TRANSFORMATION METHODS FOR USING COMBINATION OF REMOTELY SENSED DATA AND CADASTRAL MAPS

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ABSTRACT:

In order to examine using cadastral maps as base maps for aerial orthophotos, two different 2D transformation methods were applied between various coordinate systems. Study area was chosen from Kagithane district in Istanbul. The used data is an orthophoto (30 cm spatial resolution), and cadastral map (1:1000) taken from land office, containing the same region. Transformation methods are chosen as; 1st Order Polynomial Transformation and Helmert 2D Transformation within this study. The test points, used to determine the coefficients between the datums, were 26 common traverse points and the check points, used to compare the transformed coordinates to reliable true coordinates, were 10 common block corners. The transformation methods were applied using Matlab software. After applying the methods, residuals were calculated and compared between each transformation method in order to use cadastral maps as reliable vector data.

1. INTRODUCTION

Modern mathematics characterizes transformations in terms of the geometric properties that are preserved when the transformations are applied to features. For mapping, analysis, and georeferencing purposes we usually value one particular set of properties over all others: area when computing areas, orientation when computing directions, distance when computing distances, (local) angles when computing angles, similarity when comparing shapes, incidence and inside versus outside when performing topological comparisons, and so on. In each case there is a group of invertible transformations of the plane that preserves the desired properties. As surveyors we practise our engineering analyses in alternative coordinate systems. So in most cases, like every map and GIS user, we use 2D and 3D coordinate transformations. In this research 2D coordinate transformation procedures for 1st degree Polynomial Transformation and Helmert Transformation are implemented to compare cadastral map coordinates of the 10 check points of two block corners.

A polynomial transformation is a non-linear transformation and relates 2D Cartesian coordinate systems through a translation, a rotation and a variable scale change. The transformation function can have infinite number of terms (Knippers, 2009).

Calculation of transformation parameters between aerial orthophoto and cadastral map coordinates using first order polynomial transformation can represent in mathematically as follows.

$Xn = a_1Xo + a_2Yo + a_3$

$Yn = a_4 Xo + a_5Yo + a_6$

Xo – X coordinates of aerial orthophoto

Yo – Y coordinates of aerial orthophoto

Xn – X coordinates of cadastral map

Xn – X coordinates of cadastral map

a1, a2, a3, a4, a5 and a6 are unknown parameters.

2D Helmert transformation is a special case that is only needed 4 parameters (two translations, one scaling, one rotation). It is needed at least two known points (X, Y), İf there is more than two known points, it is needed to apply adjustment operations, and check points can be used for accuracy calculations.
The other name of this transformation method is similarity transformation. In this transformation, figures preserve own shapes which means angles between lines does not change. The edges of the smooth geometric shapes grow or shrink at the same rate.

First system coordinates (given): x_o, y_o;
Second system (transformed) coordinates: x_n, y_n;
k_{01}, k_{02}: displacement parameters
ϕ: rotation angle; angle between x'and x; y' and y.
λ: scale;
$x_o \rightarrow \lambda x_o$, $y_o \rightarrow \lambda y_o$
A sample of graphic representation of the systems is shown in Figure 1 below.

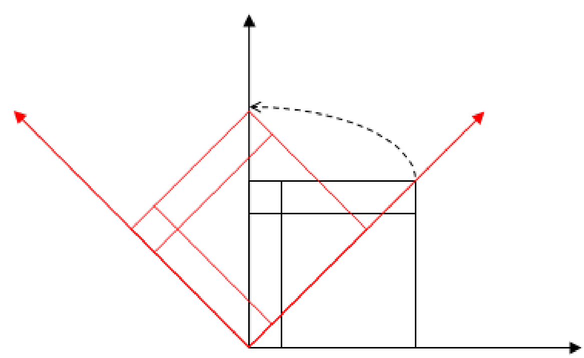

Figure 1. Graphic representation of 2D Helmert transformation

General formula is shown:

$x_n = k_{01} + \lambda\, x_o \cos\phi - \lambda\, y_o \sin\phi$
$y_n = k_{02} + \lambda\, x_o \sin\phi - \lambda\, y_o \cos\phi$
k_{01}, k_{02}, λ, ϕ are translation parameters. These equations;
with translation of $k11 = \lambda \cos\phi$ $k11 = \lambda \sin\phi$;
$x_i' = k_{01} + xi\, k_{11} - y_i\, k_{12}$
$y_i' = k_{02} + y_i\, k_{11} + x_i\, k_{12}$; and scale factor($\lambda$), ϕ are calculated as;
$\lambda = \sqrt{(k11)^2 + (k12)^2}$
$\phi = \arctan \frac{k12}{k11}$ (Demirel, H.)

2. DATA SET

The used data is an orthophoto (30 cm spatial resolution), and cadastral map (1:1000) taken from land office, containing the same region.

The test points, used to determine the coefficients between the datums, were 26 common traverse points; the check points, used to compare the transformed coordinates to reliable true coordinates, were 10 common block corners.

Point I.D.	Aerial Orthophoto Traverse Point Coordinates (ITRF96)	
	Xo (m)	Yo (m)
3481	4549961.084	415150.253
3482	4549976.166	415121.215
3483	4549991.675	415093.301
3484	4550004.615	415063.577
3485	4550018.322	415035.793
3486	4550035.790	415004.512
3617	4549828.135	414973.700
3618	4549798.466	414963.811
3696	4550006.120	414918.530
3698	4550070.894	414960.235
3699	4550051.187	414976.807
3700	4549990.610	414947.434
3702	4549935.854	414959.106
3704	4549958.513	415005.709
3707	4549923.337	415057.907
3708	4549906.493	415086.225
3709	4549894.942	415128.947
3724	4549912.044	415015.247
3726	4549868.332	415082.328
3731	4549838.663	415179.418
3735	4549797.395	415117.895
3739	4549839.144	415076.666
3742	4549775.768	415077.065
3747	4549875.937	415023.037
3749	4549903.251	414956.335
3750	4549947.093	414931.083

Table 1. Aerial orthophoto traverse point coordinates (ITRF96)

Figure 2. Aerial orthophoto test point representation

Point I.D.	Cadastral Map Traverse Point Coordinates (ED-50)	
	Xn (m)	Yn (m)
3481	11051.470	-6637.240
3482	11066.210	-6666.450
3483	11081.390	-6694.540
3484	11093.980	-6724.410
3485	11107.360	-6752.350
3486	11124.460	-6783.830
3617	10916.480	-6812.210
3618	10886.700	-6821.750
3696	11093.790	-6869.450
3698	11159.040	-6828.510
3699	11139.530	-6811.710
3700	11078.620	-6840.370
3702	11024.010	-6828.060
3704	11047.210	-6781.730
3707	11012.650	-6729.130
3708	10996.140	-6700.620
3709	10985.090	-6657.770
3724	11000.860	-6771.650
3726	10957.940	-6704.070
3731	10929.410	-6606.650
3735	10887.430	-6667.680
3739	10928.690	-6709.390
3742	10865.330	-6708.250
3747	10964.850	-6763.440
3749	10991.380	-6830.450
3750	11034.920	-6856.210

Table 2. Cadastral map traverse point coordinates (ED50)

Figure 3. Cadastral map test point representation

3. APPLICATION

After applying the 1st order Polynomial transformation and 2D Helmert transformation methods, the transformation coefficients calculated using Matlab software.

Parameter	Approximated Value (1st order Polynomial)
a_1	0.999830533153803
a_2	0.011687641358797
a_3	-0.000000000106766
a_4	-0.011686688064981
a_5	0.999830239688893
a_6	-0.000000000091252

Parameter	Approximated Value (2D Helmert)
k_{01}	-4542989,16636722
k_{02}	-368541,351771835
k_{11}	0,999830254761944
k_{12}	-0,0116870608244562

Table 4. Calculated transformation coefficients for 1st Order polynomial and Helmert transformation

The least square method used to calculate the coordinates of the block corners to compare them with the reliable aerial orthophoto coordinates. To do such residuals calculated in order to determine using cadastral maps as base maps.

After extracting the obtained coordinates from the aerial orthophoto coordinates of the block corners both transformation method gives a reliable accuracy for using cadastral sheets for base maps.

Point ID	1st order Polynomial Transformation	
	Residuals in Xn (m)	Residuals in Yn (m)
1	-0.061113	0.153939
2	-0.934553	3.009963
3	-2.612569	1.784752
4	-1.677428	0.169056
5	-0.165847	0.840253
6	-0.688147	1.729389
7	-0.849622	1.740335
8	-1.482626	2.932406
9	-2.625343	2.837968
10	0.546605	-0.720273

Table 5. Residuals for 1st order Polynomial Transformation

Point ID	2D Helmert Transformation	
	Residuals in Xn (m)	Residuals in Yn (m)
1	-0,061035	0,153953
2	-0,934487	3,009981
3	-2,612468	1,784793
4	-1,677315	0,169093
5	-0,165830	0,840255
6	-0,688134	1,729394
7	-0,849611	1,740340
8	-1,482620	2,932414
9	-2,625306	2,837996
10	0,546654	-0,720251

Table 6. Residuals for 2D Helmert Transformation

4. RESULTS

As known, field measurements and remotely sensed images as well are used for calculating coordinates for logically defined datums and systems. The coordinates of the image or cadastral datas does not have only one standard or unique coordinate system, they are usually needed to be transformed with operations. These transformation methods describe a new surface and new system with different origins and dimensions.

In this paper, 2D transformations are discussed with some perspectives. These transformations types were; 2D Helmert transformation and 1st order Polynomial transformation. For both, same data (control and check points) are used, certainly different transformed coordinates are obtained. When the residual values are focused on, it can be easily compared the diagnostic test mathematically. In this stage, number of transformation parameters are another important issue for comparing and deciding convenient method.

According to study, these two transformation methods results show that, cadastral maps can be used reliably as a base map with integrating cadastral maps with using of such types of transformation methods. Another several transform methods and comparison of them are aimed to study for the future researches.

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