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LINE GENERALISATION AND AUTOCAD MAP

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Dani su rezultati izvornih istraživanja o primjeni AutoCAD Mapa na generalizaciju linija. Ustanovljene su sličnosti i razlike u metodi za pojednostavljivanje linija što je ugrađena u AutoCAD Map i Douglas-Peuckerovoj metodi. Utvrđene su netočnosti iz AutoCAD Mapova priručnika koje se odnose na pitanja širine koridora i tolerancije te širine linije prije i nakon pojednostavljivanja. Daju se preporuke o primjeni uklanjanja pseudočvorova. Uočeno je da AutoCAD Mapova metoda za pojednostavljivanje nije neovisna o redoslijedu točaka. Primjena metode ilustrirana je na primjeru obalne linije Istre.

Ključne riječi: AutoCAD Map, generalizacija linija, metoda pojednostavljivanja, kartografija

The paper offers the results of original research made on the application of AutoCAD Map in line generalisation. The differences and similarities have been found out between the Douglas-Peucker method and the method of line simplification that is incorporated in AutoCAD Map. There have been also the inaccuracies found out in AutoCAD Map manual relating to the issues of buffer width and tolerance, and the line width before and after simplification. The paper gives recommendations about pseudo nodes dissolving. It has been noticed that AutoCAD Map simplification method is not independent of the order of points. The application of the method is illustrated by an example of coastal line of Istria.

Keywords: AutoCAD Map, line generalisation, simplification method, cartography

Introduction

AutoCAD, the product of the firm Autodesk, is a programme for drawing and editing of drawings on graphic display. It is considered as one of the most popular and most widespread CAD (Computer Aided Design) programmes. Apart from graphics workstations, it is also very successful in operating on personal computers (URL1).

AutoCAD Map is intended to engineers, technicians, planners and other persons working on production, creation, maintenance and analysing of maps. One can say, that it is a mapping version of AutoCAD because it is based on AutoCAD, retaining thereby all its functionality supported by special tools directed to cartographic applications and GIS. By means of AutoCAD Map it is possible to create, maintain and analyse map information in multiple AutoCAD drawings and in external databases connected with them.

AutoCAD Map modernises the digital mapping procedures in designing, editing, analysing and delineating maps.

AutoCAD has been used for several years already in the courses of some subjects at the Faculty of Geodesy, University of Zagreb, as one of the tools for drawing by means of computers. AutoCAD Map was introduced in the academic year 1997/98 into the course of lectures titled *Digital Cartography II* (now *Cartography and GIS*), and there was an adequate manual made to help students in learning (LAPAINE et al., 2001). Both softwares, AutoCAD and AutoCAD Map, can be mastered by students even better through seminar and diploma theses.

In the previous works (LAPAINE, 1999, 2000) there was the application of AutoCAD Map explained on the examples of producing thematic maps, of analysing a network topology for the purpose of finding the shortest path, and to constructing buffers around the baseline in order to determine the state border at sea. In this work we deal with the problems connected with the application of AutoCAD Map in line generalisation.

For almost thirty years, some scientific institutions in the world have carried out research on the automation of map generalisation, but no definite solutions have been found yet, not only for the problem itself, but also for some partial problems like linear elements generalisation. The size of the problem is evidenced by the fact that there has been a working group founded within the International Cartographic Association that has grown into the ICA Commission on Map Generalisation (URL2).

The research on automating linear map elements generalisation has been carried out also in the Institute for Cartography at the Faculty of Geodesy, University of Zagreb (FRANČULA, 1997). The beginning of this research dates as far as in 1973.

There are a lot of algorithms to be found in the literature referring to automatic line generalisation. The question about which of them would be the best, or the best for a certain type of lines, has not been solved completely. One of the solutions is also offered by the firm Autodesk in its programme AutoCAD Map.

Map generalisation

Let us just remember briefly the term of map generalisation. E. Imhof (1968) in his book *Gelände und Karte* gives his definition of generalisation: "In the interest of better legibility, maps are simplified more and more along with the scale reduction. The simplification or generalisation moves them away from the landscape image reliable in the sense of shapes. Unimportant issues are left out, the important ones are emphasised, some individual features or content elements are condensed or, on the other hand, shown with exaggerated dimensions. Very often there are standardised symbols presented instead of object plans."

"Map generalisation is a series of procedures that provide adequate accuracy and integrity in the production of a small scale map from a large scale map, preserving its legibility" (LOVRIĆ, 1976).

Generalisation is defined in the same way by the International Cartographic Association as well: "Generalisation is a series of processes applied in encompassing and/or presenting objects on maps by means of which unimportant details are neglected in terms of geometry, concept and time, and essential issues are pointed out and translated into higher units" (HEUPEL, 1982).

At first sight it is intuitively clear what is to be expressed by these definitions. Especially cartographers will have a clear notion of what it is really about. Observing more closely what this concept is based on, one can see that it much less results from comprehensiveness and detailed status of the definitions, but much more on the experiences acquired by observing, using and producing maps at various scales. This experience is much more important than the definition itself for successful realisation of manual generalisation.

The situation is inverted in attempts of automation. The experiences can be automated if it is classified into precisely describable elementary procedures.

Generalisation by using AutoCAD Map

Description of method and the problem of tolerance

The firm Autodesk offers a special tool in its programme AutoCAD used for simplifying line objects. Although in AutoCAD one understands line, polylines and circular arcs under the term line objects (Autodesk 1997, page 195), one can simplify only polylines by means of AutoCAD Map. If some complex line to be simplified consists of AutoCAD linear objects – lines, circular arcs, polylines – then this group should first be turned into a single polyline.

The simplification procedure reduces the number of complex line points by defining the tolerance value, i.e. the buffer width.

It has been determined through testing (VUČETIĆ, 2000) that the simplification procedure installed into the AutoCAD Map is based on one version of Douglas-Peucker's algorithm (DOUGLAS, PEUCKER, 1973). The method starts with defining the first point on a line as an anchor, and the last as a floating point. These two points define a straight line segment (chord). Other points along the line are tested in such a way that we find the one with the distance between it and the straight line segment defined with the anchor and the floating point being the largest. If this distance is smaller than the tolerance given, then this chord is appropriate for the presentation of the entire line. If the condition is not fulfilled, the point located most far away from the chord becomes a new floating point. By repeating this procedure the floating point comes closer to the anchor. When the demand on maximum distance is met, the anchor point is moved to floating, and the last line point becomes a new floating point, and the whole procedure is repeated. The points that were announced as anchors represent a generalised line.

The difference between the Douglas-Peucker method and the method installed in AutoCAD Map lies in the fact that in the second case it is still tested whether a circular arc can be defined by means of three consecutive anchor points providing that the distance among the points ejected from the circular arc on that part of the line remains within the tolerance (see left and right end on Fig. 1 and 2). By comparing Fig. 1 and 2 one can notice the difference between these two methods.

Let us go back to the tolerance. In the description of the procedure it was mentioned that if the distance of the most remote interventing points from straight line segment (contours of the first and the last point of a curved line) is smaller than the given tolerance, then this segment is convenient for presenting the whole line. This fact will be used as a proof for real tolerance.

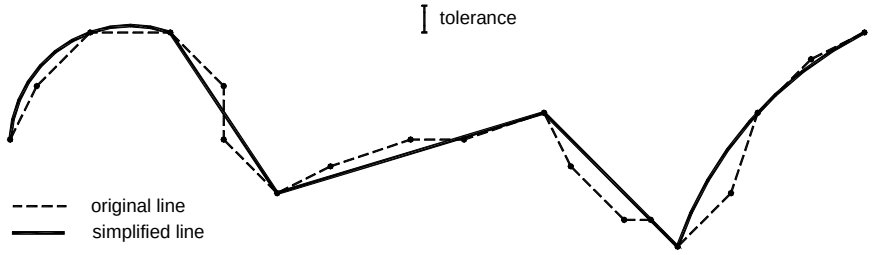

Fig. 1 Line simplified by using AutoCAD Map
Sl. 1. Linija pojednostavljena pomoću AutoCAD Mapa

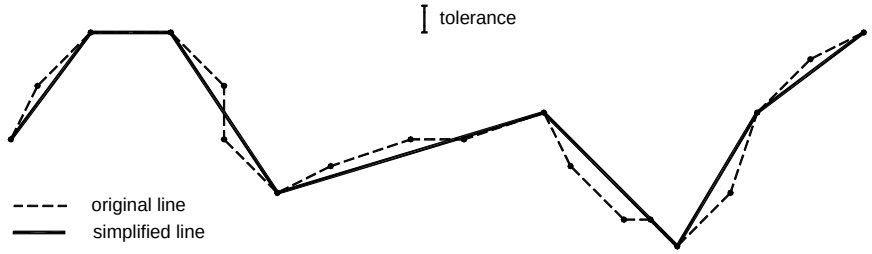

Fig. 2 Line simplified by using Douglas-Peucker method
Sl. 2. Linija pojednostavljena Douglas-Peuckerovom metodom

According to the explanations on pages 42 and 210 in the User's Guide (Autodesk, 1997) the buffer consists of two parallel straight lines parallel with the contour of the first and the last line points that are being simplified (Fig. 3).

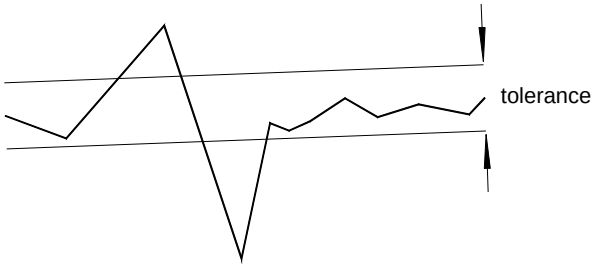

Fig. 3 Tolerance in line simplification (Autodesk, 1997)
Sl. 3. Tolerancija pri pojednostavljivanju linije (*Autodesk, 1997.*)

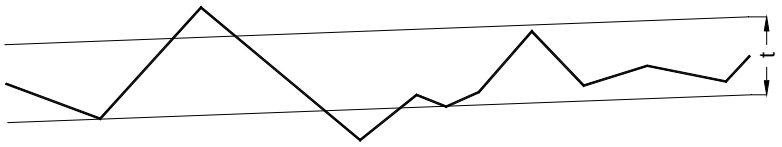

Fig. 4 Buffer and tolerance according to Autodesk (1997)
Sl. 4. Koridor i tolerancija prema Autodesku (1997.)

If the buffer was set up in such a way, the original line on Fig. 4 would not fall entirely within the buffer having given width, so the contour of the first and the last point would not be convenient for the presentation of the entire line.

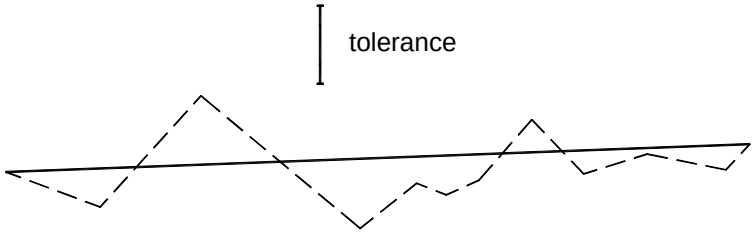

Fig. 5 Line simplified by using AutoCAD Map
Sl. 5. Linija pojednostavljena AutoCAD Mapom

Since the results of simplification by means of AutoCAD Map look as on Fig. 5 (straight line), there is conclusion imposed upon us that the buffer width is equal to double tolerance as it is shown on Fig. 6.

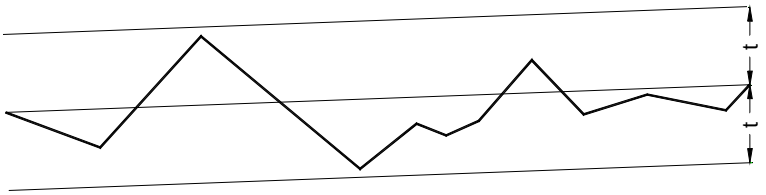

Fig. 6 Buffer and tolerance for line simplification by using AutoCAD Map
Sl. 6. Koridor i tolerancija za pojednostavljivanje linija pomoću AutoCAD Mapa

Problem of line simplification and line width

At the beginning it was said that only polyline can be simplified by means of AutoCad Map, and it is well known that it can have some width in AutoCAD. There is a question raised about what happens with its width during the simplification, i.e. whether the simplified line will have the same width as the original one or not.

Although Autodesk warns in its manual that the width is removed after applying the tools for simplification of linear objects, the testing has confirmed (VUČETIĆ, 2000), that the width is not only removed, but remains equal to the width of the original line (See Fig. 7).

Fig. 7 Width of original and simplified line
Sl. 7. Širina izvorne i pojednostavljene linije

Problem of transformation of complex line into simple polyline

There is a question raised what are the ways that a complex line consisting of lines, circular arcs and polylines can be transformed into the single polyline. It can be done in AutoCAD Map in two ways. One of the ways is realised through the command *pedit*, i.e. by selecting Modify → Object → Polyline → Pedit, and the other one by removing pseudonodes through the selection of Map → Map Tools → Drawing Cleanup → Dissolve Pseudo Nodes.

Although it says in the manual that the option for removing pseudo nodes can be used along with the simplification of linear objects, it is still not recommendable. Namely, if these two possibilities are taken simultaneously, the AutoCAD Map will remove pseudo nodes, but it will simplify only the part of the line that is delineated by means of the command *pline* (see Fig. 8).

If the option for removing pseudo nodes is to be used for the purpose of transformation, then the transformation should be done first and only then the line simplification. The obtained result is shown on Fig. 9.

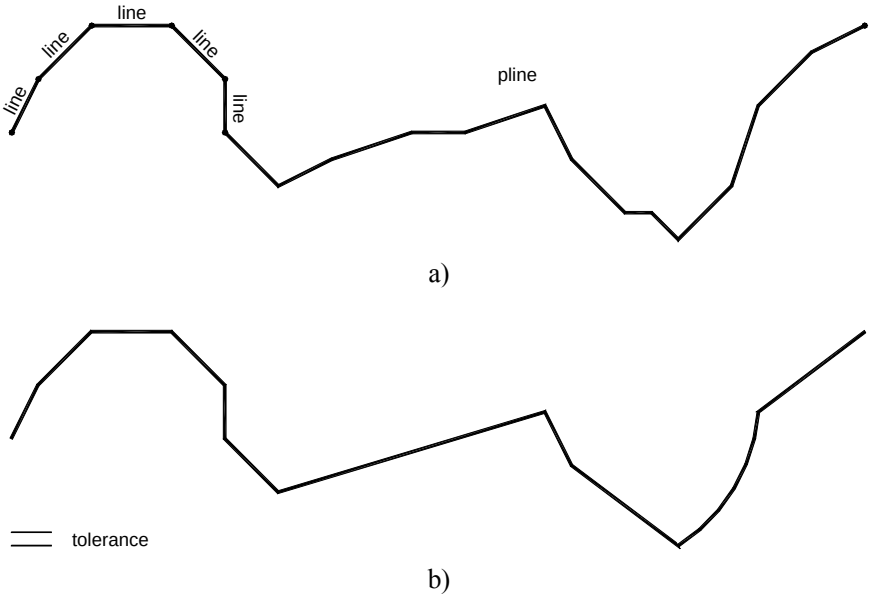

Fig. 8 a) Original line; b) The result of line simplification and pseudo nodes dissolving
Sl. 8. a) Izvorna linija; b) Rezultat pojednostavljenja zajedno s uklanjanjem pseudočvorova

Before carrying out the pseudo nodes dissolving one should know that this operation records the values of point co-ordinates symbolising the line in the inverse order, i.e. from the last point of original line towards the first one, which has also happened with the line on Fig. 8. Why is it important? Because in the case of AutoCAD Map method for simplification it is not quite the same whether the line is digitised from the point T_p to the point T_z or from the point T_z to the point T_p (see Fig. 10). Namely, we sometimes get various results as the consequence of the fact that only metrical criterion has been installed into the method, and the visual similarity between the original and simplified line is obtained only as the consequence of this criterion.

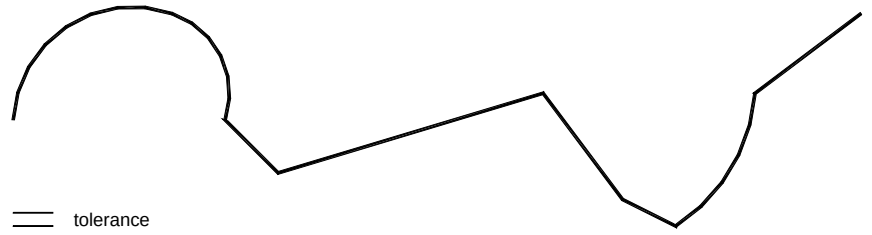

Fig. 9 The result of line simplification after pseudo nodes were dissolved
Sl. 9. Rezultat pojednostavljenja nakon uklanjanja pseudočvorova

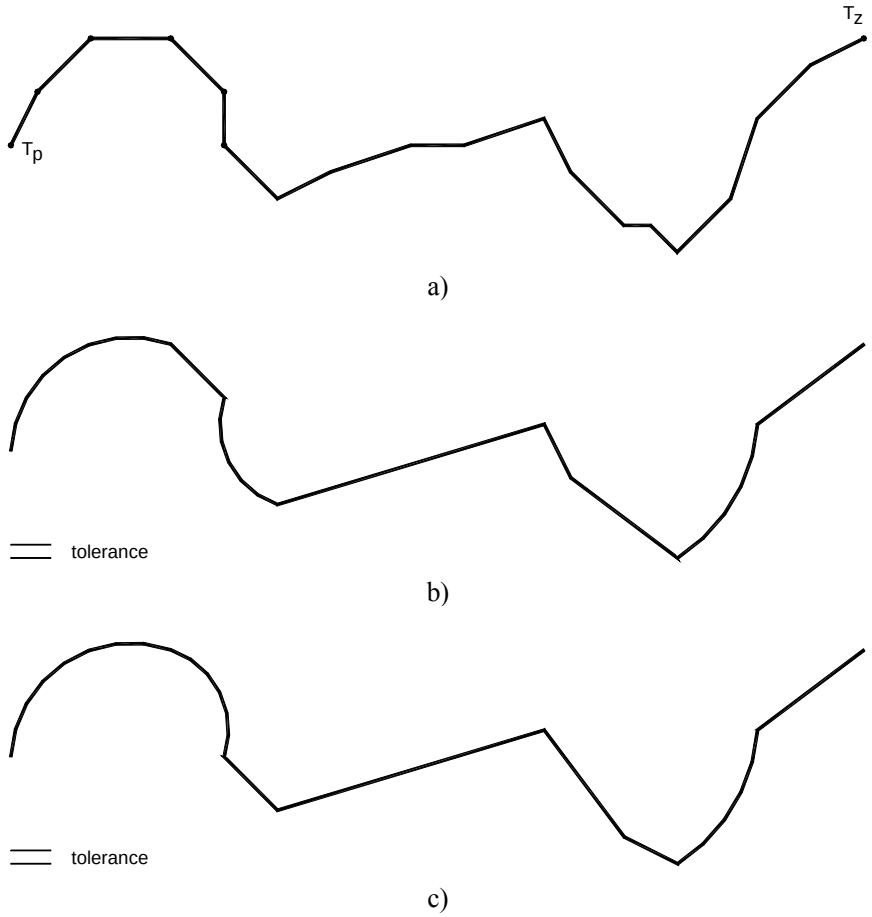

Fig. 10 a) Original line; b) Simplification of line that was digitised in T_pT_z direction; c) Simplification of line that was digitised in T_zT_p direction
Sl. 10. a) *Izvorna linija; b*) *Pojednostavljenje linije koja je digitalizirana u smjeru* T_pT_z; *c*) *Pojednostavljenje linije koja je digitalizirana u smjeru* T_zT_p

Application of AutoCAD Map for mapping coastal line and border line

In order to illustrate the line generalisation by means of AutoCAD Map there was a coastal line of Istria and a part of Croatian land border with the Republic of Slovenia chosen.

Fig. 11 The coast line of Istria and a part of border line at the scale of 1:1 000 000
Sl. 11. Obalna linija Istre i dio kopnene granice u mjerilu 1:1 000 000

The data used have been obtained by means of digitising with the digitizer CalComp 9100 from the Institute of Cartography at the Faculty of Geodesy, University of Zagreb in the local system (ČIPČIĆ, 1991; RUKAVINA, 1992), and have been later transformed into the co-ordinate system of Gauss-Krüger projection by means of Helmert transformation of co-ordinates (RADETIĆ, 1992; POSLONČEC, 1992). It has been digitised from the map of territorial division of the Republic of Croatia at the scale of 1:1 000 000 produced in the Institute of Cartography, at the Faculty of Geodesy in 1979 in Gauss-Krüger projection with the central meridian $\lambda_0 = 16°30'$. On Fig. 11 there is an original presentation given. On Fig. 12 and 13 there are the presentations given at the scale of 1:2 000 000. Before analysing the presentations let us take a look at the tolerance, or to be more precise, at the units by which it is expressed. AutoCAD knows only its own distance unit, and it is adopted in advance. Since AutoCAD Map contains AutoCAD core, the above stated is valid for the AutoCAD Map itself.

The co-ordinates of points of the Istrian coastal line and of the part of Slovenian land border are in metres, therefore one AutoCAD unit corresponds here to one meter. Since the tolerance value is given in AutoCAD units, it is in this case clearly in meters.

The quality of line simplification by means of AutoCAD Map has been tested on the line with 0.13 mm width.

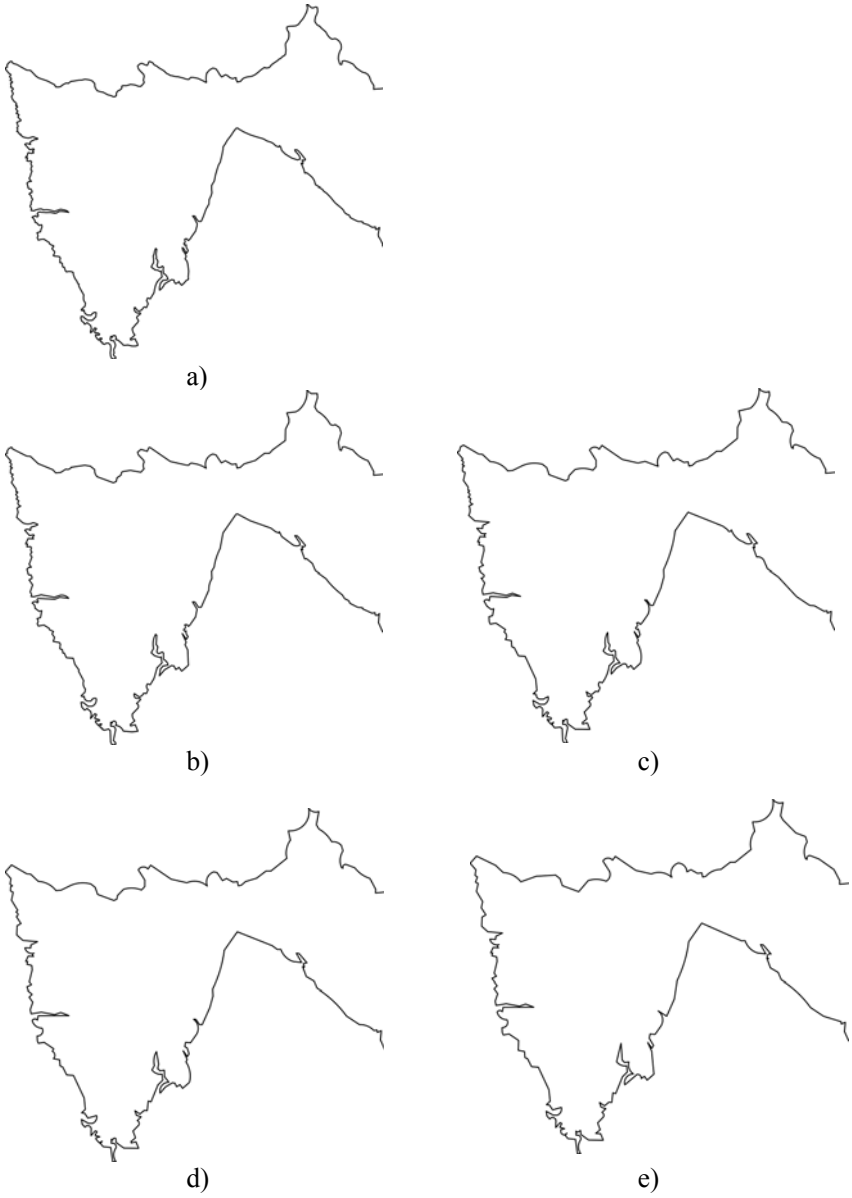

Fig. 12 The coast line of Istria and a part of border line at the scale of 1:2 000 000
a) reduced original representation; AutoCAD Map: b) t=200, c) t=300, d) t=350, e) t=400
Sl. 12. Obalna linija Istre i dio kopnene granice u mjerilu 1:2 000 000 a) smanjeni izvorni prikaz; AutoCAD Map: b) t=200, c) t=300, d) t=350, e) t=400

The best presentation at the scale of 1:2 000 000 that can be achieved by means of AutoCAD Map is for the tolerance t=350 (Fig. 12d). Although the line is broken at some place, this presentation can be regarded as a very good basis that will yield well-generalised presentation with a little help of a mapmaker. In the presentations obtained for t=200 and t=300 (Fig. 12b and c) the line is too much tremulous, and for t=400 (Fig. 12e) it is very much broken.

a) b)

Fig. 13 Manual generalisation: a) original representation first reduced, then simplified, b) original representation simplified for the scale of 1:2 000 000 and then reduced to the scale of 1:2 000 000

Sl. 13. Ručna generalizacija: a) izvorni prikaz smanjen pa generaliziran, b) izvorni prikaz generaliziran za mjerilo 1:2 000 000 potom smanjen fotografski u mjerilo 1:2 000 000

On Fig. 13 there are the presentations obtained by means of manual generalisation, and they were made by Igor Birin, B.Sc., of the Institute for Cartography at the Faculty of Geodesy in Zagreb. All presentations obtained by means of manual generalisation have been transformed into digital form by means of scanning with roller scanner CalComp SCANPlus III 1800T in the resolution 800×800 dpi.

Comparing Fig. 13 with Fig. 12d one can come to the same conclusion, i.e. that the presentation of Fig. 12d can be regarded as the basis from which well generalised presentation will be obtained with a little help of a mapmaker.

A few more examples of applying AutoCAD Map in line simplification can be found in the seminar thesis made by N. Vučetić (2000).

Conclusions

The following conclusions can be derived from the research made:

- A method for line simplification incorporated into AutoCAD Map is very similar to the well-known Douglas-Peucker method (DOUGLAS, PEUCKER, 1973). The difference between the Douglas-Peucker method and the AutoCAD Map method is in the fact that the second performs a test for whether a circle arc can be defined by means of three

successive retained points of the original line, providing that the distance of the points put aside from the circle arc on the observed line section is within a given tolerance.

- The explanation of the buffer width given in the manual (Autodesk, 1997) is not correct. The buffer width is actually equal to double tolerance.
- The information from the manual (Autodesk, 1997) saying that in the process of line simplification its width is removed is not correct. The simplified line has the same width as the original line.
- Although it is written in the manual (Autodesk, 1997) that the option for pseudo nodes dissolving can be used together with the simplification of line objects, it is nevertheless not recommendable. Namely, if these two possibilities are taken simultaneously, then AutoCAD Map will remove pseudo nodes, but it will simplify only that line section that is drawn by means of the command *pline*.
- The result of applying the adapted algorithm for simplification depends on the points ordering making the line. It is therefore necessary to be aware before removing the pseudo nodes, that this procedure sometimes records the values of point co-ordinates in an inverted order, i.e. from the last point of original line towards the first one.
- The appropriate selection of tolerance might yield simplified representations of lines on the basis of which the map representations can be very well generalised.

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SAŽETAK

Nada Vučetić, Miljenko Lapaine: Generalizacija linija i AutoCAD Map

U literaturi se nailazi na mnoštvo algoritama za automatsku generalizaciju linija. Pitanje koji bi od njih bio općenito najbolji, ili najbolji za određenu vrstu linija, nije definitivno riješeno. Jedno od rješenja nudi i tvrtka Autodesk u svom programu AutoCAD Map, i upravo je taj algoritam predmet istraživanja ovoga rada.

Na temelju provedenih istraživanja mogu se donijeti sljedeći zaključci:

- Metoda za pojednostavljivanje linija ugrađena u AutoCAD Map vrlo je slična poznatoj Douglas-Peuckerovoj metodi. Razlika između Douglas-Peuckerove metode i metode ugrađene u AutoCAD Map je u tome što se kod ove druge još ispituje može li se definirati kružni luk pomoću tri uzastopne zadržane točke izvorne linije uz uvjet da udaljenost izbačenih točaka od kružnog luka na promatranom dijelu linije bude unutar tolerancije.
- Objašnjenje širine koridora kako je opisano u priručniku (Autodesk, 1997) nije ispravno. Širina koridora zapravo je jednaka dvostrukoj toleranciji.
- Podatak iz priručnika (Autodesk, 1997) da se pri pojednostavljivanju linija uklanja njihova širina nije točan. Pojednostavljena linija ima istu širinu kao i izvorna.
- Iako u priručniku (Autodesk, 1997) piše da se opcija za uklanjanje pseudočvorova može upotrebljavati zajedno s pojednostavljenjem linijskih objekata, to ipak nije preporučljivo. Naime, ako se te dvije mogućnosti uzmu istovremeno onda će AutoCAD Map ukloniti pseudočvorove, ali će pojednostaviti samo onaj dio linije koji je nacrtan pomoću naredbe *pline*.
- Rezultat primjene ugrađenog algoritma za pojednostavljivanje ovisi o redoslijedu točaka koje čine liniju. Stoga prije uklanjanja pseudočvorova treba znati da taj postupak ponekad vrijednosti koordinata točaka zapisuje u obrnutom redoslijedu, tj. od zadnje točke izvorne linije k prvoj.
- Odgovarajućim izborom tolerancije moguće je dobiti pojednostavljene prikaze linija na temelju kojih će se uz malu intervenciju kartografa moći dobiti dobro generalizirani kartografski prikazi.

Za ilustraciju generalizacije s pomoću AutoCAD Mapa izabrana je obalna linija Istre i dio kopnene granice između Hrvatske i Slovenije.

SOMMAIRE

Nada Vučetić, Miljenko Lapaine: Généralisation des lignes et AutoCAD Map

On trouve dans la littérature un grand nombre d'algorithmes pour généralisation automatique des lignes. Cependant, la question, le quel entre eux est le meilleur en général, ou le meilleur pour certaines sortes des lignes, n'est *toujours* pas résolu. La société Autodesk dans son programme AutoCAD Map présente une des solutions, et c'est précisément cet algorithme qui fait l'objet des recherches de cet article.

Les conclusions suivantes résultent des recherches effectuées:

La méthode de simplification des lignes installée dans AutoCAD Map ressemble beaucoup à la méthode bien connue de Douglas-Peucker. La différence entre Douglas-Peucker méthode et la méthode AutoCAD Map est dans le fait que cette dernière teste la possibilité de définir le cercle arc avec trois points successifs arrêtés de la ligne originale, sous condition que la distance entre les points écartés et de cercle arc, sur la section observée de la ligne soit dans la tolérance.

L'explication sur la largeur du corridor donnée dans le manuel (Autodesk, 1997) est incorrecte. La largeur du corridor en effet est égale à double tolérance.

La donnée dans le manuel (Autodesk, 1997) que lors de la simplification des lignes leur largeur s'élimine est incorrecte. La largeur de la ligne simplifiée est la même que la largeur de la ligne d'origine.

Malgré l'information dans le manuel (Autodesk, 1997) que l'option pour éliminer les pseudo-nœuds peut être utilisée avec la simplification des objets lignes, cela n'est pas recommandable. A savoir, si on prend les deux possibilités en même temps AutoCAD Map éliminera les pseudo-nœuds, mais par contre simplifiera seulement les lignes présentées sous la commande *pline.*

Le résultat de l'application d'algorithme scellé pour simplification dépend de l'ordre des points formant la ligne. Donc, avant l'élimination des pseudo-nœuds il faut savoir que quelques fois cette procédure enregistre les valeurs de coordinates des points dans l'ordre inverse à savoir, du dernier point de la ligne d'origine au premier point.

Avec la sélection appropriée de tolérance il est possible d'obtenir des présentations des lignes simplifiées et à la base des quelles, avec une simple intervention des cartographes, on peut obtenir des présentations des cartes bien généralisées.

Pour illustrer la généralisation des lignes avec AutoCAD Map, on a choisi la côte d'Istrie aussi bien qu'une partie de la frontière continentale entre la Croatie et Slovénie.