УДК: 004.89

A.S. Chupryna, Alzubidy Ahmed Same

Kharkov national university of radioelectronics, Kharkov

MODELS AND METHODS FOR POLYGONAL APPROXIMATION OF OBJECTS

The goal of this work consists in research of existing models and methods of approximation and obtaining of software system that provides approximation of objects borders by their digital images with respect to the a specified accuracy criterion. The objects of study are models, methods, algorithms and computer technologies for solving of the problems of object boundary approximation in GIS for presenting these boundaries as minimal vertex polygons within a specified accuracy.

Keywords: *polygonal approximation, geo information systems, criterion of accuracy, error.*

Introduction

Geographic information systems (GIS), which have been around for 30 years, acquires recently becoming more widely used. For a long time only they were used only to create maps, but now they become the basis for the construction of complex control systems. In recent years significantly increased the complexity of the models of governance in large corporations and businesses becoming more common methods for streamlining administrative processes. The practice of these methods [1] shows that the more measurements in the model, the more predictable and manageable it becomes, allowing you to receive more and more complex solutions.

It is noted that it is the geographic information becomes critical component in solving most problems. Therefore, geographic information systems with their opportunities to collect, visualize and analyze data geo referenced become an integral part of most control systems.

GIS [2] can provide sample opportunities for the analysis of spatial and attribute data about space and ground facilities, allows the analysis to create a new data to peer review or withdraw a decision. To the attribute values include: category, rank, number, size, relationship.

Modern GIS can create and process data about discrete, continuous and generalized on the object plane, the characteristics of which are composed of spatial and attribute components.

In turn, the spatial data is represented by two types of models: vector and raster [3]. In the vector model, each object corresponding to a record or a set of pairs of pairs of coordinates X, Y (B, L). Objects are represented by individual points, lines or polygons. Raster model displays a continuous space in the form of a matrix. If the vector model gives information about where is located this or that object, bitmap - the information about that is located in any point of the surface.

Different types of objects are represented by different data models. So discrete objects and data, which are summarized by area, are represented by the vector model. Continuously categories represent both vector and raster models. A continuous numeric values often are using the raster model.

In analyzing the data in the GIS often solved such a problem as the analysis of the location. Analysis of the location helps to determine the areas that meet certain criteria location, or objects, which require specific actions.

For example, the analysis of the passage of the satellite track or concentration zones inspection can help identify objects, causeway, which attract attention, to determine the relationship between the actions and events that occur and change the trajectory of reconnaissance satellites.

It is important in the analysis of information about space objects that the searching facilities that fall within the specified area, and determination of their geometrical parameters [4]. Since the identification of certain types of ground objects that fall in the surveillance zone reconnaissance satellite, makes it possible to take a decision about the need to issue a warning. Solution set of this type may be the identification of space objects, which are able to observe a particular object or event in a given time period, with the aim, for example, request information from them or assessing the possible effects of monitoring.

GIS can make the results of the analysis in the form of graphs, tables, diagrams, which are dependent on the job are displayed directly on the screen, are imported into external software systems, databases or electronic card as separate objects. The analysis can be presented in the form of bitmaps, which are superimposed on the image of the terrain. If the results of the analysis are characterized by time parameters, then in present-GIS can be represented in the form of video clips.

© A.S. Chupryna, Alzubidy Ahmed Same

Statement of the problem. For definiteness, we consider the general problem of approximating [5] the image boundaries of objects, segmented by the digital photo, the example of lake.

Suppose that the initial object is some body of water. On the source of the image (Fig. 1.a) is considered the earth's surface, select the source of ordered sequence of boundary points, which is taken as the boundary of the reservoir (Fig. 1.b) and with an accuracy which is an error obtaining initial data.

Typically, such a high accuracy is excessive, and therefore using less of scale required to describe the same boundary, but a smaller number of pixels (Fig. 1, c).

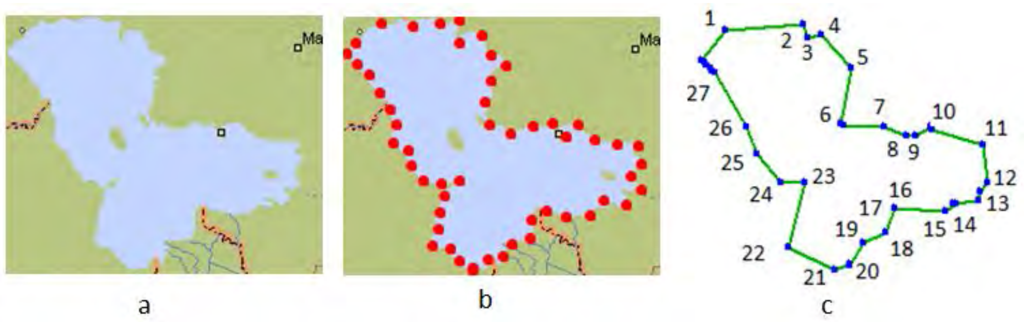

Fig. 1. Satellite image of the reservoir, the initial description of its borders and its polygonal approximation to a given accuracy

However, although the border is represents as polyline and, in contrast to the problems of approximation [6] of functions of one variable, in this case the direct application of traditional methods of computational mathematics is unacceptable for several reasons. The object in question, as a rule, is a non-convex, the use of spline approximation leads to an extraordinary increase in complexity, as it requires the consideration of the local coordinate systems for fragments of the border, the dimension of which can be hundreds of points.

In addition, various problems have different requirements with respect to accuracy criteria for the same object.

Thus, if the estimation of the surface area of the reservoir adequate measure of approximation quality criterion is the mean square deviation, then the estimation of the length of the coastline, or the height difference in the design of roads will be more appropriate to use the measure of deviation by Chebyshev [7].

Thus, in order to enhance the effective using of GIS and other systems of the map segmented images the actual problem of approximating the boundaries of non-convex polygonal objects with help of polylines, the method of its solution must be efficient computationally to provide work in real time, and provide an opportunity polygonal approximation of the boundary [8], which has a minimum number of elements to a given accuracy, which can be determined by different criteria. In solving this problem it is assumed that the nodes belong to the original set approximant segmented tops, and as criteria for determining the accuracy of the approximation, the metric Chebyshev, variance, standard deviation and absolute deviation.

The method of solving he problem of approximation

For solving the task of approximation of lake boundaries we propose a method that combines the use of two procedures – algorithm number 1, which consists in ε-approximation of the boundary L by polygon $l_{\alpha,\varepsilon,n}(IB)$, and algorithm number 2, which provides a minimum number of the approximation units by varying the parameter IB. Here $l_{\alpha,\varepsilon,n}(IB)$ - this is the ε-approximation of border L, which obtained by sequential approximation of boundary L, starting from the point IB.

Algorithm 1.

1. Let $IW = IB$; $\xi = 1$, $j_\xi = IW$ and we believe that a given sequence of boundary points $T^{(0)}$ has a number $IB, IB+1, ..., IB+n-1$, $IB+n$, where point with the number $IB+n$ is the same as IB.

2. Increase k from **1** for as long as removal (by criteria ρ_α) the segment with endpoints in (x_{IW}, y_{IW}), (x_{IW+k}, y_{IW+k}) from internal points (x_{IW+1}, y_{IW+1}), … , (x_{IW+k-1}, y_{IW+k-1}) will not exceed ε or $IW+k = IB+n$.

When we reach this point we said that $\xi := \xi+1$, $j_\xi = y_{IW+k}$.

3. If $IW+k < IB+n$, set $IW := IW+k$ and go to step 2; otherwise – set $\xi := \xi+1$, $j_\xi = y_{IW+k}$ and go to step 4.

4. End: approximating polygon $l_{\alpha,\varepsilon,n}(IB)$ consists of a sequence of boundary nodes $\tau^*_{\alpha,k} = \{\tau_0, \tau_1, ..., \tau_n\}$ with initial numbers $\tau_0 = j_1$, $\tau_1 = j_2$, … , $\tau_n = j_\xi$.

Since the choice of the starting point IB can affect not only on the shape of approximant, but also on the number of units, from which its consist, then for solving the task offers two approaches - the exhaustive search method (Algorithm 2) and the Monte Carlo method (Algorithm 3).

The first of these, as shown by the numerical experiment is acceptable when the number of the initial vertexes are a few thousand, in this case a decision is reached in 15 seconds, when $N = 1000$.

In the case when the number N increases significantly, or the decision you want to get in a smaller neck time, you can use the Monte Carlo method.

Algorithm 2.

1. Set $IB := 0$, $n^* := N$, $l^*_{\alpha,\varepsilon,n^*} := T^{(0)}$.

2. With help of Algorithm 1 find $l_{\alpha,\varepsilon,n}(IB)$. If $n < n^*$, then set $l^*_{\alpha,\varepsilon,k} := l_{\alpha,\varepsilon,n}(IB)$, $n^* := n$.

3. Set $IB := IB + 1$. If $IB < N$, then go to step 2; otherwise - go to step 4.

4. End: set polyline $l^*_{\alpha,\varepsilon,n^*}$ with the number of units n^* as solution of the task.

5. Let t (t^*) – current (limit) time for solution of the task, n^{**} - a reasonable number of vertices of approximant, and $R[0, N]$ – the integer, given the sensor uniformly distributed numbers in the range from 0 to N.

Algorithm 3.

1. Let $IB := 0$, $n^* := N$, $l^*_{\alpha,\varepsilon,n^*} := T^{(0)}$.

2. With help of Algorithm 1 let's find $l_{\alpha,\varepsilon,n}(IB)$.

If $n < n^*$, then $l^*_{\alpha,\varepsilon,k} := l_{\alpha,\varepsilon,n}(IB)$, $n^* := n$.

3. Let $IB := R[0, N]$.

If $t > t^*$ (and / or $n < n^{**}$), go to step 4; otherwise - go to step 2.

4. End: let's polyline $l^*_{\alpha,\varepsilon,n^*}$ with the number of units n^* as a solution of the task.

In this algorithm, the termination of the search in step 3 continue, according to the time, number of units, or both of them.

To solve the problem in order to handle data about reservoir, were developed models and algorithms which were implemented a software system called LAKE. As initial data used a well-known analogue of GIS as a World Atlas "Encarta" of Microsoft company.

System LAKE contains three main sections designed for the segmentation [8] of the external boundary of the lake, its trace in order to provide a closed 8-connected line and polygonal approximation of interactive real-time, respectively, and a criterion of error, the first two blocks are taken from the library of special programs.

When the segmentation boundaries [9] of the lake is performed, in the first stage, the allocation of the threshold point of the lake and the color filter of the points that do not contain of 8-connected points that are not owned by the color of the lake, and then, using the wave method, selected endpoints are combined into the border. Finally, select the higher of the obtained boundary, which is the external boundary of the reservoir.

Tracing [10] the external boundary is used for its representation as an ordered sequence of a closed 8-connected points and need for further approximation. Tracing the external border of the lake produced by the method described in.

Conclusion

Based on the analysis of a wide class of applications processing segmented images for various applications - from the processing of satellite data to the analysis of biological objects - isolated conceptual problem is formulated and the corresponding problem of approximating the boundaries of segmented objects with the specified error for the four main criteria of accuracy.

Given the geometric features [11] of the problem and requirements for its solution and its use in GIS, restrictions on the functional class of approximants, represented by broken lines, the choice of sites for approximation and efficiency of its solutions.

Analysis of these restrictions shows that to solve the problem of traditional methods of segment approximation and regression analysis are unacceptable, especially - because of their high computational complexity, because they are not focused on solving the problem of approximating a non-convex region with restrictions imposed.

Therefore, to solve the problem of approximating the boundaries of segmented objects with the specified error for the four main criteria of accuracy developed method based on the use of brute force algorithm approximant starting points and estimate the accuracy of the approximation, while minimizing the number of links approximant.

To solve the problem in order to handle data on water bodies developed models and algorithms are implemented as a software system called LAKE; as input used a well-known analogue of GIS as a World Atlas "Encarta" of Microsoft company.

The computational experiment carried out with the system LAKE confirmed the effectiveness of the proposed algorithms in terms of quality of approximation and efficiency of computation, for example, to Lake Victoria, the source for the number of boundary which was about 2000 nodes, the trace and the approximation is 15 to 26 seconds, in proportion to the error.

References

1. Chen C.H. Handbook of Pattern Recognition and Computer Vision / C.H. Chen, L.F/ Pau, P.S.P. Wang. – Word Scientific Publishing Company, 1993. – 984 p.

2. Sonka M. Image processing, analysis, and machine vision / M. Sonka, V. Hlavak, R. Boyle. – USA, California: Cole Publishing Company, 1999. – 770 p.

3. Devroye Luc. A Probabilistic Theory of Pattern Recognition / Luc Devroye. – USA, Springer, 1996. – 636 p.

4. Morozhenko O. State of the near-Earth space environment of the Earth, its relationship with the problems of ozone layer and climate change / O. Morozhenko // National Space Agency of Ukraine. – 2001. – № 1. – P. 50-59.

5. Krasovskiy G.Y. Information Technology space monitoring of aquatic ecosystems and forecast water bridge / G.Y. Krasovskiy, V.A. Petrosov. – K.: Naukova Dumka, 2003. – 224 p.

6. Kosilova R.A. Using guidelines to videosupervision systems / R.A. Kosilova, U.I. Tanihyn // Automation, Communications, Information. – 2001. – № 7. – P. 31-33.

7. Devroye Luc. Combinatorial methods in density estimation / Luc Devroye, Gábor Lugosi. – USA, 2001. – 208 p.

8. Lyashenko V.V. Models and methods for analysis and image processing / V.V. Lyashenko // Problems of bionics. – 2000. – № 52. – P. 63-66.

9. Pratt W. Digital Image Processing. In the 2-volumes / W. Pratt. – Verlag, 1982. – Vol. 1. – 312 p., Vol. 2. – 480 p.

10. Batyrshin Ildar. Time Series Pattern Recognition Based on MAP Transform and Local Trend Associations / Ildar Batyrshin, Leonid Sheremetov. – USA, 2005. – 900 p.

11. Vijay V. Vazirani. Approximation Algorithms / Vijay V. Vazirani. – USA, 2004. 78 p.

Надійшла до редколегії 6.03.2013

Рецензент: д-р техн. наук, доц. К.С. Смеляков, Харківський університет Повітряних Сил ім. І. Кожедуба, Харків.

МОДЕЛЮВАННЯ І МЕТОДИ БАГАТОКУТНОЇ АПРОКСИМАЦІЇ ОБ'ЄКТІВ

А.С. Чуприна, Алзубіді Ахмед Саме

Метою даної роботи є дослідження існуючих моделей і методів апроксимації та отримання програмного комплексу, що забезпечує апроксимацію меж об'єктів за їх цифровим зображенням відповідно до заданого критерію точністю. Об'єктами дослідження є моделі, методи, алгоритми та комп'ютерні технології для вирішення проблеми апроксимації меж об'єктів в ГІС, з метою представлення цих меж у вигляді полігону з мінімальною кількістю вершин згідно до заданої точності.

***Ключові слова**: багатокутна апроксимація, геоінформаційні системи, критерій точності, помилка.*

МОДЕЛИРОВАНИЕ И МЕТОДЫ МНОГОУГОЛЬНОЙ АППРОКСИМАЦИИ ОБЪЕКТОВ

А.С. Чуприна, Алзубиди Ахмед Саме

Целью данной работы является исследование существующих моделей и методов аппроксимации и получение программного комплекса, обеспечивающего аппроксимацию границ объектов по их цифровым изображениям в соответствии с заданным критерием точностью. Объектами исследования являются модели, методы, алгоритмы и компьютерные технологии для решения проблемы аппроксимации границ объектов в ГИС, с целью представления этих границ в виде полигона с минимальным количеством вершин в пределах заданной точности.

***Ключевые слова:** многоугольная аппроксимация, геоинформационные системы, критерий точности, ошибка.*