COORDINATE TRANSFORMATIONS IN ORDER TO INTEGRATE LOCAL MAP INFORMATION IN THE NEW GEOCENTRIC EUROPEAN SYSTEM

TRANSFORMARI DE COORDONATE IN SCOPUL INTEGRARII INFORMATIEI CARTOGRAFICE LOCALE IN NOUL SISTEM GEOCENTRIC EUROPEAN

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Abstract. *The concept of "geodetic datum" was recently assimilated by geodetic specialized Romanian literature, and through it, we can operate in the more complex space of coordinate systems along with the reference surface specifications to which they relate. The necessary correspondence between local and global-geocentric data constitutes a current problem which is resolved under the accuracy terms, claimed in general by the terrestrial measurement works and in particular by the cadastral survey works. Thereby its aims the validation of currently using existing space data in the Local-Iasi area and the integration in the European new coordinate system, adopted in 2009, of the local information, for the urban real-estate works. The conducted study is linked to the final transition, of our country, to the national geodesic satellite network and the achievement of a new digital city plan.*
Key words: Datum, Data, coordinate, survey

Rezumat. *Noțiunea de „datum geodezic” a fost asimilată de curând şi în literatura de specialitate geodezică din țara noastră, iar prin intermediul ei, putem opera în spațiul tot mai complex al multitudinilor de sisteme de coordonate, împreună cu specificațiile suprafețelor de referință la care acestea se raportează. Corespondența necesară între datumurile geodezice locale şi cele global – geocentrice constituie o problemă de actualitate, care se cere rezolvată în termenii de precizie pe care îi necesită lucrările de măsurători terestre, în general şi cele de cadastru, în mod special. Prin aceasta, se urmăreşte, validarea utilizării datelor spațiale existente în prezent în spațiul Local-Iasi, pe zona de studiu şi integrarea informației locale în noul sistem european de coordonate adoptate în anul 2009, pentru lucrările de cadastru imobiliar-edilitar. Studiul efectuat este legat de trecerea definitivă la rețeaua geodezică națională satelitară a țării noastre şi de realizare a unui nou plan digital al municipiului Iaş.*
Cuvinte cheie: Datum, date, coordonate, cadastru

INTRODUCTION

Romania’s admission as a member with full rights into the European Union, event of historic importance, involves the adoption and/or elaboration of technical standards for the elaboration of digital cartographic outputs, which must

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fulfill the international standards concerning the codification, symbolism, manner of reference of data, storage of spatial information, creation and administration of a national GIS (Geographic Information System). This framework will enable the exchange between the European Community and international community and the creation of an infrastructure of National Spatial Data which will be compatible with the infrastructure for spatial information from Europe. These desideratum are possible and achievable by the adoption and fulfillment of the International Standard ISO 19111, adopted as a pan-European standard with the purpose of a precise and correct identification of the system of reference and of coordinates for each. The global positioning system (GPS) is frequently used in establishing geodetic networks because GPS provides location and time information with a high accuracy anywhere on the Earth.

Regarding the transition from local-national to European datum the solution implementations phase was successfully resolved (creating the permanent GNSS reference station network and coordinates transformations “Transdat” soft-A.N.C.P.I.). This procedure should be extended to other local reference systems such as those created for big cities and municipalities. This local system served to create some small dimension local geodetic networks, which afterwards, formed the base on surveying the terrain details.

For further application of 2D coordinate transformation models it is necessary to know the minimum number of points, according to the used model, which have plane rectangular coordinate in both local and global reference system. Data required for the coordinates in the European system (ETRS 89) have been obtained through GPS measurements campaigns conducted in 2005 with the creation of geospatial network of Iasi and then in 2010 with the network extending for the entire metropolitan area of Iasi [10].

The calculation algorithms present the following steps:

1. Parameters calculation of the WGS-84 coordinates (epoch 2005) 3D transformation in ETRS-89 coordinates, based on three shared points, by applying the transformation model with 7 parameters, like „Bursa-Wolf” [1].

2. WGS-84(epoch 2005) coordinates transformation of 7 shared points from GPS thickening network in ETRS-89 coordinates, expressed in Cartesian ellipsoidal system.

3. Ellipsoidal geodetic coordinate’s conversion of the 7 shared GPS thickening points in Stereo-70/GRS-80 cartographic projection system (Stereo-2010).

4. 2D transformation parameters calculation of specified 7 points from the „Local-Iasi” into Stereo-70/GRS-80 system, with conformal linear method (table 2).

5. 2D transformation parameters calculation of those 7 points from the „Local-Iasi” into Stereo-70/GRS-80 system, with affine method (table 3).

7. Coordinates transformation of those 7 shared points from „Local-Iasi” in Stereo-70/GRS-80 system (Stereo 2010), using trans-calculus parameters previously calculated (table 1, table 3).

CONFORMAL LINEAR TRANSFORMATION IN 2D SPACE

This transformation keeps only the topographic conditions and use the simplified hypothesis of one system translation and rotation in the same space from the other [5].

The correction equations is written in linearized form :

$$x_i * a - y_i * b + \Delta x - X_i = v_{x_i}$$
$$y_i * a + x_i * b + \Delta y - Y_i = v_{y_i}$$

and in matrix form:

$B_{2n,4}X_{4,1}+L_{2n,1} = V_{2n,1}$ where:

where **n** is the number of double points with known coordinates in both systems.

The unknowns of the system are the $(\Delta x, \Delta y)$ translation and (a, b) rotation parameters, unknown coefficients (x_i, y_i) are the coordinates of the double points in the ""source" system and the (X_i, Y_i) free terms are the coordinates of the same points in ""the target" system.

Introducing the minimum condition $([vv] \rightarrow min)$[6] and canceling the function partial derivatives, related to unknowns of the system, is obtained by *the normal equations system,* with four equations with four unknowns$(a, b, \Delta x, \Delta y)$:

$N_{4,4}X_{4,1} + B^T_{4,2n}L_{2n,1} = 0_{4,1}$ where $N_{4,4} = B^T_{4,2n}B_{2n,4}$

The unknowns matrix in calculated with the matrix inverse method:

$$X_{4,1} = -\left(N_{4,4}\right)^{-1}B^T_{4,2n}L_{2n,1}$$

The precision determinations of each trans-calculus parameter from the unknown matrix is expressed with a mean square error:

$s_j = s_0\sqrt{Q_{jj}}$, j= $\overline{1,4}$ in which : $s_0 = \sqrt{\frac{V^T_{1,2n}V_{2n,1}}{2n-4}}$

In the end, based on trans-calculus parameters, these formulas will determine the new points coordinates:

$$\begin{pmatrix} X_i \\ Y_i \end{pmatrix} = \begin{pmatrix} \Delta x \\ \Delta y \end{pmatrix} + \begin{pmatrix} a & -b \\ b & a \end{pmatrix} * \begin{pmatrix} x_i \\ y_i \end{pmatrix}$$

In table 1.1 are the coordinates of the seven GPS thickening points, in "Iasi-local" and Stereo-70/GRS-80 coordinates systems. The coordinates from the local system have been obtained with specific method of thickening the local geodetic network (backward multiple intersection method), rigorously compensated, applying the least squares principle, indirect measurements process.

AFFINE TRANSFORMATION IN 2D SPACE

In two dimensional affine transformation different corrections are introduced for each of the two coordinates axes directions [5].

For the affine transformations are considered known seven GPS thickening points coordinates in both system, “Iasi-local” and Stereo-70/GRS-80, from the table 1. The transformation results are in the table 1.3

Table 1

Coordinates of the GPS thickening points in “Iasi-local” and Stereo-70/GRS-80 system

Point	Plane rectangular coordinates “Iasi-local”system		Plane rectangular coordinates „Stereo-70/GRS-80” system	
	X(m)	Y(m)	X(m)	Y(m)
I 130	10596.933	9027.482	633186.851	695299.976
I 131	10419.701	9297.834	633017.575	695675.456
I 132	9764.476	9515.597	632368.889	695812.583
I 133	9375.654	9726.531	631986.453	696034.953
I 137	9751.542	10637.455	632389.108	696934.600
I 138	9422.152	10859.701	632066.365	697166.475
I 150	9506.601	8753.605	632088.538	965058.326

Table 2

Conformal linear transformation („Transdatum”soft [2])

Trans-calculus parameters from the unknowns matrix			Point	Plane rectangular coordinates „Stereo-70/GRS-80”system	
				X(m)	Y(m)
Para meter	**Value**	**Determi nation error**	**I 130**	633186.797	695299.952
Δx	622325.27870319 m	0.22 m,	**I 131**	633017.585	695575.478
Δy	686587.22275504 m	0.22 m.	**I 132**	632368.919	695812.561
a	0.9998058950 rad.	0.00 rad.	**I 133**	631986.403	696034.938
b	-0.029536821000 rad.	0.00 rad.	**I 137**	632389.124	696934.583
Standard trans-calculus error for a point		**0.036m**	**I 138**	632066.362	697166.515
			I 150	632088.588	695058.333

Table 3

Affine transformation („Transdatum”soft [2])

Trans-calculus parameters from the unknowns matrix			Plane rectangular coordinates „Stereo-70/GRS-80”system		
Parameter	**Value**	**Determi nation error**	**Point**	**X(m)**	**Y(m)**
Δx	622324.898668895 m.	0.485 m.			
Δy	686587.286455268 m.	0.485m.	**I 130**	633186.813	695299.958
a	0.999834584 rad.	0.00 rad.	**I 131**	633017.598	695575.490
b	0.029546926 rad.	0.00 rad.	**I 132**	632368.916	695812.562
c	-0.029535567 rad.	0.00 rad.	**I 133**	631986.390	696034.937
d	0.999798047 rad.	0.00 rad.	**I 137**	632389.131	696934.575
Standard trans-calculus error for a point		**0.038m**	**I 138**	632066.362	697166.505
			I 150	632088.569	695058.340

THE TRANSFORMATIONS COORDINATES POSSIBILITIES BETWEEN GEODETIC DATUM USING ANNS

1. Back propagation artificial neural network

- Neural networks have emerged as a field of study within AI and engineering via the collaborative efforts of engineers, physicists, mathematicians, computer scientists, and neuroscientists
- A neural network is first and foremost a graph, with patterns represented in terms of numerical values attached to the nodes of the graph and transformations between patterns achieved via simple message-passing algorithms. Certain of the nodes in the graph are generally distinguished as being *input* nodes or *output* nodes, and the graph as a whole can be viewed as a representation of a multivariate function linking inputs to outputs. Numerical values (*weights*) are attached to the links of the graph, parameterizing the input/output function and allowing it to be adjusted via a *learning algorithm* [5].
- Neural networks have been trained to perform complex functions in various fields of application including pattern recognition, identification, classification, speech, vision, and control systems. Back-propagation (BP) was created by generalizing the Widrow-Hoff learning rule to multiple-layer networks and nonlinear differentiable transfer functions. Input vectors and the corresponding target vectors are used to train a network until it can approximate a function, associate input vectors with specific output vectors, or classify input vectors in an appropriate way as defined by you [7].

The multilayer perceptron (MLP) model was selected for this study because MLPs have ability to learn, operate fast, require small training sets and can be implemented simply among several kinds of ANN models. MLP consists of one input layer with N inputs, one hidden layer with q units and one output layer with n outputs. The output of the model (y) with a single output neuron can be represented by:

$$y = f\left(\sum_{j=1}^{q} W_j f\left(\sum_{l=1}^{N} w_{j,l} x_l\right)\right)$$

where W is the weight between the hidden layer and the output layer, w is the weight between the input layer and the hidden layer, x is the input parameter. A sigmoid function is used as activation function for hidden and out layers that is defined by: $f(z) = 1/\left(1+e^{-z}\right)$

where z denotes the input information of the neuron.

Each neuron within network collects information by means of all its input connections fulfills a predefined mathematical operation and offers an output value. Neurons are linked by weighted connections, storing the information. By adjusting the weights, the neuronal network is able to learn.

The network contains I input neurons, J hidden neurons and K output neurons. The weights of the input layer and the hidden one, respectively the hidden layer and the output one are noted with $w = \{w_{ij}\}$, respectively $v = \{v_{jk}\}$.

Functions of activation the neurons in the hidden layer and in the output one are noted with $g(\cdot)$, $h(\cdot)$ respectively. Driving such a network is made by using a set of driving data which make use of M desired in - out pairs, under the following form:

$x^{(m)} = \{x_1^{(m)}, x_2^{(m)}, \ldots x_I^{(m)}\} \div d^{(m)} = \{d_1^{(m)}, d_2^{(m)}, \ldots d_K^{(m)}\}$,
m=1,...,M

Consequently, for an approximation as correct as possible of the desired outputs $d^{(m)}$, through the real outputs $o^{(m)}$, it is to be applied an adjusting grid weights method using as a target function a valuation of the approximation errors with the total square deviation.:

$$APT = \sum_{m=1}^{M} \left\| d^{(m)} - o^{(m)} \right\|^2 = \sum_{m=1}^{M} \sum_{k=1}^{K} \left(d_k^{(m)} - o_k^{(m)} \right)^2$$

- **BPANN** model was selected because it has been more widely applied in engineering among all other ANN applications. BPANN has a feed-forward and supervised learning structure which consists one input layer, one or more hidden layers and one output layer, as shown in Figure 1[8].

For determining the performance of the neural network, the mean square error (MSE) can be used that is defined by:

$$MSE = \sum_{1}^{N} \left(y_{known} - y_{neuronal} \right)^2 / N^2$$

where N is the number of the inputs, *yknown* denotes the known (target) output value and *yneural* denotes the network output value.

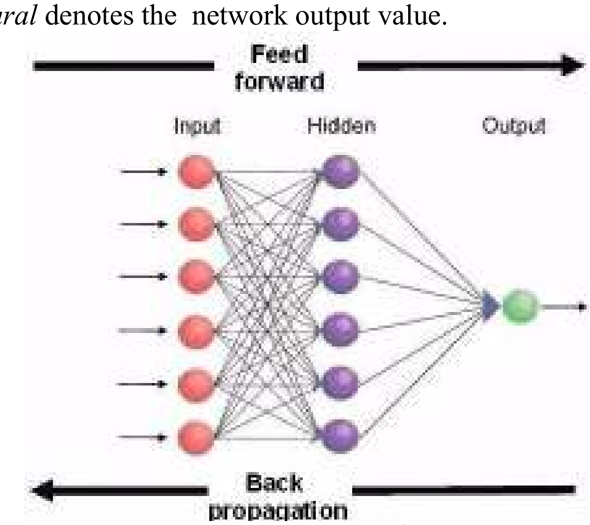

Fig.1 - The general structure of a BPANN [9]

CONCLUSIONS

1. The existing graphical information in the “Local-Iasi” system can be spatial integrated in the new European geodetic datum, through the coordinates transformation with an precision appropriate with real estate cadaster rules.

2. In order to determine the 2D trans-calculus parameters, were applied three coordinate transformation models (linear, affine and second degree polynomial), with similar results falling within the tolerance of 5 cm for the position of a point in the plan. The best result of ± 3,6 cm was obtained for the linear transformation but it is possible that an extension of shared points increase in number the precision on the other two transformation methods, which are related to a complex distribution of the relative position error of those two work systems.

3. An artificial neural network can be applied to cadastral coordinate transformation.

4. In order to study the 2D coordinate transformation, algorithms of applying a back-propagation artificial neural network (BPANN) is proposed.

5. For testing the accuracies of the proposed algorithms, some points must be used to train the artificial neural network, and others to evaluate the performance of the proposed algorithms. The points used to train the artificial neural network will be defined as reference points, while the other points which will be used to evaluate the performance of the proposed algorithms will be defined as check points.

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