0.04 m was estimated by comparing gooid undulations of 59 control points which were not used in the model development. These data indicate a well selected methodology and the execution of numeric computation, as well as high absolute reliability of HRG2009 gooid model for the entire area of the state.

For the purpose of transformation of the heights from the old reference vertical system (Trieste) into the new Croatian vertical reference system (HVRS71) the transformation height model HTMV08 was developed [Rožić, 2009]. The transformation model includes datum and distortion components that are realized in the form of grid density of 45 x 30 seconds on the basis of 8448 bench marks with the heights in both systems. The external accuracy of the model obtained with the standard deviation of ± 0.01 m on the basis of 1589 points that were not used for the production of the model. The model is implemented in the computer programme T7D and as such it is used for the transformation of heights between the height systems.

5 Development of transformation model T7D

A unique transformation model T7D (7 parameters + distortion), has been developed in collaboration with the Faculty of Geodesy, University of Zagreb at the end of 2009 [Bašić and Šljivarić, 2006; Bašić, 2009]. There were 5034 identical points (Figure 3) used for the development of the model, and these points cover the entire territory of the state with known coordinates in both reference systems [Marjanović et al., 2009]. The model is based on the principle of GRID transformation and includes the whole territory of the state, and it consists of parameter transformation being in $15 \ge 20$ seconds regular raster of predicted distortion values for the positional coordinates and heights. The model is uniform, reliable and simple for use.



Fig. 3: Identical points used for T7D

The final product is the computer programme T7D that provides positional and vertical accuracy of the transformation of ± 0.06 m (in both directions) for the whole state area. HRG2009 geoid model and the height transformation model are integrated in the programme.

6 CROPOS on-line transformation services

The unique T7D transformation model and new geoid model HRG2009 are integrated in the CROPOS system with the Trimble Transformation Generator (TTG) software. TTG is standalone application installed on two servers (one service – one server), which are used for preparing of RTCM 3.1 messages 1021 and 1023 for the users in the field. Source table of CROPOS system is updated with two new services:

• CROPOS VRS HTRS96 (geoid model),

• CROPOS VRS HDKS (datum transformation and geoid model).

When user starts field measurement and connect to CROPOS system, the rover coordinate in NMEA format is send to GPS Net RTCM generator which generates RTK corrections and send it back to the rover. In case of new on-line transformation services the rover coordinate is send forward to TTG generator which prepares transformation data based on rover position, send it back to GPS Net RTCM generator and together with RTK corrections send the data to the user (Figure 4).



Fig. 4: Transformation data flow

The usage of new services does not require any additional registration of users, the needed service is only selected when connecting to CRO-POS. The user's rover need to have the possibility of receiving RTCM 3.1 format messages (the usage of transformation messages 1021 and 1023), i.e. the possibility of applying the emitted RTCM transformation corrections within the user's rover.

6.1 CROPOS VRS HTRS96

CROPOS VRS HTRS96 service has been developed for determination of coordinates directly in the new map projection – HTRS96/TM and the new official height system - HVRS71 without any additional computations.

By means of the service CROPOS VRS HTRS96 the user's rover determines the official ETRS89 (HTRS96) ellipsoid coordinates (φ, λ) by applying RTK corrections sent by CROPOS system, and the users need to set up on their rovers the parameters for the presentation of the coordinates in the plane projection HTRS96/TM (E, N). Within the frame of this service there are also the geoid undulations Nsent of the new geoid model HRG2009 in the official height system HVRS71, and the obtained ellipsoid heights h are computed by rover into the orthometric heights H in real-time (H = h - N).

The testing of CROPOS VRS HTRS96 service was performed on 604 control points by comparing the on-line results and by using HRG2009 geoid in T7D model. The differences of the obtained orthometric heights (on-line vs post-processing) are of accidental character (0 mm, +1 mm or -1 mm), which is completely satisfactory for the practical application. The service has been officially applied since January 3^{rd} , 2011.

6.2 CROPOS VRS HDKS

Sine the old Croatian coordinate system HDKS is still used in the Republic of Croatia, the determination of coordinates in real-time in this system has got large practical value for the users in their field work.

Within RTCM 3.1 format the transformation parameters (Message 1021: TX, TY, TZ, dM, RX, RY, RZ) and the values of distortion corrections and geoid undulation (Message 1023: $\delta\varphi$, $\delta\lambda$, δN) are emitted in real-time to perform the datum transformation. The rover transforms the ETRS89 (HTRS96) coordinates (φ , λ , h) to HDKS reference system and Gaus-Krü plain projection (y, x) as well as ellipsoid height to orthometric heigth in old height system Trieste (H = h - N).

The testing of CROPOS VRS HDKS service was performed on 1008 control points by comparing the on-line results and by using postprocessing transformation T7D model. The differences of the obtained coordinates and orthometric heights (on-line vs post-processing) have standard deviation ± 0.01 m, which is completely satisfactory for the practical application. The service has been officially applied since July 18^{th} , 2011.

7 Conclusion

The performance of geodetic works by the usage of new CROPOS on-line transformation services is quicker, simpler and more efficient, enabling increase of reliability and accuracy in determining the coordinates. The determined coordinates are in unique global and local reference frame. Global reference frame is ensured with CROPOS system and local with new transformation model T7D.

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