Feature Geometry and topology issues in transformation process between different geodetic reference systems

Vivian de Oliveira Fernandes*, Günther Schmitt, Ruth Nogueira*****

* Bahia Federal University
** Karlsruhe Institute of Technology
*** Santa Catarina Federal University

Abstract. A great instrumental evolution has been noticed with the development of new technologies through the years; processing methods and spatial data analysis, among others, bringing a sensible change in cartography and related areas. The adoption of the Geocentric Reference Systems took place as a consequence of the increasing utilization of the Global Navigation Satellite System – GNSS. The adoption of the International Terrestrial Reference System – ITRS, widespread in each continent as a reference system, allows a consistent integration with networks throughout the world. In Brazil, the Resolution nº1/2005 was deliberated by IBGE on February 2005, establishing the Geocentric Reference System for the Americas (SIRGAS), which was accomplished in 2000 – SIRGAS2000 and adopted by the Brazilian Geodesic System and the National Cartographic System as the new geodesic reference system. The geodetic transformation system needs is a global reality in mapping activities. A qualitative study about the change of geodetic reference was made to indicate probable consequences that could occur in a mapping targeted to software such as Geographic Information Systems and CAD software. These analyses were based on digital maps of cities in southern Brazil. Some sources of positional variations were pointed out. The sources were arranged in a table according to the graphic primitives where the implications were analyzed according to the following sources of variation: a) the transformation of geodetic references; b) editing topological structure adequacy; c) conversion between vector file formats; d) mapping updates. The results showed that when transforming a mapping into a reference digital medium with some software, a range of tasks necessary to fit the data must be provided. Besides the transformation itself, format conversion, editing of topological structure and incorporating new mapping techniques that may be more or less compatible with the techniques used thus far need to be performed.

Keywords: Feature Geometry, topology issues, Geodetic Reference System.

1. Implications inherent to software on geometric and topological features

In the transformation of geodetic reference mappings to digital media there is the possibility of using the GIS and CAD software. They transform vectors and not only isolated coordinates.

In CAD software with "*Map*" versions, there are tools for transforming referentials, with options to input parameters calculated by the user, and for the software's "*default*" parameters. In most software, the user does not have access to these parameters "*default*". However, the user is directed to enter the parameters of interest.

In the Geographic Information Systems – GIS, there are also tools for transforming references. A GIS is capable of generating new information, providing models and simulations of geographically referenced data while CAD provide efficient support in editing map data, except for the "*Map*" versions. Despite the fact that the GIS also edits cartographic data.

The process of geodetic reference transformation works similarly in GIS and CAD, however some GIS offer a wider range of model transformation choices to be used. For example, in ArcGis version 9 there are eight models based on translations and three models which are based on calculating the change in grid.

As one of the objectives of this research is to indicate the possible implications of the change of geodetic reference due to the use of a specific type of software with mapping in digital media. We evaluated a CAD software and a GIS software: AutoCAD2006 and ARCGIS 9.2, respectively, and the mapping of the City of Curitiba-PR.

2. Results and Analysis

Figure 1 shows the vectors in SAD69 (in gray) and SIRGAS2000 (in magenta) of the referential transformation process performed in CAD software. In this transformation, the translation parameters of the IBGE were used for the vectors related to street layout and street names.

Figure 1: Transformation of geodetic reference held in a CAD software

In a CAD environment, after proceeding to the transformation, a new file referenced to the new SGR was created. There were no problems in editing the features, as can be seen in figure 1.
However, in a GIS, a new file with the new SGR is also generated. But problems occurred in the new file when editing place names, as **figures 2 and 3** show. Requiring a mapping editing process after the transformation process.

Figure 2: Excerpt from the original Curitiba map

Figure 3: Excerpt from the post-processing Curitiba map

There is no ideal transformation solution for the layers and place names problems. These are issues that must be dealt with separately.

CAD store spatial data as graphical entities. These are software that were developed to facilitate the creation of engineering and architecture projects, but are often used in digital cartography. In CAD software, information is accessed from data organized in *layers* and is effective in the process of editing vector graphics, data conversion and plotting.

It was observed that the major consequences occur when there is a need to use a software that allows performing a spatial analysis, which is one of the greatest potential of GIS software. To enable spatial analysis it is necessary that the topological structure allows this. The topological structure instructs the computer on how geographic features are logically connected to each other, it is based on the relative positions of features and connectivity in space, orientation, adjacency and contingency, determining whether two features intersect or not and what type of intersection between them. The storage of the topological component is responsible for spatial relationships, which are functions that use spatial attributes present in databases to answer questions about the real world.

A study on the geodetic reference change was made to indicate probable consequences that could occur in a mapping directed to a Geographic Information System. These analyses were performed based on the mapping of São José dos Pinhais. Some sources of positional variation were suggested which do not refer only to the geodetic reference transformation, because there are other sources that may possess greater magnitude of positional variation. The positional variation sources evaluated were:

A) *Transformation of geodetic reference*: references vector files that had their origin in surveys referenced to SAD69, decoupled from other coordinate aggregated to a geocentric reference. In the latest surveys, the association is generally inherent to the satellite positioning technology referenced

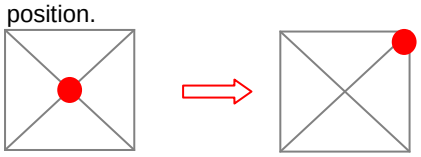
to WGS84, compatible with the SIRGAS2000 official Brazilian *Datum*. Also included in this topic is the use of different parameters and transformation models;

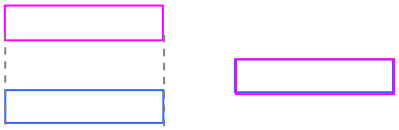
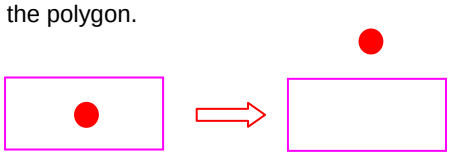
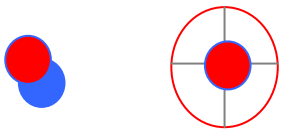
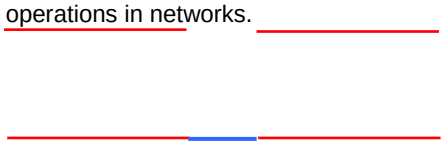
b) *Edition for adaptation to the topological structure*: concerns the adequacy of the vector files that it ensures the properties and relationships of connectivity, adjacency, proximity, relevance, continence and intersection. These relationships are important in the tasks performed by Geographic Information Systems;

C) *Conversion between vector file formats*: refers to portability problems inherent to different vector formats. These conversions are sometimes necessary to perform transformations of geodetic references in some editions;

d) *Mapping update*: refers to both the inclusion of new features as to modifying existing features reusing the original mapping.

For these analyzes Table 1 was constructed from graphics primitives: point, line and area (polygon). The indication of a possible problem, the source of positional variation and the implications thereof and examples. The letters A, B, C, D were assigned. The letter A - transformation of geodesic reference; B - editing to fit the topological structure; C -conversion between vector file formats; and D - mapping update, are sources that suffer positional variation.

Primitive Graphic	**Implication**	**Source of variation Positional**	**Example**
Point	Change in point position	A, B, **C**, D	(C) Each symbol is associated with a point called anchor that serves as the symbol location in the vector file. In some conversion processes between formats the position of the anchor point is changed to the center of the symbol, causing a change in position.  Anchor Point

	Overlap	D	(D) In update processes where features have been updated without the proper disposal of old features, they can overlap in the updated file. 
	Non contingency of a point on a polygon	B, **C**, D	(C) In cases where the anchor point related to place names must be inside the polygon for the realization of some researches in Databases, however with file format conversion processes, they can lose this relationship of the point being contained inside the polygon. 
Line	Exceeding the intersection limit	**A**, B, D	(A) There are GIS who do not require overlapping points. They use a threshold of intersection between the nodes. In these cases, the effect of transformations between references may cause unwanted variations of the relative positions of these nodes. 
	Did not reach the intersection limit	**A**, B, D	(A) Case where GIS do not require overlapping points. They use a threshold of intersection between the nodes. In these cases, the effect of file format conversion may cause unwanted variations of the relative positions of these nodes, not reaching the threshold defined by the system.
	Discontinuity of a line	**B**, D	(B) Editing shifts points to provide continuity of lines in case there is the need to perform operations in networks. 
	Overlapping lines	**D**	(D) In update processes where features

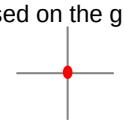
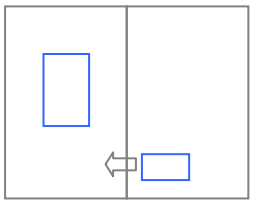
			have been updated without the proper disposal of old features, they can overlap in the updated file.
	Lack of association of a node, notifying the intersection point.	B**, D**	(D) Creation of a point in the vector file that was not raised on the ground. 
Area (Polygon)	Open Polygon	A, **B**, C, D	(B) In the editing process there is a need to change the position of the vertices, so that the polygon is continuous. That is, the starting and end point is the same and the perimeter line is not interrupted.
	Non adjacent polygon - no coincidence of nodes	**A**, B, D	(A) In update cases the new limits and adjacencies do not match with the point raised. Thus, to preserve the property of adjacency, the nodes in old or new limits need to be displaced.
	Changing the relationship of relevance.	B, **D**	(D) In update cases where an updated building ends up appearing in another lot and not the lot to which it belongs. 

Table 1. Positional variation sources

By adopting a new geodetic reference, one must provide a range of tasks necessary to adequate the data already collected to the characteristics of future updates. Among the tasks, other than the transformation of the reference itself, there are format conversions, editions to the topological structure and incorporation of new mapping techniques that may be more or less compatible with the techniques used thus far.

Thus, one can better understand the direct and indirect implications presented in Table 1 with the adoption of a geocentric reference.

It can be seen that this qualitative analysis, the variation derived from the processing of the geodetic reference is present in only some cases of interference on topological features in comparison with editing and update of the topological structure. However, as stated in previous topics, the other processes present in table 1 as a source of positional variation are related to the adoption of a new framework. Thus, it can be stated that the implication of this adoption indirectly interferes in these steps.

There are major restrictions regarding the quantification of these influences, due to the high complexity of the variables involved in these processes, ex. interface type, file format, interoperability between interfaces etc. Thus this study was restricted, in that topic, to a qualitative assessment.

3. Conclusion

The procedure of converting geodetic references into vector files used in cartography and related activities requires specialist knowledge. The use of different conversion procedures generates differences in the values of transformed coordinates. The consequences of these differences are perceived in the merge/joint data from multiple sources, for example. Two databases may be in the same reference system, but if they were converted through different procedures, the conversion of a feature may result in two different representations. Therefore, information coming from the mapping is essential when using softwares in the transformation of coordinates and vector files. When entering the parameters for the transformation in question, the technical documentation of the data and procedures applied to them must be accompanied by the spatial information in order to be uniformly employed. Accordingly, studies are recommended for the standardization of attributes in Geographic Information Systems. There is a need for attention to conversion procedures. Knowledge of the conversion model in which the parameters were determined and used in the selection of the models deployed in softwares.

Four sources were delimited where direct or indirect sources of positional or thematic error exist in digital maps: the very transformation of geodetic reference, the editing process for adaptation to the topological structure, conversion between vector formats and mapping update processes. These sources can cause changes in the actual position of the feature, overlapping these features, the non contingency of a point in a given polygon, exceeding and not reaching intersection limits, discontinued lines, lack of nodes association, open polygons, non coincidence of nodes, among others. It should be noted that there are major constraints when it comes to quantifying these influences. The qualitative evaluation of the sources of positional variation is recommended, taking into account the complexity and variables such as computer interface, file format and interoperability between interfaces

References

BURROUGH, P. A.; MCDONNELL, R. A. Principles of Geographical Information System. Spatial Information System and Geostatistics. Oxford University. Oxford: 1998.

Fernandes, V. de O (2009). Implicações da Mudança do Referencial Geodésico SIRGAS 2000 na Cartografia em Escala Grande. Tese. Universidade Federal de Santa Catarina. Florianópolis. 2009.

IBGE. South American Geocentric Reference System (1997) Final Report. Working Groups I and II. Diretoria de Geociências. Departamento de Geodésia. Rio de Janeiro.

ILLNER, M. Jäger, R. Schmitt, G. Transformationsprobleme. DVW-Landesverein Baden-Württemberg 38, Sonderheft GPS und Integration von GPS in bestehende geodätische Netze. Karlsruhe: 1991.

NOGUEIRA, R. E. Cartografia: representação, comunicação e visualização de dados espaciais. Ed. da UFSC. Florianópolis: 2006.

SIMEK, J.; KOSTELECKY, J. (2000) Modern Geodetic Network and Datum in Europe. FIG Working Week. Prague.

VANÍCEK, P.; STEEVES, R.R. (1996)Transformation of Coordinates between Two Horizontal Geodetic Datums. Journal of Geodesy. Heidelberg: 1996.