HOMOGENIZATION OF THE CADASTRAL MAP OF CADASTRAL MUNICIPALITY PLOMIN IN CROATIA

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Summary: *Official cadastral maps of the Republic of Croatia were made in different historical time periods utilizing different surveying methods, under changing social and political structures and under rapid technological growth. It is estimated that 75% of all cadastral maps in Croatia are still based upon the 19th century graphic survey. Homogenization of Digital Cadastral Maps (DCMs) is one method of spatial accuracy improvement of existing maps without the need for new comprehensive cadastral surveys. Under the supervision of the State Geodetic Administration (SGA) of the Republic of Croatia, methodology and technical solutions for the homogenization of DCMs were developed. In this paper homogenization of the DCM of cadastral municipality Plomin in Croatia is presented.*

Keywords: *Cadastral map, graphic survey, homogenization, digital cadastral map, IMPROVeR*

1. INTRODUCTION

Cadastral maps are the foundation of every land administration system in any country. First systematic cadastral surveys on the territory of modern-day Republic of Croatia began in the 19th century when Croatia was part of the Austro-Hungarian Monarchy [1]. That military survey was the basis for property tax and was based on the graphic survey method and use of the geodetic table. Historical political circumstances led to the neglecting of ownership registration in Land Registry which further led to major disparities between the two registers that are still present and create enormous complications to today's users. This fact is the main reason why today in Croatia two separate registers exist, and why their data to a greater or lesser extent differ.
In the late 20th century cadastral maps were still maintained in analog form (changes were drawn manually on paper by hand), and the registration of ownership was

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handwritten in Land Register books. With the goal of digitizing and harmonization of Cadastre and Land Registration datasets and building an efficient land management system, the Government of the Republic of Croatia in 2003 initiated the Real Property Registration and Cadastre National Project [2]. One of the first steps was conversion of all cadastral maps in digital form. The Real Property and Cadastre Joint Information System (JIS) has been developed with the main goal to merge the two historical registers into one unified database.

Although today's official cadastral maps are digital (Digital Cadastral Maps – DCMs) they are a product of the 150-year-old Austro-Hungarian military graphic survey. It is estimated that 75% of all official cadastral maps of the Republic of Croatia originate from that period [3]. Through extensive analysis of the data status, many deformations, inhomogeneities and anomalies were recognized. They were generated during the initial graphical survey, during many years of cadastral dataset maintenance, upon vectorization of analogue cadastral map sheets and their georeferencing while approximate parameters were used etc. [4]. Consequently, if we overlap such official DCMs with the actual situation (e. g. Digital OrthoPhoto maps – DOPs), greater of smaller spatial misalignments exist. Next key part of the National Project is the improvement of such DCM, i.e. their homogenization. From 2015 until 2017, under the supervision of the State Geodetic Administration (SGA) of the Republic of Croatia, a methodology and technical solutions were developed, and a sustainable model as a systematic measure has been proposed.

2. HOMOGENIZATION METHODOLOGY

Homogenization of Digital Cadastral Maps (DCMs) is a technical procedure of spatial accuracy improvement of cadastral maps of graphic survey [5]. During years of maintenance of cadastral maps, changes were most often drawn by the method of adjusting measured data to the map. Accordingly, the purpose of homogenization is the geometric improvement of DCMs to the point that the changes on the field, i.e. newly surveyed detail, can be drawn on the map by the method of overlapping measured data on to the improved map [4]. This will not be possible on those parts of the DCM where the field situation has changed to the extent that no kind of cadastral map transformations are possible.

Within the homogenization process of DCMs points of the map that have already been mapped by the overlapping method must keep their position unchanged during the transformation, and possibly points on the DCM for which actual (measured) coordinates exist, must be brought into their actual position [4]. Furthermore, it is necessary to handle several anomalies on the DCM, and that includes anomalies which were generated during the initial graphic survey, anomalies of the vectorization process and anomalies created during the maintenance of maps in analog and digital form. Most of these anomalies are commonly associated with abrupt and sudden changes in spatial data continuity [4].

Therefore, four types of parameters need to be defined for the homogenization process:

- identical points for homogenization,
- measured points from existing geodetic elaborates,
- boundaries of isolated areas and

- control points (don't affect the transformation process but serve as quality control).

Because the DCM contains parts of different homogeneity, this approach is very advantageous and allows different parts of the DCM to be transformed individually, and at the same time points from the geodetic elaborates in the transformation process improve the transformation result in a way that points mapped by the overlap method keep their position on the map, but points that were mapped shifted (method of adjusting) are brought to the actual position [5].

Identical points

The most important and demanding part of the homogenization is the definition of identical points. Identical points are those points whose coordinates can be reliably determined on the DCM and in the field. Actual field coordinates must be defined from the best available data (existing geodetic elaborates, DOP etc.). They are defined as vectors where the starting point of the vector is a point of the DCM, and the end of the vector is the point of actual position in the field [4]. Identical points for homogenization must be determined according to the defined density and spatial distribution. It is recommended to define one point on 5 hectares. Within city limits identical points are defined more frequently, and outside in rural areas rarely [6].

Measured points

Existing measured points, which licensed geodetic surveyors register everyday through their submitted elaborates, are a key factor in the homogenization. Points that were mapped on the DCM by the overlap method must keep their defined position on the DCM, and points that were mapped on the DCM by the adjusting method (shifted position) must be brought to their actual position and simultaneously improve their surroundings. For automatic identification, collection and analysis of points a technical solution named CeeSVE has been developed [5]. Coordinates from these points are collected from official Cadastral archives and JIS database.

The purpose of these points in the homogenization process is [4]:

- preserving the position of DCM points that were mapped by the overlap method,
- shifting points of DCM that were mapped by the adjustment method,
- updating relevant point attributes in the JIS database and
- as possible identical points.

Isolated areas

As stated earlier, anomalies on the DCM are commonly associated with abrupt and sudden changes in spatial data continuity. DCM originated from the graphic survey often has areas of different quality that positionally significantly differ from their immediate surroundings and rest of the cadastral municipality. It is of crucial importance that such areas aren't homogenized with the same parameters as the whole cadastral municipality. Such isolated areas are defined as closed polygon around the desired part of the cadastral map [4]. Such an approach potentiates the homogenization process because every isolated area can [5]:

- keep their position if no identical points, or one or more null vectors are defined,
- move as a block completely independent of the rest of the DCM if only one identical point (vector) is defined,

- translate, rotate and scale as a block completely independent of the rest of the DCM if two identical points (vectors) are defined,
- locally transform (adaptive transformation) without quality control if three identical points (vectors) are defined and
- globally (affine transformation) and locally (adaptive transformation) transform with quality control if four or more vectors are defined.

Identical points (vectors) defined outside the isolated area have no influence on the transformation of the isolated area, nor the vectors defined inside the area have any influence on the transformation of the whole cadastral municipality. Size and number of isolated areas are not limited, nor any hierarchy between the areas exist.

Control points

Control points are identical points and serve for independent quality control of the transformation process. They are defined as vectors according to the same rules and conditions as identical points. The only difference is that they aren't used for the calculation of transformation parameters, but they are transformed with the whole DCM. After transformation, the resulting position of control points are compared, and differences are calculated, with its predefined position given with the endpoint of the control vector. Control point must be defined at least twice as often as identical points [5].

Transformation procedure

As the fundamental part of the National Project an algorithm and technical solution for the homogenization of DCMs have been developed. The transformation algorithm is named IMPROVeR and is developed as an FME procedure. IMPROVeR is based upon previously defined homogenization parameters and includes four steps [5]:

- global transformation,
- local transformation,
- fine transformation and
- isolated area transformation method.

Global transformation is a 6 parametric affine transformation. Its parameters are calculated based on all identical points defined in the DCM. This transformation globally improves the DCM and removes those characteristic deformations that are typical to the whole cadastral municipality. Inside the IMPROVeR algorithm this transformation is defined with the FME AffineWarper transformer [5].

Local transformation is an adaptive transformation defined with the FME RubberSheeter transformer. This transformation preforms warping operations on the DCM using inverse distance weighting. It uses all defined identical points and removes local deformations and inhomogeneities originating in the graphic survey.

Fine transformation is a second adaptive transformation defined with the FME RubberSheeter transformer. This transformation uses measured points from geodetic elaborates and further improves the DCM by forcing shifted points to their actual position whereby retaining points mapped by the overlap method on their original position on the DCM.

Isolated area transformation method is a part of the IMPROVeR algorithm which uses all three above mentioned steps within every defined isolated area. Isolated areas are defined with its boundaries, i.e. closed polygons, and transformation of each area is defined with the definition of its identical points, i.e. vectors. The main purpose of this method is the transformation of each isolated area independently from the rest of the DCM.

After the initiation of the IMPROVeR algorithm, all its four steps preform completely automatic one after the other. The algorithm has built-in components for transformation accuracy and quality control [4]. The transformation results with a homogenized DCM and quality control tables. Control of the resulting DCM and quality parameters is obligatory. If the result isn't satisfactory, transformation parameters are redefined, and a new "test" transformation is carried out.

3. CADASTRAL MUNICIPALITY PLOMIN

Cadastral municipality Plomin is located on the eastern coast of the Istrian County, Croatia (Figure 1). It falls under the jurisdiction of the Regional Cadastral Office Pula. The cadastral map of the municipality was created in 1820 at scale 1:2880 by the graphic surveying method and in 1936 was renewed by lithographic procedures [7].

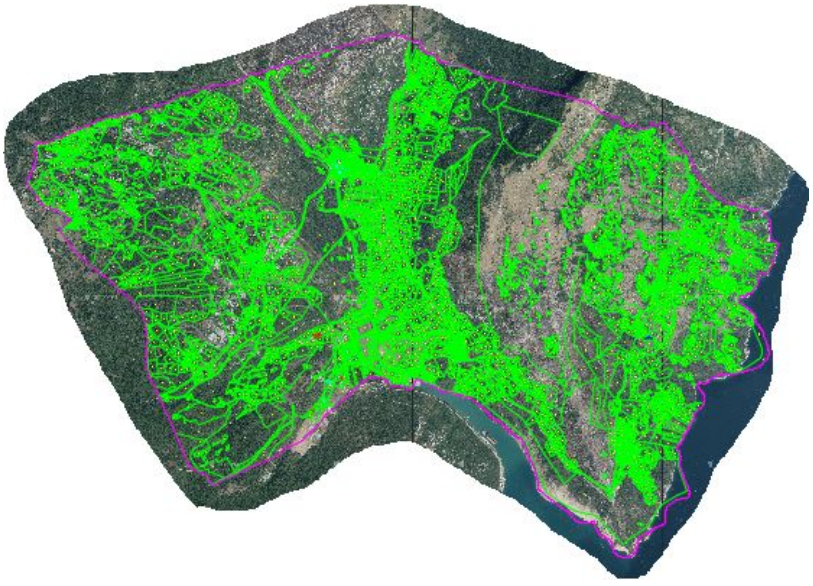

Figure 1. DCM of Plomin overlapped with DOP map (DOP 2014/16) [7]

The DCM of the cadastral municipality Plomin (Figure 1) was created with the vectorization process and today is stored in JIS databases [7]. In its analog and digital form the map was mostly maintained by method of adjusting measured data.

4. HOMOGENIZATION OF THE DCM OF PLOMIN

The initial step in the homogenization process of the DCM of cadastral municipality Plomin is to collect all needed data as shown in the methodology procedure. That includes basic information about the cadastral map, measured points from geodetic elaborates, DOP and DCM of the whole municipality. Measured points from geodetic elaborates were delivered by the Regional Cadastral Office as 9 standard and 5 nonstandard files. The DOP map of Plomin was downloaded from the WMS service of the SGA. The Central Office of SGA prepares and delivers the DCM to geodetic contractors which preform the homogenization of DCMs. The delivered map dataset consisted of DCM in shape format (*.shp*) and CAD drawing format (*.dwg*) with all relevant layers already prepared.
Utilizing CeeSVE all 14 received measured point files from geodetic elaborates where systematized and standardized. To that database all DCM points from the JIS where loaded as reference points, unnecessary points are removed from the database, point coordinates that aren't, are transformed into the official system/map projection of the Republic of Croatia (HTRS96/TM) and the automatic processing is initiated. The result of the automatic analysis on the point database within CeeSVE is the recognition of eligible points for the automatic use in the homogenization process (Figure 2). At the end, all relevant points are exported into CAD drawing exchange format (*.dxf*) to be imported into the CAD file (*.dwg*) where the homogenization parameters area defined. In total, 2940 points were identified as eligible for the use in the homogenization process.

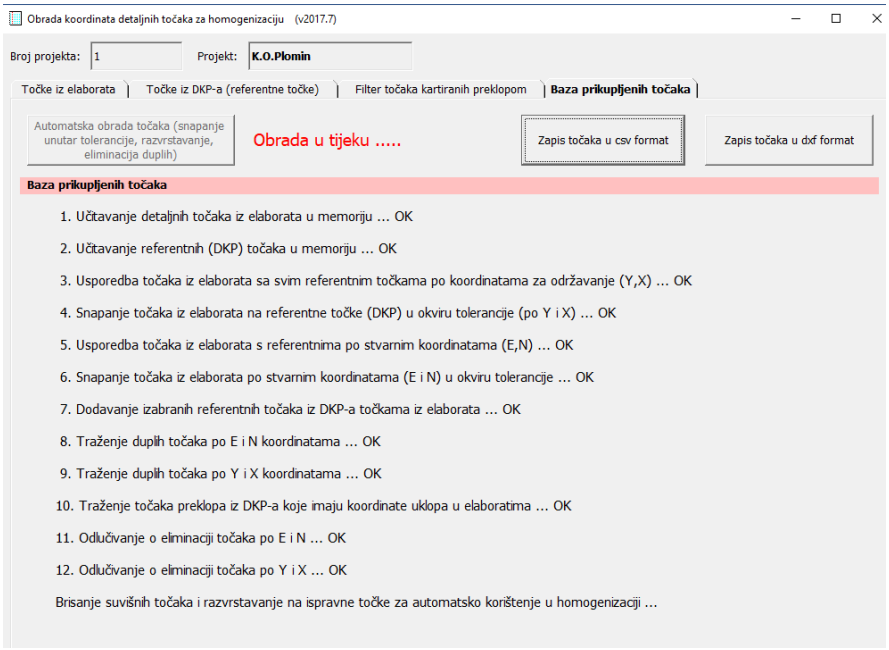

Figure 2. Automatic point analysis within CeeSVE [7]

According to the described methodology, parameters for the homogenization are defined, i.e. identical points, measured points and isolated areas. These parameters are defined within the CAD drawing file (*.dwg*) that was prepared and delivered by the SGA. Identical points are defined in the "IP-vectors" layer, measured point in the "8_points_1" layer, vectors based on measured points in the "DP-vectors", isolated areas in the "IA-border" and control vectors in the "CP-vectors" layer.
Figure 3 depicts part of the DCM and the definition of transformation parameters. Isolated areas are shown as closed polygons in magenta, identical points as yellow vectors, measured points from geodetic elaborates are depicted as red vectors and control points as orange vectors.

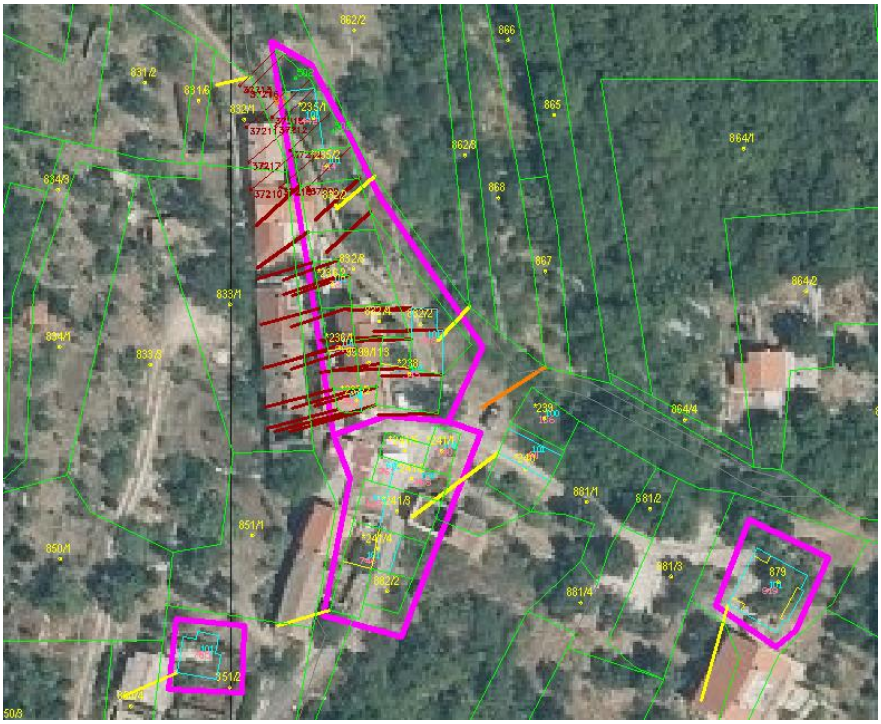

Figure 3. Part of the DCM with its defined transformation parameters [7]

Finally, the result of the homogenization process of the DCM of cadastral municipality Plomin (Figure 4) was obtained after 33 "test" transformation with the following number of transformation parameters:

- IP-vectors: 823,
- DP-vectors: 3339,
- CP-vectors: 81 and
- isolated areas: 279.

Figure 4. Homogenized DCM of cadastral municipality Plomin [7]

Figures 5 and 6 depict the result of the homogenization in an inhabited part of Plomin. On Figure 5 one can notice a large spatial misalignment of the DCM and DOP map which is corrected through the homogenization.

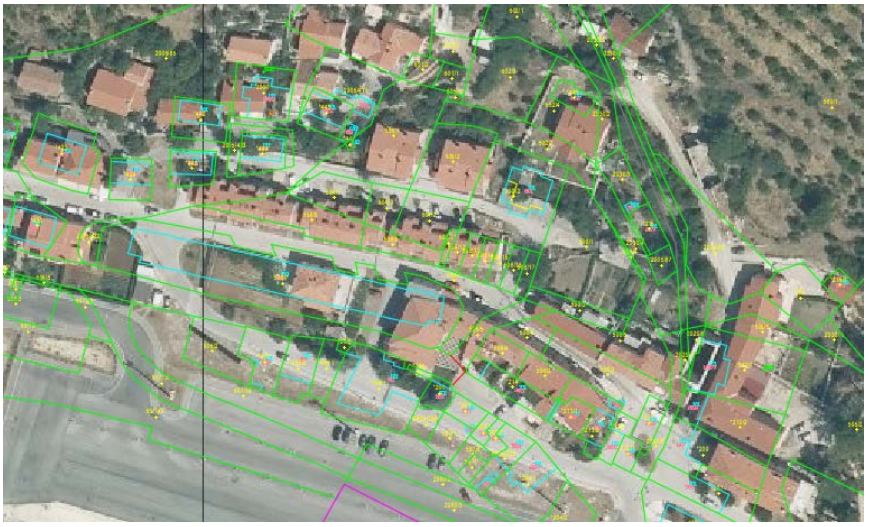

Figure 5. Part of the DCM of Plomin before homogenization [7]

Figure 6. Part of the DCM of Plomin after the homogenization [7]

5. CONCLUSION

New cadastral survey of a whole cadastral municipality is the best way of obtaining precise and up to date spatial information and no homogenization can replace it. However, until all cadastral municipalities of the Republic of Croatia are re-measured, homogenization is a worthy substitution. It is also important to emphasize that through the homogenization process the legal status of cadastral and land registry data doesn't change.

Through visual analysis of the overlap of homogenized DCM of cadastral municipality Plomin with the DOP map it is determined that the DCM on the whole municipality area had been satisfactorily improved geometrically and spatially. Parts of the DCM that were during the maintenance process mapped by the overlap method retained its position, and parts that were mapped by adjusting method were successfully brought to their actual position and simultaneously improved their surroundings. It is concluded that the homogenization of the DCM Plomin has been correctly and completely conducted and the main purpose of homogenization is fulfilled.

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ХОМОГЕНИЗАЦИЈА КАТАСТАРСКОГ ПЛАНА КАТАСТАРСКЕ ОПШТИНЕ ПЛОМИН У ХРВАТСКОЈ

Резиме: *Катастарски планови Републике Хрватске израђени су у различитим хисторијским раздобљима, користећи различите методе истраживања, под промењивим друштвеним и политичким структурама и под утецајем брзог развоја технологије. Процењује се да се 75% свих катастарских планова у Републици Хрватској темељи на графичкој измери из 19. века. Хомогенизација дигиталних катастарских планова (ДКП) је метода геометријског побољшања постојећих планова без потребе за опсежним новим катастарским измерама. Под водством Државне геодетске управе (ДГУ) Републике Хрватске развијени су методологија и техничка решења за хомогенизацију ДКП-а. У раду је приказана процедура хомогенизације ДКП-а катастарске општине Пломин у Хрватској.*

Кључне речи: *Катастарски план, графичка измера, хомогенизација, дигитални катастарски план, ИМПРОВеР*