Aspects Concerning the Geo-reference of Geodesic Trapeziums within the Cadastral Information Systems

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***Abstract**: The integration into a GIS project of the cartographic fund existent for a certain geographic area represents a necessary requirement both as work basis, up to the completion of the measurement projects necessary in order to update the cartographic information, and as a possibility for spatial analysis in comparison with the prior situation in the field. In this context, to geo-reference the raster image of the cartographic product, the Artificial Neuronal Networks represent a modern complementary approach as compared to the classical techniques and provide the advantage of modeling a multivariable problem without requiring the establishment of complex dependences between the input variables. Thus, in order to make a cartographic digital database with features related to the precise positioning of field details, a case study is here presented concerning the geo-reference of the raster images of the plan sheets for a locality by means of a model using the Artificial Neuronal Networks(ANN).*

1. Introduction

The cartographic database building up in the digital system, for a certain cadastral territory, includes using as a data source the plans and maps existing in the analogical system, which are to be integrated in the digital system by the processes of scanning, geo-reference and vectorization. The deformations error analysis accompanying the scanning process give points to the optimal geo-reference method and, at the same time, indicates which are the maps' or planes' sheets with minimal deformations in order to be used as basic elements in the geo-reference process and lead-in process for the surrounding sheets.

Errors resulting after geo-reference, shall be analyzed by different transformation types, using classical methods and ANN, in comparison with the results obtained by applying certain specialized programs, operating in the GIS medium (*Autodesk Map 2005*).

It was considered a geodesic trapezium for illustration, representing a basic topographic plane at a scale of 1:1 000 within the city of Iassy, made on paper, in this city's own system of coordinates (*figure 1*).

The geodesic trapezium was scanned and then the resulted raster image was inserted in the graphical medium of *Autodesk Map 2005*, with random origin. The points defining the trapezium four corners were marked, as well as the intersections of the rectangular grid, whose coordinates were extracted by the specific function of point identification.

29 specific points resulted with coordinates known both in the projection system LOCAL-IASSY (real coordinates in the field, obtained by graphic reading from the plane), and in the digitized system (graphic coordinates in *Autodesk Map 2005*) - (*fig. 1*).

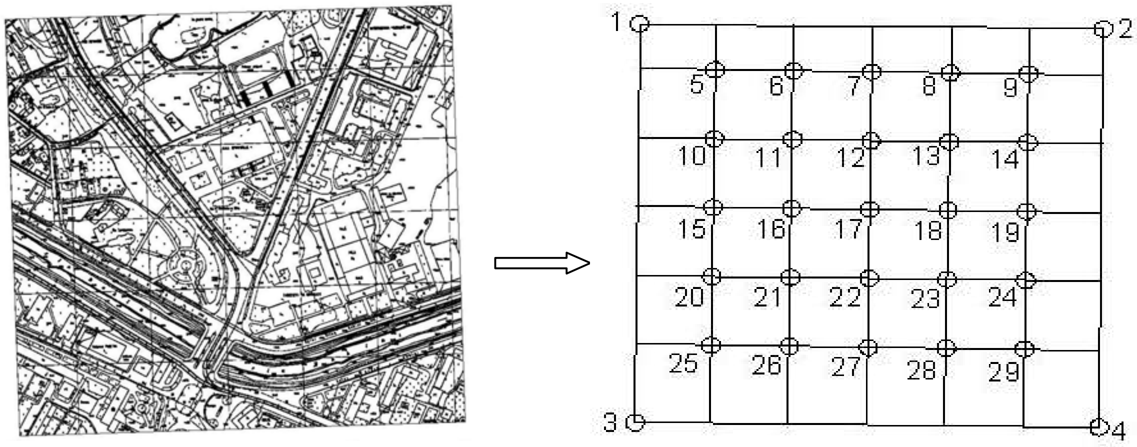

Fig. 1 – Specific points determined for the plane sheet at the scale of 1:1000

2. Geodesic trapezium geo-reference

In order to geo-reference the geodesic trapeziums, in case of the classical methods polynomial transformations can be applied assuring a proper precision to the established size grade. The system of the corrections equations is written in a specific way, according to the model of linear, affine or superior degree polynomial transformation. In each of these cases it is necessary that a minimum number of double coordinates points both in the real system in the field and in the digitized one should be established.

Approaching is made by applying the least squares' theory, by a matrix-typed solving, being obtained in turn, the system of the normal equations, matrix of the unknown elements by means of the method of reverse matrix and, finally, valuation of the results' precision, by highlighting the mean square error of transcomputing a point [3].

As a consequence of the latest achievements in the field of the artificial intelligence in the last two decades, new methods appeared, based on artificial neuronal networks (ANN), having superior results in relation to the classical ones. Considering this aspect, we present now the development model in case of geo-referencing a geodesic trapezium, with help of the artificial neuronal networks (ANN).

It may be admitted that, for certain types of problems, the human brain proves a greater performance because it uses a model of analyzing the information different to the ones used in informatics nowadays. On the one hand, analyzing the information inside the brain is massively made in a parallel way, while the most part of the electronic computers use the sequential processing. On the other hand, the biological memory is diffuse, being allocated into the very structure of neurons and synapses, while the computers' memory is localized and it is addressable owing to this very type of structure.

The former of these differences ensures superior information processing speeds in the human brain. The latter one ensures to the nervous system an enhanced vigor from the point of view of the degradation possible to appear in its structure (daily hundreds of thousands of neurons die without significantly affecting the brain's performances).

Knowledge acquisition is made by learning. Neuron represents an element of information processing which shapes, in a simplified way, the real neuron.

In an extensive way, ANN can be described by:

1. *Topology* – the way a neuronal network is organized in layers and the way these layers are connected;
2. *Learning process* – the way the information are stored inside the network;
3. *Generalization (remembering) process* – the way the information are recovered from the network.

Starting from this aspect, it is presented hereinafter the architecture of an artificial neuronal network, *Multi Layer Perceptron (MLP)* type.

Each neuron within a 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:

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

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.:

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

Neuronal network driving was made by using as a driving procedure *Rprop* (*Resilient Propagation*) function.[4].

3. Case study

For the basic topographic plane with the nomenclature *L-35-32-C-a-2-I-4-b*, at the scale 1 : 1 000, there were considered the 29 specific points with coordinates known both in the GIS medium *Autodesk Map 2005* („*source*” system), and in the projection system Local-Iassy („*target*” system) (*table 1*).

Table 1

Point #	Graphic coordinates *Autodesk Map*		Plane coordinates Local - Iassy	
	x (m)	y (m)	X (m)	Y (m)
1	1000,0083	1000,6535	9619,270	9081,962
2	1000,6005	1000,6479	10211,626	9083,880
3	1000,0027	1000,0742	9621,143	8503,027
4	1000,5949	1000,0688	10213,556	8504,944
…	…	…	…	…
26	1000,1824	1000,1692	9800,000	8600,000
27	1000,2825	1000,1679	9900,000	8600,000
28	1000,3825	1000,1667	10000,000	8600,000
29	1000,4824	1000,1654	10100,000	8600,000

In order to geo-reference, there were applied the following for a comparative study:

- affine transformation by classic methods (least squares method);
- transformation using Artificial Neuronal Networks (ANN);
- „rubber sheet” geo-reference function within Autodesk Map 2005.

Differences between the transcomputed plane rectangular coordinates and the real ones from the projection system LOCAL – IASSY, reduced to the plane scale of 1 : 1 000 are presented in *Table 2*. (The measurement unit is the millimeter.)

Table 2

Point #	Differences between the transcomputed coordinates and the real ones, at the plane's scale					
	Affine transformation		„Rubber sheet" transformation		Transformation with ANN	
	ΔX (mm)	ΔY (mm)	ΔX (mm)	ΔY (mm)	ΔX (mm)	ΔY (mm)
1	-0.66	0.45	-0.61	0.46	0.00	0.02
2	-0.33	0.51	-0.32	0.48	0.00	0.13
3	-0.29	0.26	-0.24	0.33	0.00	0.01
4	-0.15	0.11	-0.14	0.17	0.00	0.00
5	-0.21	0.06	-0.21	0.12	0.00	0.15
6	0.12	-0.08	0.12	-0.10	0.00	-0.28
7	-0.66	0.39	-0.59	0.36	0.08	0.39
…	…	…	…	…	…	…
22	-0.16	0.04	-0.15	0.07	0.07	0.93
23	-0.33	-0.01	-0.35	-0.03	0.00	-0.16
24	-0.09	-0.06	-0.17	0.00	0.00	0.03
25	-0.47	0.12	-0.45	0.13	0.04	0.37
26	-0.34	0.17	-0.32	0.15	0.04	-0.21
27	-0.20	0.13	-0.24	0.15	0.00	0.05
28	-0.17	0.18	-0.15	0.11	0.00	-0.01
29	-0.23	0.13	-0.25	0.06	0.00	0.02

4. Conclusions

Geo-reference of the geodesic trapeziums is based, in case of the classic methods, on algorithms of polynomial transformation, their degree being determined according to the desired transformation precision. Testing the „*rubber sheet*" geo-reference function in the GIS medium of *Autodesk Map 2005* shows that the transcomputation precision of a point is similar to the affine transformation. On basis of the specific points represented by the corners of the geodesic trapezium and the intersections of the rectangular grid, there was built up the solving model by means of the architecture of the Artificial Neuronal Networks (ANN), *Multi Layer Perceptron* (MLP) type. Adjusting grid weights method uses as a target function a valuation of the approximation errors with the total square deviation. Neuronal network driving was made by using as a driving procedure *Rprop* (*Resilient Propagation*) function.

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