GEODEZJA I KARTOGRAFIA
GEODESY AND CARTOGRAPHY
Vol. 53, No 2, 2004, pp. 131-135

Testing broken lines – transformed with use of objective global algorithm – as simplified geometric data

Tadeusz Chrobak

AGH University of Science and Technology
Faculty of Mining Surveying and Environmental Engineering
30 Mickiewicza Al., 30-059 Krakow
e-mail: tchrobak@uci.agh.edu.pl

Received: 19 February 2004/Accepted: 5 May 2004

Abstract: The paper discusses the global algorithm of broken line simplification, that: does not depend on parameters set by a map editor and maintains the accuracy of the O-1 Instruction (General principles of surveying practice) of the Head Office of Geodesy and Cartography, Poland, for each map scale (smaller than the source map scale). In the discussed process of line simplification parameters depend on the map scale and on the smallest length of an elementary triangle (this length is a measure of the ability of the drawing recognition). In the process of simplification performed with the use of the discussed algorithm, the same shape of a line is ensured (maintaining the ability of the drawing recognition), since generalised data differ with the bigger or smaller range of scales from the source data. Besides, limits of intervals of generalisation thresholds have been specified, which are required for the process of automated selection of cartographic presentation methods exhibiting the results of line simplification.

Keywords: Map generalization, line simplification

1. Introduction

Answers to the following questions are presented in the paper

- Whether a global algorithm [1] of broken lines transformation maintains its objective features;
- Whether geometric transformations performed with the use of a global algorithm maintain accuracy specified by the standards of the Head Office of Geodesy and Cartography (GUGiK) in Poland (O-1, 1998);
- Whether it is possible to specify measurable criteria for stages of generalisation performed to simplify lines in order to automatically select methods of cartographic presentation.

Getting positive answers to those questions would contribute to the increase of the automation level of the computer map generation process.

[1] Classification of line simplification algorithms according to McMaster (McMaster, 1986)

2. The global algorithm for transformation of broken lines

McMaster Classification (McMaster, 1986) used for simplification of broken lines distinguishes the global algorithm, being Douglas algorithm. Similarities to Douglas algorithm were presented in the developed Chrobak algorithm, what allows for including the last to the group of global algorithms. Results of works performed with the use of Chrobak algorithm do not depend on parameters assumed by a map editor (what is required in the case of Douglas algorithm); it is a function of the map scale and the elementary triangle [2], that specifies the ability of the drawing recognition (Chrobak, 1999). Those relations maintain objective features and the process of line simplification maintains the shape of the primary line.

Chrobak algorithm is adapted to simplification of closed and open lines. In the case of closed lines (Chrobak, 1999) the following elements are additionally considered

- the geometric centre of the closed area,
- the longest distance between the geometric centre and the point of a line.

3. Precision of line simplification versus source data scale

In the process of line simplification with the use of the global algorithm, investigations concerning determination of the number of signals defined by the x,y parameters, written in the form

$$M_0\ (\Sigma x, y) > M_1\ (\Sigma x, y) > M_2\ (\Sigma\ x, y) > \ldots\ M_n\ (\Sigma\ x, y) \qquad (1)$$

have been initiated.

The relation (1) specifies the reduction of signals (line vertices) in the process of quantitative cartographic generalisation, what leads to decrease of the number of events shown on a map (Ratajski, 1989).

The algorithm has been tested in order to state, whether the line shape is modified after simplification, when the process .is performed either in several stages, i.e. $M_0 \to M_1 \to M_2 \to \ldots M_n$, or in one stage, but with an arbitrarily wide range of scales: $M_0 \to M_n$ when data belongs to the set: $M_0 \supset M_i$ and $M_i \to M_n$, (i = 1, 2, 3...n-1).

The results of investigations presented in (Chrobak, 2003) allows for stating that the accuracy of the 2nd group of details, according to (O-1, 1998) is maintained for cases specified in items 1 and 2.

The simplification process using Chrobak algorithm does not depend on the range of scales and it maintains the required accuracy. It is thus the method of simplification of open and closed lines.

4. Stages of generalisation of transformed lines

In the cartographic generalisation model Ratajski (Ratajski, 1989) distinguishes the so-called "generalisation thresholds", i.e. the change of cartographic presentation methods

[2] An elementary triangle is an arbitrary triangle (its shortest side equals to s=0.5mm for a printed map, and 0.6mm for a displayed image), created out of vertices, every three adjacent of which are sequentially tested: from the first to the last vertex

that most frequently results from the loss of detailed information on maps for the benefits of generalised information; the generalisation process between the initial capacity and the generalisation threshold is called "the generalisation stage". The following generalisation stages might be considered when lines are tested in the process of simplification

- approximation I,
- approximation II,
- approximation III,
- symbolisation.

Approximation I is the transformation, in which the number of points after simplification differs from the number of primary points not more than 5%. This difference results from disturbances caused by selection of points of the primary line in the process of digitising (replacement of a continuous line with a broken line).

Approximation II is the process of rejection of points from the primary line. The number of rejected points changes the line shape. The line simplified by means of Chrobak method maintains the primary line shape with the accuracy represented by the mean error m_0 of length that is comparable to the error specified by the GUGiK Instruction (O-1, 1998).

According to definition, the mean error corresponds to the probability of 68% of events (for 100 events, for which the deviation from the most probable value is below the error value). Assuming that after simplification 68% of line vertices are left, such transformation of the line is called "the approximation II".

Justification of the above statement is based on the fact, that in the case of Chrobak method, the mean error is determined (following the law of error propagation) by the sum of deviations that are the shortest distances between the remained points (which describe the most probable shape of the line) and the rejected points (which deform the line). In such a case the number of points of the line is the quantitative measure of the simplification process.

For the assumed quantitative criterion of the simplification process by means of Chrobak method, 5% tolerance should be allowed, that considers selection of points in the process of line digitising, similarly to the Approximation I.

Approximation III is the process, in which the number of rejected points (without invariants of transformation) corresponds to the double value of the mean error m_0. In the simplification method it equals to 90% of rejected points with respect to the primary line points; this corresponds to the double value of the mean error. It is proposed that such a result of transformation is called the Approximation III. Similarly to the above geometric transformations, 5% tolerance should be considered.

Line smoothing is applied in the Approximation III process, what differs this process from the Approximation II (for which line smoothing is not recommended).

Symbolisation is the process of simplification, which corresponds to transfer of cartographic presentation from a line method to the point method for surface objects, and to elimination of line objects. It is performed when 95% ± 5% of n points of the primary line are rejected. Generalisation stages are presented in Fig. 1.

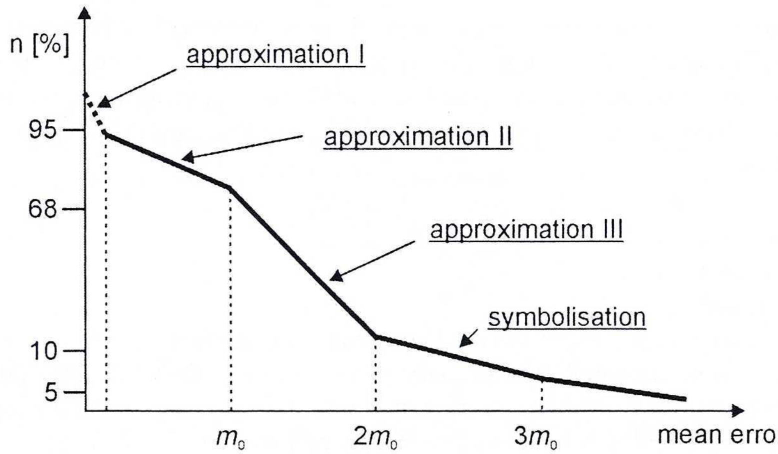

Fig. 1. Stages of generalisation

Conclusions

1. Chrobak algorithm meets the requirements of the method of (closed and open) line simplification, since it does not depend on subjective approach of a map editor; it depends of objective factors of map generation. Those factors are
   - the ability of the drawing recognition defined by the shortest side of an elementary triangle,
   - the result of line simplification that depends on source data but not on the number of simplification stages.
2. The method of line simplification maintains the accuracy of the II group of details, specified in the O-1 GUGiK Instruction (O-1, 1998).
3. Stages of generalisation, and – to tell more precisely – intervals of generalisation, are based on the concept of the root mean square error.

   Presented conclusions are the results of all practical experiments (more than 3500) conducted.

Acknowledgements

Works have been performed within the statutory project No.11.11.150.478, financed by the Polish State Committee for Scientific Research (KBN).

References

Chrobak T., (1999): *Testing the usefulness of an elementary triangle for computer-assisted cartographic generalisation* (in Polish), AGH Uczelniane Wydawnictwa Naukowo-Dydaktyczne, Kraków, 1999.

Chrobak T., (2003): *An objective method of simplification of a broken line when the scale of a map changes*, 10th International Conference, GI/GIT Theory and Practice – Bring Them Together, Ostrava, Czech Republic, 2003.

McMaster R.B., (1986): *A statistical analysis of mathematical measures for linear simplification*, The American Cartographer, Vol. 13, No 2, pp. 103-116.

O-1, (1998): *Ogólne zasady wykonywania prac geodezyjnych (General principles of surveying practice)*, Instrukcja GUGiK.
Ratajski L., (1989): *Methodology of social-and economic cartography* (in Polish), PPWK, Warsaw, 1989.

Badanie krzywych łamanych – przekształcanych obiektywnym algorytmem globalnym – jako danych geometrycznych upraszczanych

Tadeusz Chrobak

Akademia Górniczo-Hutnicza im. St. Staszica w Krakowie
Wydział Geodezji Górniczej i Inżynierii Środowiska
Al. Mickiewicza 30, 30-059 Kraków
e-mail: tchrobak@uci.agh.edu.pl

Streszczenie

W artykule omówiono algorytm globalny upraszczania linii łamanych, który nie zależy od parametrów ustalanych przez redaktora mapy oraz zachowuje dokładność instrukcji branżowej O-1 GUGiK (Ogólne zasady wykonywania prac geodezyjnych) dla każdej skali opracowania (mniejszej od źródłowej). W tym procesie upraszczania krzywych parametry są zależne od skali mapy i najkrótszej długości trójkąta elementarnego (długość ta jest miarą rozpoznawalności rysunku). W procesie upraszczania tym algorytmem zapewniony jest ten sam kształt krzywej (z dokładnością rozpoznawalności rysunku), gdy dane uogólnione od źródłowych różnią się większym czy mniejszym rozstępem skal. Ponadto ustalono granice przedziałów progów generalizacji, niezbędnych w procesie automatycznego doboru metod prezentacji kartograficznej obrazujących wynik po upraszczaniu krzywych.