A NEW METHOD FOR BUILDINGS 3D MODELS COMPARISON

Valeria Ersilia ONIGA – Teaching assistant, Ph.D Eng., Technical University „Gheorghe Asachi" of Iasi, Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering, Department of Terrestrial Measurements and Cadastre
e-mail: *ersilia.oniga@tuiasi.ro*

Abstract: *In order to obtain the 3D model of a building, many data sources and methods have been developed in literature. To evaluate the accuracy of this models, they must be compared with a reference model, considered a high precision model. The Euclidean distance is the most used method, but it not offers a global comparison. In this paper a new method for buildings 3D models comparison is proposed, which implies the transformation of the 3D model into 3D mesh surface. The differences between the two models are calculated using the Hausdorff distance, considering as reference model the one created based on TLS data. The aim of this research is to determine the differences between two 3D models, especially CAD models, with high precision, in a completely automated way. To obtain the results, the 3D modelof a building was created, based on ALS data and precise measurements made with a terrestrial laser scanner. The proposed method, highlights the differences between two models using a color palette, offering in the same time a global comparison.*

Keywords: Hausdorff distance, ALS, 3D model, quality assessment

1. Introduction

Over the years, there were made comparative studies on 3D models created based on different data sources, most of them being focused on comparing characteristic points coordinates, 3D distances, areas or buildings volumes.

The problem of assessing the accuracy of the 3D model creation has already appeared in the literature. In 2010, Akca proposed internal accuracy assessment of the 3D model based on bringing the three-dimensional surfaces in correspondence, by the least squares method and calculate the Euclidean distances between the two surfaces [1].

In [2] a complex analysis of errors that influence the 3D modelling precision of building different elements (espacially roofs), is presented. The proposed method for assesing the accuracy is based on a comparison of the model with data resulted from airborne laser scanning.

In this paper, a new method for buildings 3D comparision is proposed. Knowing that most of this 3D models are CAD models, we suggested to transform them into 3D mesh surfaces. The differences between the two models, are now calculated using the Hausdorff distance, considering as reference model the one created based on TLS data.

The Hausdorff distance was implemented in 2002 in the "Metro tool" software, displaying the errors numerical values and their distribution as a histogram and also a visualisation of errors at a local level, by using a color palette [3], [4], in the "MeshDev" software [5] and in the "CloudCompare" software [6]. The last software can process 3D point clouds, but also mesh surfaces. First, was design to compare two point clouds or a point cloud with a mesh surface. [7].

2. Presentation of the study area, materials and equipment

2.1. Presentation of the study area

The „Department of Terrestrial Measurements and Cadastre" building, from the Technical University „Gheorghe Asachi" of Iasi, has two building parts with different heights, both with a regular shape that is rectangular parallelepiped.

(a)

(b)


Fig. 1**.** The study area, the "Department of Terrestrial Measurement and Cadastre" − (a) digital image representing the main facade, (b) digital image representing the secondary facades

2.2. Materials and Equipment

The main materials for this task are the ALS data, TLS data and data acquired with standard surveying tools. The topographic measurements were made using the Leica TC(R) 405 total station, having the data processed with the TopoSys software, while the 3D points were acquired with the ScanStation2 laser scanner, achieving five scans (ScanWorlds) - each of them approximately in a 45 minutes time frame and handled using Leica Cyclone v.6.0 and Cloud Compare software.

The ALS data were acquired in March, comprising a total of 800 bands acquired with the Leica ALS50 sensor with a wavelength of 1064 nm. The ALS points have an accuracy of 70 cm in horizontal plane and 20 cm in vertical plane [7], the plane rectangular coordinates were calculated in the National Projection System, namely "Stereographical on unique secant plan-1970" and the normal altitudes in the „Black Sea 1975" reference system for heights.

2.3 The Hausdorff distance

Hausdorff Distance - named after Felix Hausdorff, is the most famous metric for comparing two mesh surfaces, providing a global comparison.

Hausdorff symmetric distance $d_S(S,S')$, is defined as follow:

$$d_S(S,S') = max[\,d(S,S'),d(S',S)\,]. \quad (1)$$

The symmetrical distance offers a more accurate measurement of the differences between two surfaces, because the one-side distance can lead to an underestimation of the distance values between the two surfaces [8].

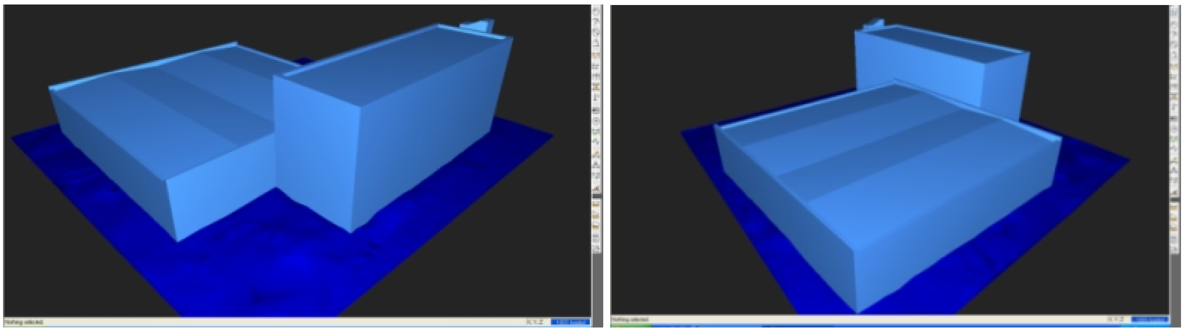
The distance accompanied by its sign was introduced in the "*Cloud Compare*" software for a independent evaluation of the areas that belong to the first surface and are situated inside or outside the space, relative to the second surface.

3 Results and discussion

3.1 Creating the 3D model of the „Cadastre” building, based on ALS data

The building modeling process was performed using the "Leica Cyclone" software by the following steps:

– The parameters determination of the surface that best fit the ALS points and their representation in the 3D environment;
– Creating the building edges and the roof edges by the least square method;
– The building walls reconstruction;
– Checking and correcting the joints of adjacent surfaces;
– Creating the final 3D model of the building (Fig. 2).



(a) (b)

Fig. 2. The final 3D model of the „Cadastre” building, obtained with the „Leica Cyclone v6.0” software, based on ALS data, (a) south-west view, (b) north-west view

For a first check of the accuracy of the 3D building model reconstruction, this, represented in red colour, was integrated into the ALS point cloud represented by triangular finite elements with blue (Fig. 3), observing visually, that the performed operations were correct, producing a correct 3D model of the "Cadastre" building.

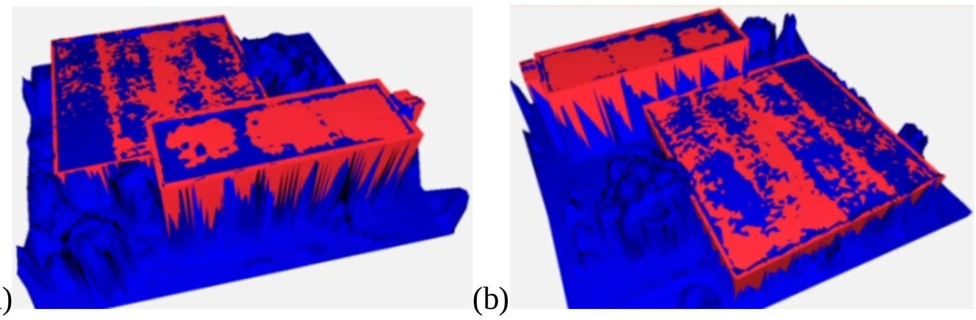
(a)  (b)

Fig. 3. The “Cadastre” building modeled in 3D using the ALS data inserted in the TIN model obtained based on the ALS point cloud (a) south view, (b) north-east view

In order to assess the accuracy of obtaining the roof edges based on ALS data, the edges were superimposed on the ones obtained with a high accuracy based on the measurements made with a total station (Fig. 4), the differences being, not more than 60 cm, for the north building part, respectively 70 cm, for south building part [7].

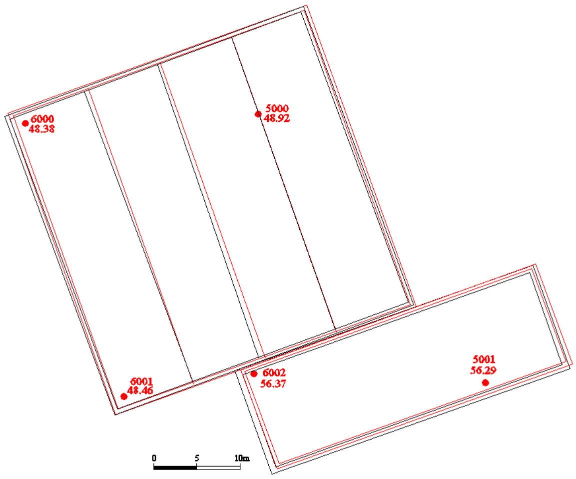


Fig. 4. The roof boundary and edges of the “Cadastre” building, with red being marked the ones obtained based on total station measurements and with black colour those obtained based on ALS data

3.2 Comparing the buildings under study by the proposed method

To determine the accuracy of the buildings 3D models by the proposed method, these must be compared with a reference model considered for this case study, the 3D model created based on the TLS data.

In order to evaluate the interior accuracy of the 3D model created based on the TLS point cloud, will be compared, using the Hausdorff distance and "CloudCompare" software with the point cloud resulted from the scanning and manual filtering processes.

The point cloud filtering process, must be realize very carefully, because any point that has not been used in the modeling process, may lead to large error. By filtering process we must understand the elimination of points that do not belong to the building of interest, namely: vegetation, air conditioning, lighting sources or external stairs mounted on the facades of the building, stormwater drain tubes, cables and also points measured inside the building through its windows. Two examples of such objects located on walls of the study building, can be found in Fig. 5.

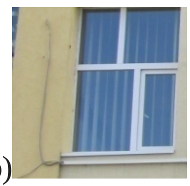
(a)  (b) 

Fig.5**.** Elements that do not belong to the building of interest (a) stormwater drain tube, (b) cables

3.2.1 Quality assessment of the “Cadastre” building 3D model, created based on the TLS data

First the interior accuracy of the „Cadastre” building 3D model, created based on the TLS data, was evaluated, by comparing it using the “*Cloud Compare*” software, with the point cloud resulted from the scanning and manual filtering processes, obtaining the maximum positive difference of 5.1 cm, the maximum negative difference of 5.5 cm, the mean difference of 0.004 cm and the standard deviation of 2.1 cm, as can be seen in Fig. 6.

To highlight the distances between each TLS point and the 3D building model, the "Red> White" palette was chosen from the "CloudCompare" software menu, with shades of red being highlight points for which the calculated distances were between -2.5 cm ÷ 2.5 cm, and with graycolor, points for which the calculated distances were within the ranges of -5.5 cm ÷ 2.5 cm and 2.5 cm ÷ 5.1 cm.

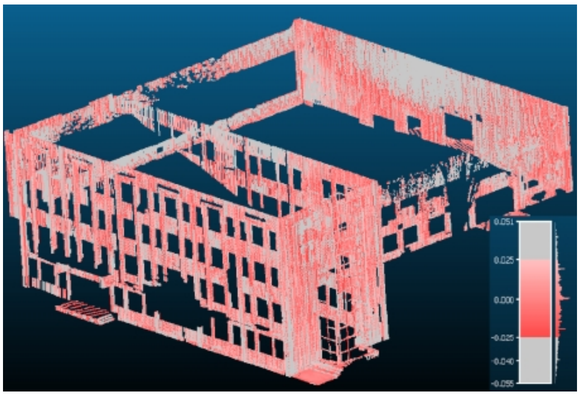
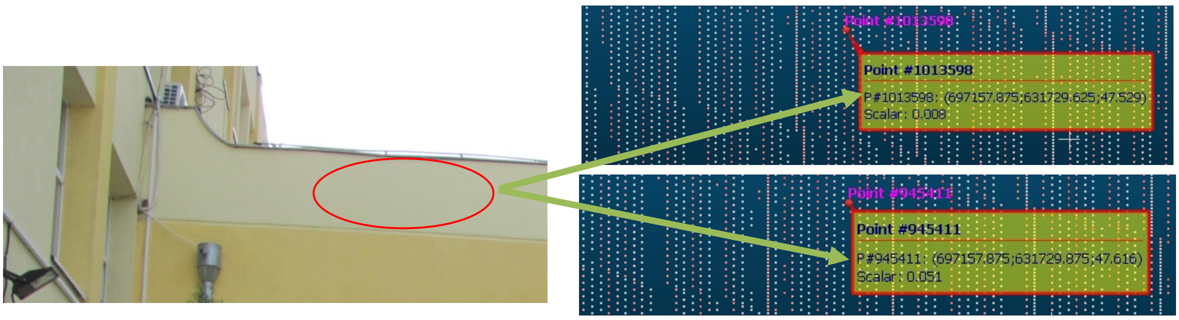


Fig.6 – The differences between the TLS point cloud and the “Cadastre” building 3D model, created based on the TLS data, using the “Cyclone” software

Certainly, TLS data processing, involves manual steps, the building components being created by approximation with their mathematical shape (finding the best fitting geometric elements), using the "Leica Cyclone" software functions, therefore the accuracy of the 3D model is not the same with the terrestrial laser scanning system measurement accuracy.

From Fig. 7 it can be seen that, TLS points belonging to closely scan lines, located on the same plane from the northeast facade of the “Cadastre” building, obtained by approximation using the least square method, are colored differently. The calculated distances were 8 mm, respectively 5.1 cm.



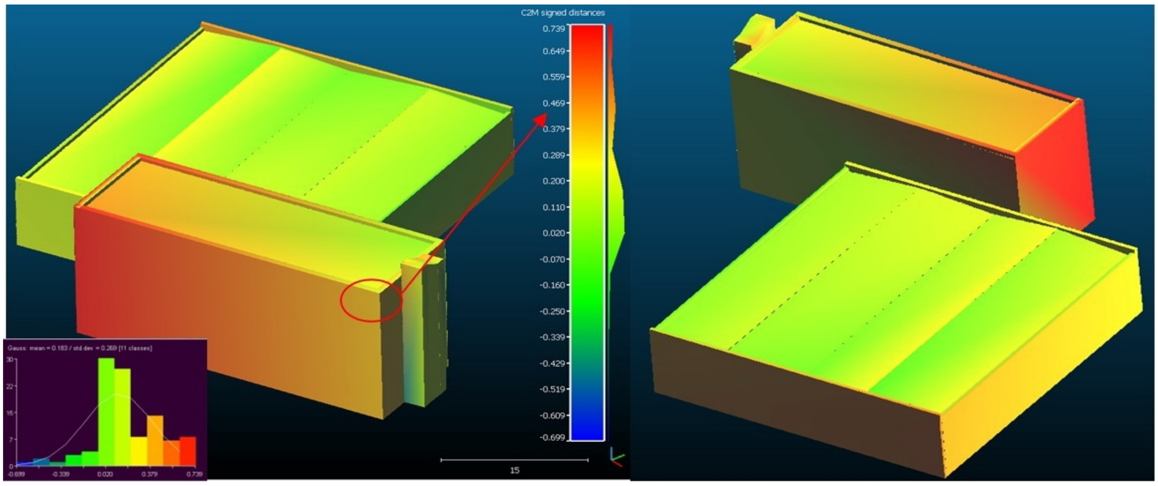
(a) (b)

Fig. 7. (a) Digital image representing the north-east facade of „Cadastre” building, (b) Differences between two TLS points belonging to the north-east facade and the 3D surface created based on TLS data, using the least square method

3.2.2 Quality assessment of the “Cadastre” building 3D model, created based on the ALS data

To determine the accuracy of buildings 3D models by the proposed method, these must be compared with a reference model. Further, the 3D model created based on TLS data will be considered as a reference model, whose roof was obtained by approximating the GNSS data by the least squares method [7].

After comparing the "Cadastre" building 3D model, created based on ALS data, with the reference 3D model of the building, the following differences were obtained: maximum positive of **73.9 cm**, maximum negative of **-69.9 cm**, mean difference of **18.3 cm**, and the standard deviation of **26.9 cm**, as can be seen in Fig. 8. Analyzing the color palette we can easily obtain the value for the Hausdorff distance, for example the south-east corner of the 3D model is colored with an orange tone, corresponding to a value of about 44 cm on the scale.



(a) (b)

Fig. 8. Differences between the 3D model of "Cadastre" building, created based on ALS data and the reference model and the differences distribution histogram, (a) south-east view, (b) north-west view

If, however, the 3D model created based on the TLS data, will be compared with the one created based on the ALS data, the differences will be much higher because they will highlight the building missing components.

The maximum positive difference between the reference 3D model and 3D model based on data TLS is **2.585 m**, the maximum negative difference is -1.402 m, **and standard deviation is 47.1 cm**, as can be seen in Fig. 9.

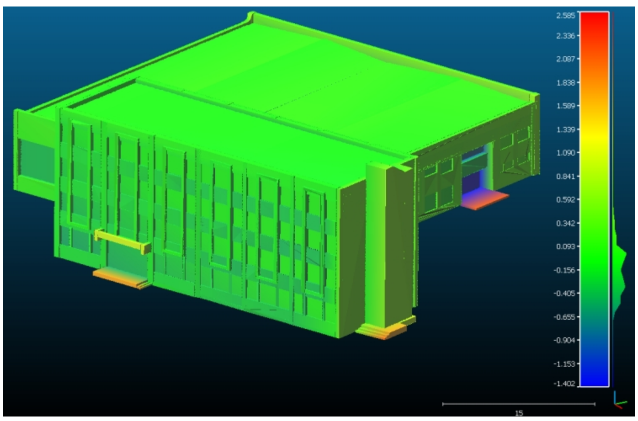


Fig. 9. Differences between the reference model and the 3D model of „Cadastre" building, created on ALS data

Analyzing the color palette in Fig. 9, it can be seen that from the 3D model of the "Cadastre" building, created based on ALS data, the following components are missing: steps of primary and secondary entrances and also windows, reflecting the low level of generality 3D model or its completeness.

Another way to highlight the missing elements is to subdivide each triangle, component of the mesh surface representing the 3D model of the building to be compared [9], in this case the one created based on the ALS data. In this way, the Hausdorff distances are calculated also inside the triangle not only in his vertices. Thus, in the case of the reference model, the windows surfaces have been removed, as shown in Fig. 10, the Haudorff distances calculated in nodes next to the windows surfaces, having the larger value than the ones next to walls for example. Also, the maximum distances were calculated in the middle of windows surfaces, their values representing the perpendiculars drawn from nodes on the closest edges of the windows.

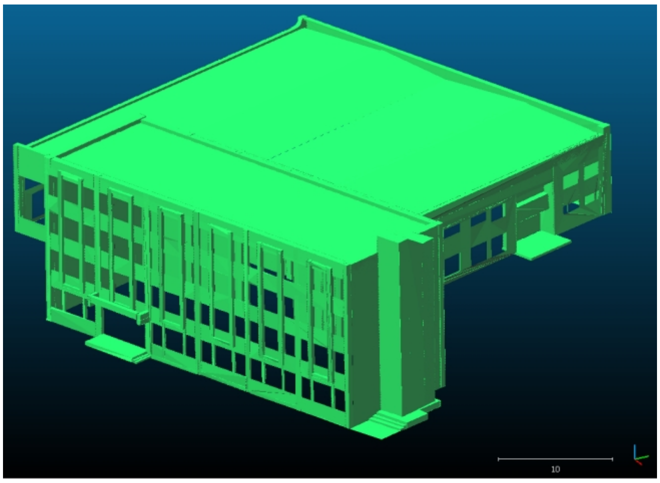
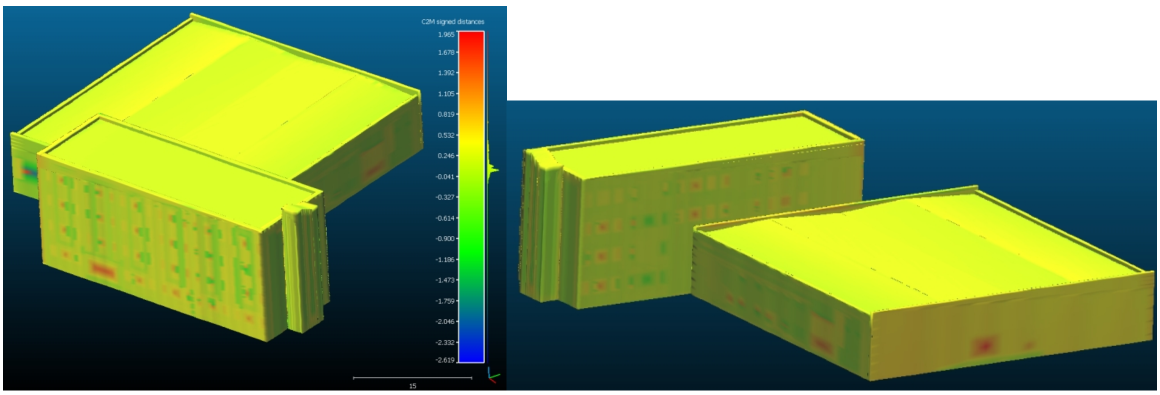


Fig. 10. The reference model of „Cadastre" building, without the windows surfaces

After comparing the divided 3D building model, considering the area of the smallest triangle belonging to the surface to be compare of 0.20 m^2, the maximum positive difference between the reference 3D model and the 3D model created based on the TLS data is 1.865 m, the maximum negative difference is **-2.619 m** and the **standard deviation is 31.3 cm**, as can be seen in Fig. 11.

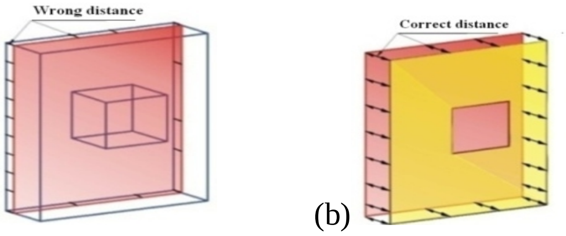


(a) (b)

Fig. 11. The differences between the "Cadastre" building 3D model, created based on the ALS data and the reference model, obtained by subdividing each triangle of the model to be compare (a) south-east view, (b) north-east view

4 Conclusions

The only inconvenience in using this method for 3D models comparing, is when the components of the reference 3D model were created by using the "extrude" function, because when there is a translation between the two 3D models facades, it is possible that this may not be highlighted correctly. The Hausdorff distances are calculated from the nearest surface, which in this case may be the one from the interior side of the element, as can be seen in Figure 12.



(a) (b)

Figure 12. (a) the wrong Hausdorff distance, calculated from the interior wall of the building, (b) correct Hausdorff distance, calculated from the exterior wall

The proposed method for buildings 3D models comparison, offers a comprehensive assessment of the differences between two 3D models by using a color palette, the user being able to quickly and accurate identify the errors of the 3D model that was compared with a reference model considered with no errors.

It also illustrates the missing elements of the 3D model that was evaluated, by changing the reference model with the compared model, or by subdividing the triangles surfaces which are components of the mesh surface corresponding to the transformed 3D model.

5. References

1 *Akca, D., Freeman, M., Sargent, I., Gruen, A. – Quality assessment of 3D building data, The Photogrammetric Record 25(132): 339–355, December 2010.*
2 *Elberink, S.O. and Vosselman, G. – Quality analysis on 3D building models reconstructed from airborne laser scanning data. ISPRS Journal of Photogrammetry and Remote Sensing 66, 157–165, 2011.*
3 *Cignoni, P., Montani, C. and Scopigno, R.– A comparison of mesh simplification algorithms. Computers & Graphics, Volume 22 (1), pages 37-54, 1998.*
4 *Cignoni, P., Rocchini, C., and Scopigno, R. – Metro: Measuring error on simplified surfaces. Computer Graphics Forum, vol. 17, nr. 2, pp. 167–174, June 1998.*
5 *Roy, M., Foufou, S., Truchetet, F. – Generic attribute deviation metric for assessing mesh simplication algorithm quality. In Proceedings of IEEE International Conference on Image Processing, pp. 817820, September 2002.*
6 *CloudCompare – CloudCompere User's Manual for version 2.1, 2012.*
7 *Oniga, V.E., Chirilă, C. - Hausdorff distance for the differences calculation between 3D surfaces, RevCAD 15/2013, pp. 193-202, 2013.*
8 *Aspert, N., Santa-Cruz, D., Ebrahimi, T. – Mesh: measuring errors between surfaces using the Hausdorff distance. In Proc. of the IEEE International Conference in Multimedia and Expo (ICME), vol. 1, pp. 705-708, Lausanne, Elveţia, August 26-29, 2002.*
9 *Roy, M., Foufou, S., Truchetet, F. – Mesh comparison using attribute deviation metric. International Journal of Image and Graphics (IJIG), Vol. 4, Nr. 1, pp. 127-140, 2004.*