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FROM COMPUTER VISION TO DOCUMENT RECOGNITION OR USING LABELING TECHNIQUE FOR MAP INTERPRETATION

S.Ablameyko, O.Frantskevich

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

ABSTRACT

This paper considers an application of computer vision notions for document recognition problem. The well developed in computer vision labeling technique is applied for interpretation of black-and-white layers of geographical maps. The knowledge base and main relations between cartographical objects and segments are extracted and described. Map-drawing interpretation process by using labeling technique is proposed. The suggested approach allows to increase a level of automatic object recognition.

INTRODUCTION

The problem of automatic map-drawing interpretation to obtain cartographic object representation in terms of CAD systems or Geographic Information Systems remains a difficult one and very important for many applications. Various approaches were developed to solve this problem and overview of used for it techniques is given in [1].

The process of map-drawing interpretation can be divided into two basic tasks: raster-to-vector transform and recognition of primitives, objects, scenes, etc. There are known many systems for solving the first task [2,3] and many of them obtain a description of line-drawings in terms of simple graphical primitives. To obtain the whole advantages of automatic map input, it is necessary to develop powerful techniques for object recognition. It is very difficult task because map-drawings are prepared for using by man and cartographical objects have many peculiarities such as different font, scale, rotation, they could be situated in various places of map-drawings, etc.

To solve this problem, knowledge-based approaches have being started to develop. Papers [4,5] describe approaches to use knowledge for map-drawing interpretation. There are two main profits of knowledge utilization in a map-drawing interpretation system:

- knowledge are used for the analysis of complex situations on the maps;
- knowledge represented in the form of knowledge base could make the system to be universal to process various types and scales of maps.

One of the powerful and developed techniques for line-drawing interpretation (but mainly for 3D line-drawings) is a labeling technique [6,7]. There are known papers devoted to application of labeling technique for interpretation of 2D line-drawings [8]. Recently, the first papers described application of this technique for interpretation of simple maps have been published [9].

Under 2D line-drawing (and particularly map-drawing) interpretation we mean the recognition of all objects on a map and determination of their characteristics. The same as in a 3D line-drawing, the objects in the map-drawing are composed from object components and are joined in scenes by using different relations between objects and components. The possible relations between objects and their components can be extracted and stored in a knowledge base. To extract and use the relations for object recognition, labels denoted these relations can be used. It allows to apply the labeling approach for the map-drawing interpretation.

In this paper, we consider application of computer vision notions for document recognition problem. More exactly, the labeling technique is applied for interpretation of black-and-white layers of geographical maps. The knowledge and main relations between cartographical objects are extracted and described. A map-drawing interpretation process by using labeling technique and knowledge is suggested and described. Object recognition process by using the given labels is suggested.

MAP LABELING TASK FORMULATION

The task of a map-drawing image interpretation can be formulated in terms of labeling technique as follows:

There are given:

- a knowledge base with information about cartographical objects and possible relations between objects and their components.
- a map-drawing image to be interpretated.

It is necessary:

- to extract objects and their components and find relations between them on the image (to give a label for each object or its component).
- to recognize cartographical objects by using a given information.

In accordance with this task let us consider the following main notions and processing steps:

- knowledge base;
- vectorization and segment extraction. Some simple labels are given to object components on this step;

- labeling of all object components;
- recognition of objects by using the given labels.

KNOWLEDGE BASE

Knowledge are generally classified according to their contents as objects, events, performance and metaknowledge. In computer vision, two types of knowledge are mainly used: objects which are also called "knowledge about scenes" and metaknowledge "control knowledge" [7]. These types of knowledge are also more suitable for document recognition. But such as scenes on map-drawings have their own sence and form more narrow class then all cartographical information, we call knowledge about scenes as actual knowledge which include knowledge about cartographical scenes, objects, components and their relationships. In other words, actual knowledge present information about facts and situations shown on the map. Control knowledge is used for decision taking on the stage of image interpretation depending on a current state of the process.

The actual knowledge are represented as a three-level hierarchical structure. Knowledge at the first level contain information about cartographical scenes, the second one about cartographical objects, and the third one about segments. The segment in our sence is a part of the object bounded by feature points (end and/or node points). The end and node points are defined by using a Crossing number.

There are following basic relations between segments and objects on a map: joining, crossing, gap, lie-inside, lie-in-neighbourhood. A set of segments united by one relation is called a situation. We shall make one-to-one correspondence between situations and labels or each situation what means that segments formed this situation get a corresponding label. The possible types of relations, situations and their labels are given in Table 1. A scene is a meaning related set of objects connected by some relations. The possible relations between objects, situations and scenes are stored in knowledge base.

Table 1

Objects and segment relations	Situation type	Label
1. Joining		a
2. Crossing		b
3. Gap		c
4. Lie inside		d
5. Lie in neighbourhood		e
6. No relations		f

IMAGE VECTORIZATION AND SEGMENT EXTRACTION

A scanned map image is represented in a binary form and is subjected to preprocessing and vectorization. It includes the following algorithms: noise reduction, thinning, feature extraction and transformation to vector form, forming a vector image representation. The algorithms used for this purpose are well known and we do not describe them here. The algorithms we used are described in our papers, for example [10]. As a result, a data base is formed which contains a description of the segments with their characteristics. It has three-level structure with information about connected components at the first level, segments at the second level and feature points (nodes and end points) at the third level [11].

SEGMENT LABELING

This step is intended for labeling segments on the image and it is based on establishing relationships between segments and its neighbours. The segment labeling step corresponds to extraction of situation by defining segments included in the situation. It means that we give to every segment its own label, which indicates relationships of the segment with another ones in the analysed situation.

Some types of relations between segments can be established during vectorization and segment extraction step and after this step some segments already have labels. Another part of labels are given to objects during the segment labeling step. The process of labeling is described as follows.

Two first labels are given to segments at the segment extraction step.

Label A is given to those three segments which are met in one node. It corresponds to the relation "joining" between segments.

If four segments are joined in one node they get a label B (relation "crossing").

It is made automatically by analyzing nodes and corresponding segments on the thinned image during forming the intermediate vector data base.

The next four labels are given to segments at this step.

Label C is given to the segments with approximately the same orientation, which end points have a distance between them less than a given threshold (relation "gap").

Label D is given to two segments one of which is included by another (relation "lie-inside").

The segments which are neighbours (are situated in a neighbouring space) get a label E. For line objects, neighbouring space is defined as a stripe with a fixed width along the object. For symbols, this space is a box with fixed parameters (relation "lie-in-neighbourhood").

If segment has not any relations with another ones, it gets a label F.

It is performed as follows. At first, the label C is given to segments by analysing a list of feature points and establishing their orientation. To give the label D to the segment, coordinates of bounding segment rectangles are calculated and analysed. For extraction of the situation with label E, the segment coordinates are analysed.

USING GIVEN LABELS FOR OBJECT RECOGNITION

To recognize a cartographical object on a map, we have to define the object coordinates, its class and characteristics. For this, the segments belonging to one object should be extracted in accordance with reference object description by using the obtained labels.

There are two main object classes on the maps: line objects which length is much longer then thickness and symbols which are bounded by a given box. A special order is used for object recognition. We start from more simple objects (line objects) and proceed to the next ones by using extracted situations and knowledge.

There are two more typical cases in this process:

1. Starting from any segment we collect segments belonging to one object by using the segment labels to obtain a description of the object. The labels A-C are used for this aim. The description is formed in terms of formal language [12]. The obtained formal description is compared with referenced one and decision is taken about type of the object. It allows to extract line objects (connected and disconnected) and several symbols. To discriminate symbols from line objects, a bounding rectangle of connected components is used. During the object tracing the segments laying in its neighbourhood are extracted and get a label E.

2.The labels D-E are used to find new objects on the image and start their recognition. The information about the determined relation between already recognised object and a new segment (or object) allows to advance a hypothesis about possible class of the object under recognition. It is made as follows:

- using an established relation between recognized object and new object or segment we can find an information in the knowledge base about what classes of objects can be in a given relation with a class of recognized object;
- a hypothesis is advanced that a new segment belongs to any one from above mentioned classes of objects;
- further recognition is performed only in the frame of these classes of objects (by using algorithms applicable for this object class). This relation (or label) and information from the knowledge base allows to reduce a number of references for the object recognition.

To recognise line objects, we use a syntactical approach with description of objects in terms of formal grammars such as to recognise symbols, a structural approach is used [12].

CONCLUSION AND DISCUSSION

The example of map processing is shown in Fig.1 After the vectorization and segment extraction we obtain the segments with characteristics and two first labels as shown in Fig.1a. The labels C-F are given to the segments at the labeling step. The result obtained after the segment labeling step is shown in Fig.1b.

Then, the recognition process begins. For the line objects we have full information about segments and after the segments assembly the class of the line objects can be obtained directly. Symbols are extracted by using the labels D-F and are recognized using the symbol segments labels and a structural approach. The resulting image after object recognition for the given example is shown in Fig.1c.

The main advantages of this approach are the following:

- it allows to formalise and prepare information for cartographical object recognition;
- it allows to reduce a quantity of referenced objects, recognition time, and raise a level of automatic object recognition.

As a drawback we could point out that the additional step of segment labeling increases a processing time.

The main distinctions of our approach from

1) 3D line-drawing scene labeling:

- we extracted basic relations between cartographical objects and segments on the map which are different from the relations in 3D scenes;
- we suggested the interpretation technology which is based on the labeling technique and knowledge;

2) map-drawing interpretation:

- we extracted knowledge types and basic relations between objects and segments;
- the suggested approach allows to increase a level of automatic object recognition.

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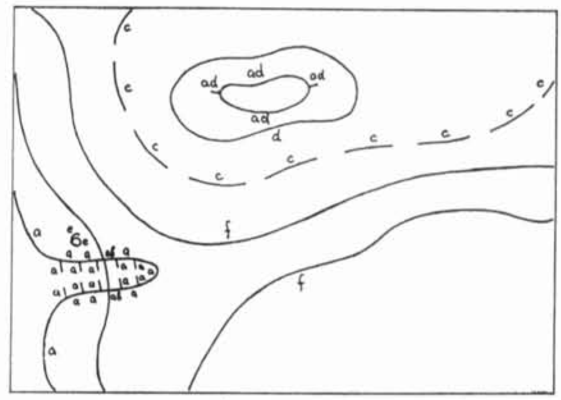

Fig. 1b

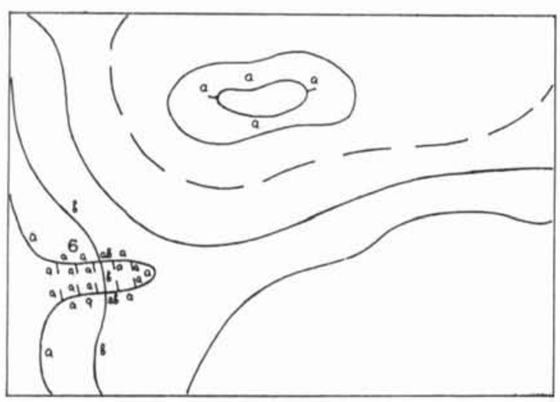

Fig. 1a

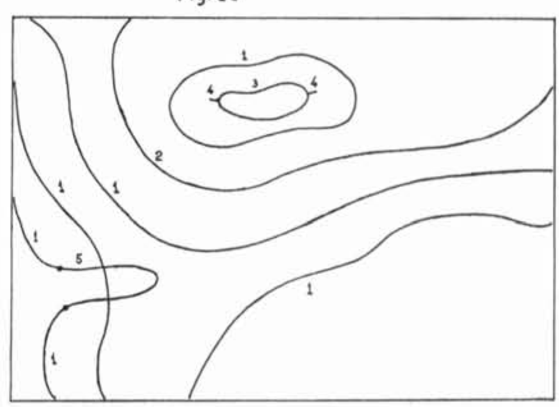

Fig. 1c

Fig.1. Example of isoline layer interpretation: a) after segment extraction step, b) labeled segments, c) recognized objects.