Polygonal Line Simplifying Methods Applied to GIS

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SUMMARY

Geographic Information Systems (ARCGIS-ESRI) have tools to produce cartographical generalizations that are based in spatial transformations which alter the geometrical data and topological representation. The major spatial objects use vector as the basic entities for representation. Vectorial generalization has been well studied and is the most common transformation used in existent systems. The three basic elements for vectorial representation are points, lines and areas and are translated to geographical objects. This article discusses polygonal line simplifying methods explains the experiments and evaluation processes for two algorithms to improve line simplification applied to GIS: an adaptation of Douglas-Peucker algorithm, an area/perimeter quotient, and an adaptation of Wang, algorithm applying arc technical recognition.

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1 INTRODUCTION

Spatial objects and phenomena can be represented in different scale maps, complying with the objectives and purposes of their applications. Currently, with the increase of use of georeferred spatial systems, in digital media, models based on methods for data treatment have been generated. Traditionally, in cartography, cartographic generalization has been used for the development of the processes of simplified scale representation. Through these processes rules are established in order to preserve geometry and topological characteristics of spatial objects.
According to Tang and Adams (1996), objects which represent the geographical space bear in itself four representation elements: geometry, non-spatial properties, topological and non-topological relations.
These objects can be transformed through generalization methods and processes. From the moment objects are generalized, geographical objects undergo changes in their geometry and, from these, significant changes may happen in the topological or non-topological relations among the elements. Nevertheless, according to McMaster and Shea (1992), generalization process must try to preserve consistency of topological matters.
Parallelly, through the increasing operational increment implemented from geographical data being brought to informatics in spatialized systems, Registering Cartography has benefited from these applications, since it needs varied scale mapping which cater the needs of the Multipurpose Technical Registering and territorial management.

2 GEOGRAPHIC INFORMATION SYSTEMS

Current GISs, such as ARCGIS from ESRI, present specialized generalization functions, which come to aid the cartographer's work and the final system user. Throughout the development of this article we present the functionalities of a GIS on automatized generation of simplified lines.
In this article we deal with line simplifying as a useful way to build a new data base through transformation and generalization operators. By doing so, data can be conformed to a representation in smaller scale. This means generalization derives new data upon the transformation of spatial and non-spatial properties of an attribute.

3 LINE SIMPLIFYING

Line simplifying is a selective reduction of the number of spots (pairs of coordinates) required to represent a feature. For instance, the number of captured spots upon digitalizing is reduced by the selection of pairs of coordinates considered more relevant in order to have features preserved; or the removal of unnecessary details as curves and floatation of a line or a area

boundary without destructing its essential shape. Simplifying is the most commonly used operator in generalization having as main goal reaching the best possible geometry. Several simplifying routines use complex geometric criteria (angle measurements and distance) to select critical or meaningful spots.
The line simplifying operator is one of the most used. According to D'alge and Goodchild (1996), since most objects use the line as a basic entity for its representation, line simplifying has been deeply studied and it is the most commonly found transformation in existing systems. The author provides some examples of algorithms for line simplifying such as: the original algorithm from Douglas-Peucker, from 1992, which uses the area/perimeter quotient and the smoothing algorithm from Li-Openshaw, from 1992, which accumulates the distances covered over each line. However, these simplifying methods act on lines without concern about topological matters previously created. That's why they must be always followed by knot and polygonization adjustment operations.
Doiuglas-Peucker – It's the most used method by GISs. Initially conceived to solve the problem of excessive number of spots resulting from the conversion of graphic data into digital format, the Douglas- Peucker method is based on the following idea: if no line spot is found farther than a certain vertical distance from the line segment which unites the edges of the line, then this line segment is enough to represent the line itself. This method is considered a global generalization technique since it analyses each line as a whole.
Area/Perimeter Ratio – This method uses the exact same procedure of global analysis of each line applied on the Douglas-Peucker method. The only difference consists on adopting the area/perimeter ratio calculated based on user's chosen tolerance. The use of the area/perimeter ratio allows triangles made up of three consecutive spots which have a very small acute angle on the second spot to be detected in a more efficient way than with the Douglas-Peucker method.
Accumulated Distance – The accumulated distance method is an adaptation of the vectorial implementation of the Li-Openshaw algorithm which uses as criterion the concept of the smallest visible object. This method accumulates the distances as the line is covered until reaching a certain threshold, removing all the accumulated spots on this part. It is, therefore, a very simple method but, different from the two previous ones, does not analyze the line as a whole.

3.1. Line simplifying algorithm in GIS

In light of the perspective of reaching cartographic precision pertinent to registering scale, this article reports the evaluation and experiments of two line simplifying algorithms applied on GIS ARCGIS (figure 1): and adaptation of the Douglas-Peucker algorithm – POINT-REMOVE, which uses the area/perimeter quotient, and an adaptation of the Wang algorithm (Wang, 1999, cited in ESRI, 2007) – BEND SIMPLIFY, which applies arc recognition techniques, analyzes its characteristics and eliminates the most meaningless ones. Since the system is not translucent to the user, subjective criteria were used to apply the algorithm, which represent chosen and tested tolerance values. The article relates the development, analysis and evaluation of the impact of different tolerances in each method. Another assessed aspect was topology, represented by spatial relations among objects, since these methods act on lines without the concern about previously existent topological relations among data, such as proximity and vicinity. By doing so, it was attempted to reach to results which minimized the knot and polygonization adjustment process.

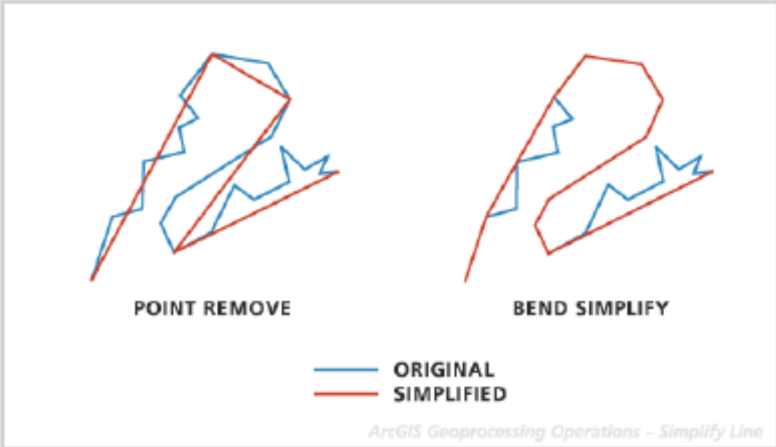

Figure 1 – SIG ARCGIS line simplifying algorithm

3.2. Algorithm Applying

The ARCGIS line simplifying algorithms were applied with the following parameters, according to figures 2, 3, 4 and 5.

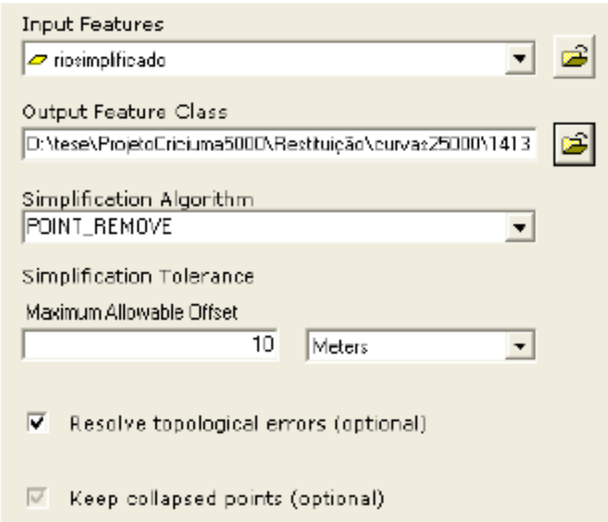

Figure 2 – POINT-REMOVE Algorithm Applying (Douglas-Peucker) - 10 m parameter.

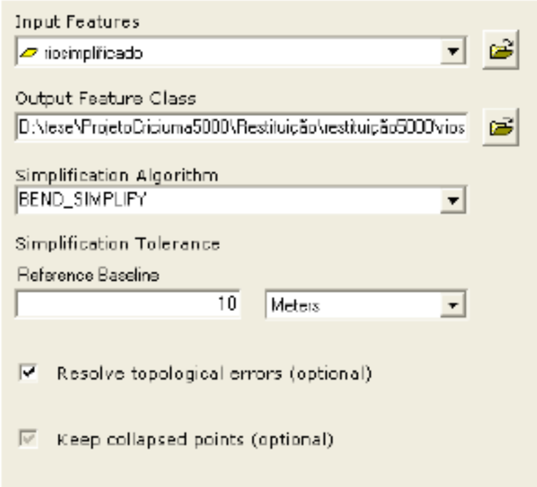

Figure 3 – POINT-REMOVE Algorithm Applying (Douglas-Peucker) - 20 m parameter.

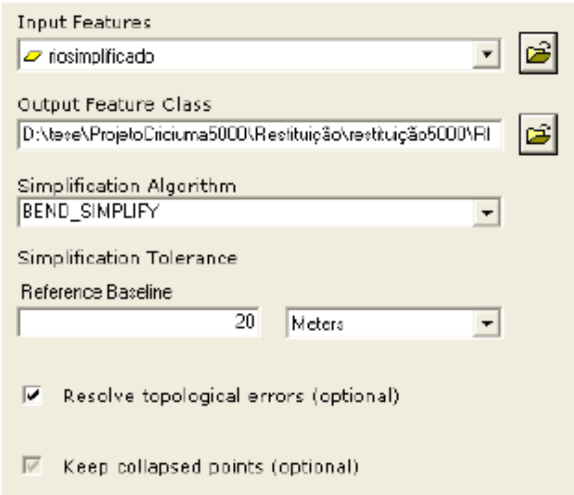

Figure 4 – BEND SIMPLIFY Algorithm Applying (WANG) - 10 m parameter.

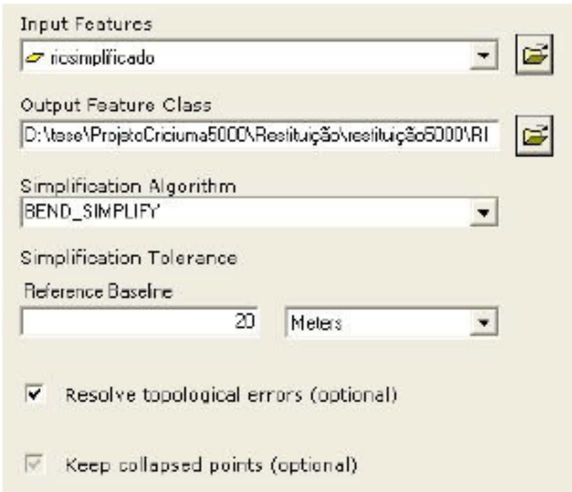

Figure 5 – BEND SIMPLIFY Algorithm Applying (WANG) - 20 m parameter.

Following, we have the original line (figure 6) and its respective number of vertices, and the result of applying the two algorithms for the established parameters (figures 7 and 10).

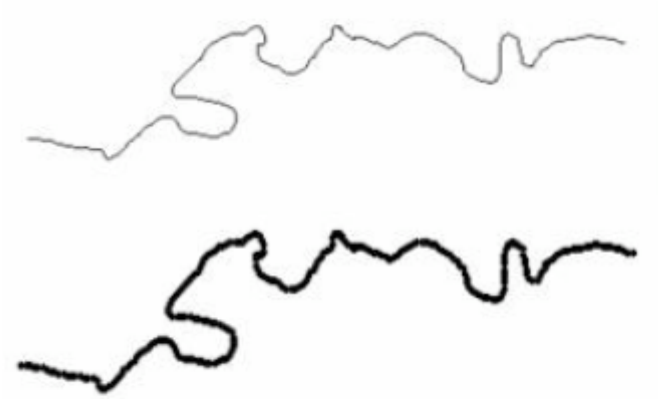

Figure 6 – Original line representation with 263 vertices (spots).

Figure 7 – Simplified line representation using POINT-REMOVE algorithm and 10 m parameter among vertices – Number of resulting vertices: 16.

Figure 8 – Simplified line representation using POINT-REMOVE algorithm and 20 m parameter among vertices – Number of resulting vertices: 9.

Figure 9 – Simplified line representation using BEND-SIMPLIFY algorithm and 10 m parameter among vertices – Number of resulting vertices: 171.

Figure 10 – Simplified line representation using BEND-SIMPLIFY algorithm and 20 m parameter among vertices – Number of resulting vertices: 147.

As seen on table 1, from a total of 263 vertices on the original line, upon applying the POINTREMOVE algorithm, adapted from Douglas & Peucker, a 94% decrease of vertices was obtained when applying the 10 meter parameter among vertices and 97% when applying the 20 meter parameter.
Yet, upon applying the BEND-SIMPLIFY algorithm, adapted from WANG, a 35% decrease of vertices was obtained when applying the 10 meter parameter among vertices and 45% when applying the 20 meter parameter.

TABLE 1 – Line Simplifying Comparison

Simplifying Parameter	*POINT-REMOVE algorithm*	*BEND-SIMPLIFY algorithm*
10 meters	16	171
20 meters	9	147

About topological relations (figure 11), simplified lines were brought together with layers referent to level curves and it was observed that, upon applying the POINT-REMOVE algorithm, despite having a larger decrease of vertices on the line, it loses its original geometry completely, which impairs its vicinity topological relations.
On the other hand, upon applying the BEND-SIMPLIFY algorithm, there is not a significant decrease of vertices, but the line presents a closer-to-the-original geometry, which outcomes in a better topological relation with the other elements in the map.

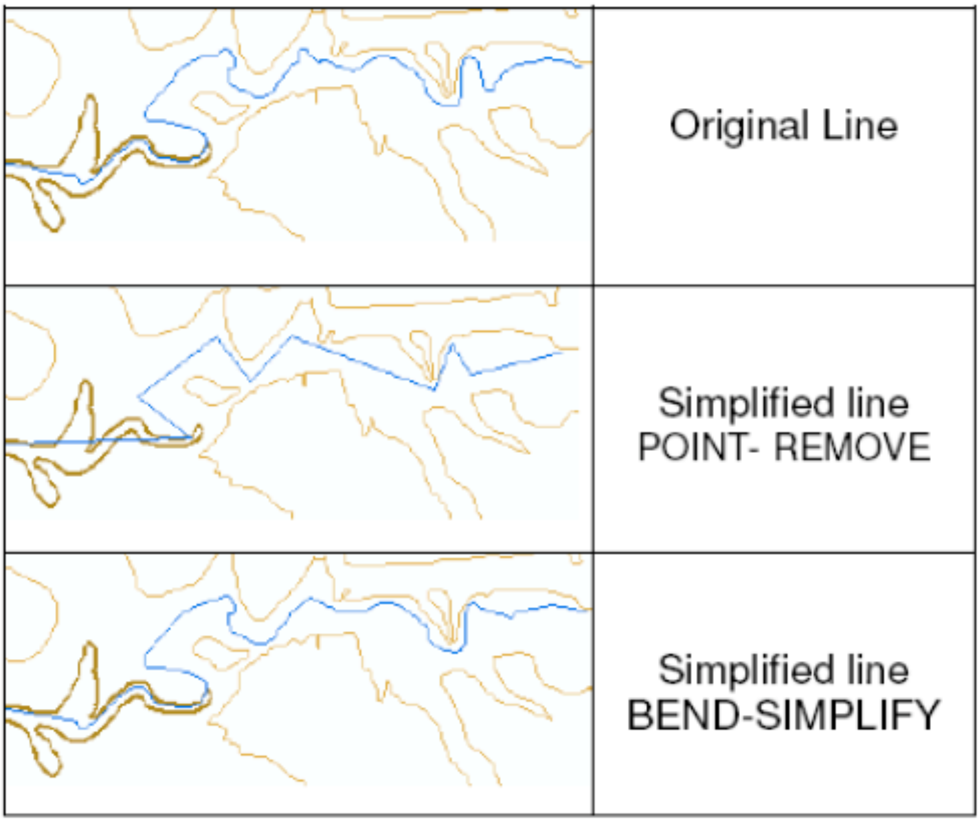

Figure 11 – Topological Relation among elements

4 CONCLUSIONS

After the experiment, using the same tolerances, it was feasible to detect that the POINT-REMOVE algorithm, adapted from Douglas & Peucker, bears the characteristic of eliminating more spots on the line, making it a lighter and more flexible data base for the user and, at the same time, it loses the topological characteristics of the original line. The BEND-SIMPLIFY algorithm, adapted from WANG, eliminates less spots, but it conserves a topology which is closer to the one from the original line. When mixed with other topological elements in the map, to verify proximity and vicinity, the Wang algorithm was the one which presented a better adjustment.

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BIOGRAPHICAL NOTES

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