MVA'94 IAPR Workshop on Machine Vision Applications Dec. 13-15, 1994, Kawasaki

AUTOMATED MAP-DRAWING DIGITIZING TECHNOLOGY BASED ON SCANNER INPUT

S.Ablameyko, V.Bereishik, A.Kryuchkov

Institute of Engineering Cybernetics
Belarusian Academy of Sciences
Surganov str., 6
220012 Minsk, Republic of Belarus

ABSTRACT

An original technology and techniques to digitize large-size maps is presented in the paper. Difficulties in automatic solution of this task made us to produce a combined automatic-interactive technology which includes together with automatic vectorization of map layers and automatic object recognition also interactive object digitizing and manual object digitizing based on image context. Such combination allowed us to reach an acceptable ratio between quality, time and automatization level of the digitizing process. Another advantage of the developed technology is that it allows to digitize large-size maps under limited computer memory resources. The techniques and algorithms realizing such a technology are shortly described in the paper.

INTRODUCTION

Map-drawing digitizing for their using in Geographical Information Systems is an important and complex task what takes many human and computer resources. The systems developed during last ten years to solve this task are based on using scanners to input data in a computer. It is impossible to give full overview of these systems, but general information and description some of them can be found in a special issue of Computer Magazine [1]. Most of the systems designed to digitize large-size map-drawings use powerful workstations or specialized hardware. It is reasonable for a big companies but for a wide practical applications it is necessary to have systems based on an ordinary personal computer with satisfactory time characteristics of map digitizing.

A process of map-drawing digitizing based on scanner input can be divided into two main stages: raster-to-vector trasform of a binary image with aim to obtain its structural representation, and recognition of cartographical objects to obtain a required final map representation. Now there are known many systems to perform raster-to-vector (r-t-v) transformation including commercial ones such as not many automatic techniques have been proposed to recognise cartographical objects. Recognition of several types of cartographical objects are given in papers [2,3] (buildings), in papers [2,4,5,6] (lines, roads, characters and symbols). Our long time experience shows that it is practically impossible to recognise automatically whole map because it was produced to read by man and include objects with different font, orientation, size, etc.

Impossibility to solve this task automatically made us to produce a combined technology presented in the paper which includes together with automatic vectorization of map layers and automatic object recognition also interactive object digitizing and manual object digitizing based on image context. Such combination allows us to reach an acceptable ratio between quality, time and automatization level of the digitizing process. Another advantage of the developed technology is that it allows to digitize large-size maps under limited computer memory resources.

MAP AND TECHNOLOGY DESCRIPTION

As an input we consider two types of map-drawings: binary map layers and colour maps. The scale of processed maps can be from 1:25000 to 1:200000 and the size of maps can reach up to 60x70 cm. There are three basic object classes on these maps: a)lines which length much bigger than their width and they have to be represented in output data base by their medial lines; b)symbols which have restricted geometrical parameters and have to be represented by one or two points; c)regions which have to be represented by their contours. To represent a cartographical object in output data base, it is necessary to determine its three main parameters: object code, metrics (geometrical coordinates), and semantics (object characteristics).

Map digitizing technology has been developed on a PC-based workstation. As peripheral devices it uses a scanner, a manual digitizer, and a plotter. Scanning one colour map of scale 1:50000 is performed with resolution of 50 points per mm by 1-1.5 hour with simultaneous extraction of 5 colours in one pass. The data are divided into different files corresponding to each colour and are recorded to hard disk in a TIFF format with simultaneous binarization. The simple operations of noise reduction like filling holes, deleting small black parts are performed apparatly inside the scanner.

The technology of map digitizing includes the next main parts A) automatic vectorization of map layers; B) automatic object recognition; C) automated object digitizing; D) contextual object digitizing. E) manual object digitizing.

It is necessary to note that B, C, and D technology parts are based on the result of image vectorization (A part) such as E part is independent digitizing process and it is used to digitize maps or their parts which can not be scanned and processed automatically by some reasons (very bad quality, too complex cartographical scenes, etc.). Figure 1 illustrates the processing technology.

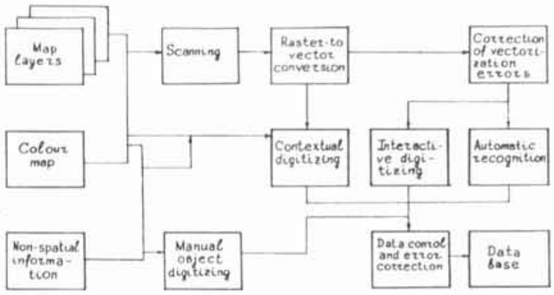

Figure 1 The technology of map digitizing

MAP IMAGE VECTORIZATION AND REPRESENTATION

The main operations of preprocessing are noise reduction (if necessary), thinning or contouring, and transformation in a vector form with segments and their characteristics extraction. We do not describe algorithms for this step in details such as it was made in some of our papers for example [7]. Shortly it consist in the following.

To store and process scanned binary images, we use a modified run-length image representation obtained from TIFF format. We use the same principles for all preprocessing operations because the result of any operation implementation with regard to any line is fully determined only by few adjacent lines. These line stripe is stored in a specially reserved buffer. Each program has access to all of these lines and can check and change their pixels using some basic techniques. The lines of the stripe are processed from bottom to top. The stripe moves consequently on the whole image from top to bottom, and all operations are performed during this move. Therefore, after every inspection of the stripe the corresponding operation is fully executed for the top line stripe. This line is removed from the stripe and a new bottom line is introduced.

To process all map-drawing image types, the following variants of raster-to-vector transform have been developed:

- Line-like layers vectorization variant which produces a skeleton description of line objects and symbols.

- Region-like layers vectorization variant which produces a contour description of objects.

In the result of vectorization, an intermediate vector data base is formed wich is based on three main element types: connected components (CC), segments bounded by feature points and feature points (nodes and end points). Nodes and end points are defined by using a Crossing number.

In accordance with three types of elements on the thinned image we use three-level representation of vector form. The first level contains the information about connected components and their characteristics; the second one - about segments with characteristics; and the third one - about feature points and their arrangement. Detailed description of these levels is given in [7]. This representation allows to easily perform a detection and automatic correction of vectorization defects like gaps, short branches and others and serveș as a base for further object interpretation.

AUTOMATIC OBJECT RECOGNITION

At this stage, based on the vector data base we recognise mainly line objects with a given structure (isolines) and roads.

1) To recognise isolines, attribute grammars are used. As terminal elements (TE) the grammars use primitives such as segment of line, gap, point. All the terminal elements are divided into two groups: constructive and connective TEs. The constructive TEs are used to obtain the geometrical coordinates of line objects, and the connective TEs are used to connect the constructive TEs in a chain. Each TE has some attributes (features) like length, thickness, type, etc. The description of lines is obtained by using different combination of TEs.

Recognition process consists of extraction of constructive TEs from vector representation, search of several variants to merge them into chain by using connective TEs, their sorting and refusing false variants on the base of special criteria.

2) The road layer contains buildings which must be represented in output data base by their contours and roads which must be represented by their skeletons. To process such a map layer, a special algorithm has been developed which includes the following steps:

- discrimination of all connected components into two classes: buildings and roads by using an average thickness of a connected component which is obtained from its area and perimeter;

- search of potential beginning of the road and extractiion of the middle line with separation of merged buildings. The algorithm includes the following basic steps: a) search of the beginning of line; b) simultaneous tracing of two line sides with middle line extraction and analysis of branches; c) cutting the branches and storing information about their beginnings; d) branch processing. Obtained information is further used to process main map layer.

MANUAL MAP DIGITIZING BY USING CONTEXT

As it was written before there are two main modes of manual object digitizing: 1) direct object digitizing; 2) contextual object digitizing. Under the first digitizing mode, the object code and characteristics are input by keyboard and special menu and the object coordinates are digitized by using a manual digitizer connected with PC. The final map representation is formed directly during digitizing.

The contextual object digitizing mode is based on input of a simplified (rough) object coordinates, its characteristics and precise metric information obtained after vectorization process. The idea of this method is to combine and change the rough metric information on precise vector model obtained after the vectorization process and add digitized object characteristics.

The simplified image description (metrics) is based on three main notions: a labeled point, a labeled region, and a labeled set. The labeled point represents coordinates of one marked point and its characteristics and is used to digitize cartographical symbols. The labeled region represents coordinates of boundary which includes objects with the same characteristics. The labeled set represents coordinates of different object types and their characteristics.

This process includes the following stages:

- rough digitizing of object metric information;
- input of object characteristics;
- object interpretation by using the automatically vectorized information and results of the previous stages.

The rough digitizing of object metric information is performed by manual digitizer or on screen of graphical monitor by mouse. Input of object characteristics is performed by a keybord. Then, a correspondance between rough digitized metric information and automatically vectorized information is established and the rough information is changed into a correct one.

AUTOMATED MAP OBJECT DIGITIZING

This technology part represents a modified automatic object recognition performed under an operator control. It is considered that the most difficult task in map interpretation is input of long twist line-like objects which are represented by line segments in the intermediate data base. To obtain the required final object representation, it is necessary to extract and join all segments forming one object. In this mode, it is made automatically for every object under operator visual control. This process includes two main tasks:

- automatic object and segment analysis in feature points and decision taken to continue the object tracing. The used algorithms are approximately the same as in the automatic recognition but with less strong restrictions.
- interaction with an operator in the places where the program can not take a decision.

Three modes of this process are extracted: automatic, semi-automatic and manual. In the first mode, a program tryes to join the segments during 15 steps automatically under given more free connection rules. In the second mode, the more strong rules are given and the segments are joined if and only if the program is sure in their correct merging. If the program is not sure in a correct merging, it passes to semi-automatic mode and asks the operator help. It extract several variants to continue the object tracing, rank them and propose the best one to the operator. Manual mode is characterised that operator picks segment by segment of digitized object by using a mouse.

DATA BASE AND CONTROL OF DIGITIZED INFORMATION

The result of map digitizing is recorded in a cartographical data base. The data base was realized on a basis of relational model and consists of three files: file of metrics, file of characteristics, and inquiry file. The records in the characteristics and metrics files have a varied length such as the inquiry file record has a fixed length.

The inquiry file contains the following information about object: classificational code, relationships with other objects, references to metrics and semantics. The file of metrics includes a geometrical object coordinates. The file of characteristics contains information about object characteristics.

Control of digital cartographic information includes the following control types: a) logical control of data structure; b) control of metric object descritpion; c) control of semantic object description.

RESULTS

The technology has been realized in map digitizing system based on IBM PC/AT computer in C language [8]. This system is used to digitize national maps of Russia and Belarus.

The input binary images are obtained either from black and white layers of maps or colour maps with size A4-A2, scale 1:25000 1:200000 digitized with a resolution of 20 or 40 pixels per 1 mm. The results of some map layers digitizing are shown in Fig.2. It should be noted that one picture shows the result of only map digitizing such as the second one shows a digital map prepared for map producing (with objects in a required form). An average time needed to digitize a Russian map of scale 1:50000 (58x61 cm) including 8000 objects on a minimal system configuration based on IBM PC/AT 386 computer is about 50 hours. An average time of manual digitizing the same map on the systems used now is equal about 150 hours.

CONCLUSION

The main distinctions of this approach from those already existed are:

- combination of different technological processes to digitize maps what allows to obtain acceptable time characteristics and high level of automatization;
- a specialized image vectorization scheme and original raster-tovector transform techniques, which allow to digitize large-size maps in a restricted computer memory;

- new developed technological processes like contextual map digitizing and automated object digitizing;
- a low cost of the system based on the developed technology.

Although this technology is used to process Russian maps, the basic methodology could be expanded to process other kinds of 2D line-drawings. For example, the technology has been tested to input cadastral maps, special forest maps and showed good results. Evidently, this technology could be used to input any 2D line-drawings.

REFERENCES

1.IEEE Computer, July 1992.

2.Ejiri M, Kakumoto S, Miyatake T, Matsushima H, Automatic recognition of design drawings and maps, Proc. 7th International Conference on Pettern recognition, pp.1296-1305, 1984.

3.Suzuki S, Yamada T, Maris: Map recognition input system, Pattern recognition, Vol.23, pp.919-933, 1990.

4.Amin T J, Kasturi R, Map data processing: recognition of lines and symbols, Optical Engineering, Vol.26, pp.354-358, 1987.

5.Boatto L, Consorti V, del Buono M, et al, An interpretation system for land register maps, Computer, Vol.25, N.7, pp.25-33, 1992.

6.Espelid R, Alvsvaag N A, Eileng J, Skauge I, Automatic digitizing of the colour-layer of thematic maps, Proc. IAPR Workshop on Machine Vision and Applications, Tokyo, pp.299-302, 1990.

7.Ablameyko S, Bereishik V, Paramonova N, Marcelli A, Ishikawa S, Kato K, Vectorization and representation of large-size 2D line-drawings. Journal of Visual Communication and Image Representation, Vol.5, December 1994.

8.Ablameyko S, Beregov B, Kryuchkov A, Automatic map digitising: problems and solution, Computing and Control Engineering Journal, Vol.5, No.1, pp.33-39, 1994.

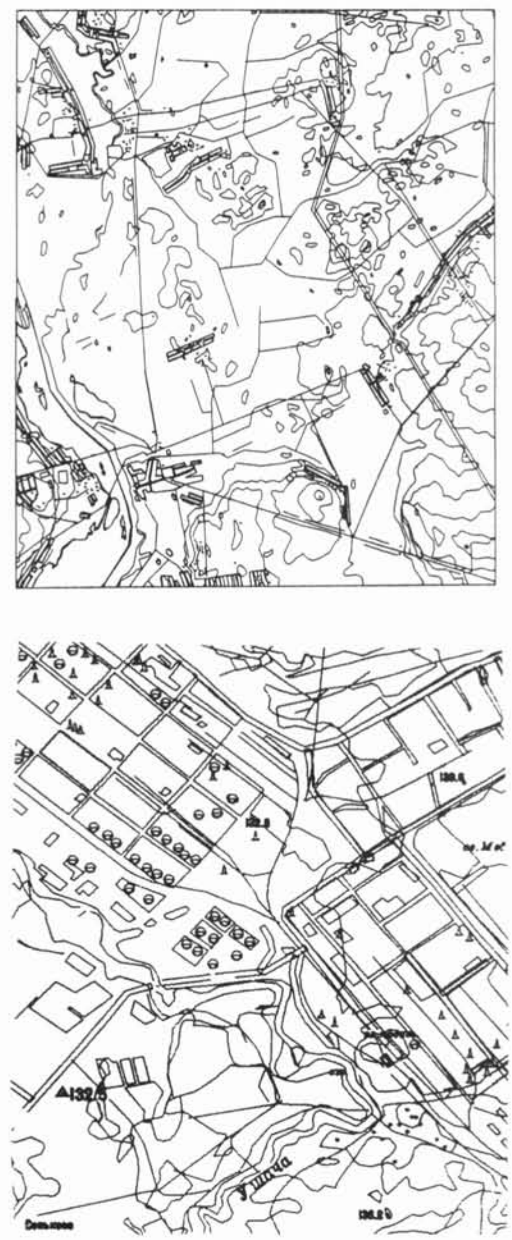

Fig.2.Examples of map layer digitizing.