Conversion of High Level Information from Scanned Maps into Geographic Information Systems

Gerd Maderlechner

Siemens AG
D-81730 München, Germany

Helmut Mayer

Technical University Munich
D-80333 München, Germany

Abstract

This paper presents a system for automatic extraction of high level information from land register maps, e.g. parcels, buildings or roads. The system uses explicit knowledge of the map, which is given by the legend of the map, the drawing rules, and the constraints by functionality. The knowledge is represented by frames and semantic networks. The system uses four levels of representation and processing and a mixed strategy by feedback cycles between the levels. Results are presented for extraction of legal information (parcels and boundary stones) and topographic information (buildings, roads, sidewalks, farmland) from land register maps of scale 1:1000 and 1:5000. The precision of the extracted legal information is sufficient for the given task.

1 Introduction

The acquisition of the relevant information to fill a Geographic Information System (GIS) is more cost-intensive than the investment in the GIS system. Compared to photogrammetry or surveying, existing paper maps are a rather low-cost source of input data.

There are four methods to acquire the relevant digital geographic information for a GIS from existing paper maps: Manual digitization using digitizing tablets; Manual digitization using overlay of scanned map in an interactive editor; Semi automatic line following systems with raster overlay and editor; Automatic conversion methods based on scanned maps.

The first three methods use the expertise of the human operator on maps, e.g. the meaning of the symbols, annotations and their constraints. The time, cost and error rate of the acquisition depends on the skill and care of the operator and the quality inspection. For the available commercial systems for automated conversion of scanned maps, e.g. [Klauer 1993], time savings of 50 % compared with manual digitising were reported. However, these techniques fail, if more complex maps of lower quality are to be converted to GIS data. In many cases the above mentioned manual digitization or overlay technique are more economical.

To compensate for the weaknesses of vectorization several solutions have been proposed. In [Mulder 1988] topographic objects and their relations are modelled, but applied to idealized line drawings. In [Antoine 1991] simple models of real world objects are introduced for the extraction of buildings and roads in French maps. An improved extraction of graphics objects and a detailed error discussion of experiments with large maps of scales 1:500, 1:1000 and 1:2000 is described in [Klauer 1993]. In [Boatto 1992] an operational system for automatic conversion of Italian Land Register Maps is described, which uses a 4 phase approach. The first two phases correspond to vectorization and building an image graph and are similar to our respective levels. The 4 level structure of our model is motivated by the traditional approaches for recognition and interpretation of line drawings, using the low level, medium level and high level representations and processing steps. [see e.g. Kasturi 1992]. The main idea of the presented new system is to make the knowledge of the domain explicit. The map is a spatial representation of real world objects. The objects are symbolized using a legend and drawing rules. Some information, e.g. roads or sidewalks in a land register map, is not symbolized in the legend, but can nevertheless be recognized in the map. The semantic information is obtained from the functionality of these objects. This knowledge forms the new fourth and highest level. We use state of the art techniques of knowledge representation and inference like frames, semantic networks, and object oriented languages. The design and implementation of this work is specialized to land register maps (in Bavaria) of scale 1:1000 and 1:5000, see Figure 1 and Figure 2.

Results of extraction of the legal parcel data as well as the topographic objects like buildings, roads and sidewalks are presented and discussed.

0-8186-7128-9/95 $4.00 © 1995 IEEE

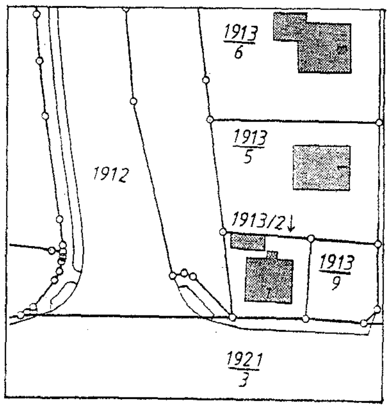

Figure 1: Part of Bavarian Land Register Map 1:1000

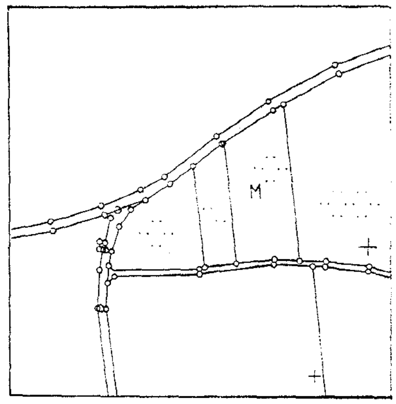

Figure 2: Part of Bavarian Land Register Map 1:5000

2 The Four Level Model

The new model for large-scale maps is organized in four levels called image, image graph, graphics and text, and semantic objects (Figure 3). They correspond to the traditional three levels of computer vision: low level, intermediate level, high level. The difference is a more detailed representation of the intermediate level (image graph and graphics and text), which is useful for line drawings. The lower levels 1, 2, and 3 are application independent to a large extent. The top level is domain specific.

For the representation of this model a semantic network is used. The main process in this conceptual network is the instantiation process, which means the allocation of values to the slots of the concepts.

The arrows in Figure 3 describe the following relations respective attached procedures of the concepts: The big arrows describe the top-down instantiation process of the semantic objects and the graphics objects. The left arrows shows the data driven bottom-up process of the operators defined in level 1 and 2. The right top-down arrows are procedural attachments for localizing regions of interest in the image graph (e.g. closed lines) or on the raster image (for OCR, template matching and correlation e.g. for circle detection). The right arrow directly connects level 1 with level 3 and shows the operation of OCR (resulting ASCII string, recognized in the region of interest) or template matching by correlation to recognize graphical symbols directly in the raster image. These operation avoid vectorization errors.

The following paragraphs describe the objects, operations and relations in each level. The Image level represents the original raster image supplied by the scanning process. The basic objects are the pixels. In this paper we started with binary images, because the high quality of the original maps justified a simple thresholding after scanning. Further objects are the connected components and skeletons.

The Image Graph level contains the line information of the image in an efficient graph representation. This so called image graph is a set of attributed undirected graphs. Each graph corresponds to one connected component (CC) in the image and represents its topology.

The Graphics and Text layer describes the well known taxonomy of 2-D computer graphics. The objects are composite or basic graphics. The Basis Graphics (also called graphical primitives) are Point, Line, Area and Text. The basic objects are defined by their usual mathematical definition and have attributes, which define their graphical appearance on the image.

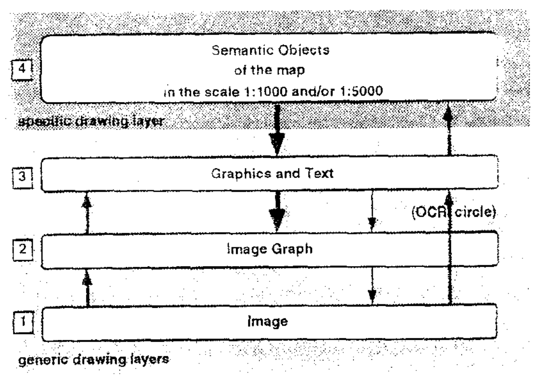

Figure 3: The four levels and the relations between the levels

In the Semantic Objects level the knowledge about the investigated types of maps is represented, as complete as possible, in an explicit and formal manner. The source of this knowledge are the map legend, the drawing rules (given by handbooks or experts), and if necessary some knowledge about the functionality of the objects (e.g. for roads or sidewalks).

The parcels and boundary stones are the essential legal information in land register maps. The map area is exhaustively filled out by non overlapping (i.e. mutually exclusive) parcels. The Parcel-ID is the unique identifier of the parcel area and a key to the owner.

The parcel is determined by the boundary stones, which are real world objects and drawn as circles of fixed radius (1.4 mm in 1:1000; 1.0 mm in 1:5000), according to the legend. The boundary line connects the boundary stones by a straight line, which is drawn with fixed line width (0.35mm in 1:1000; 0.18mm in 1:5000). There are no parcel-IDs in the map of scale 1:5000, but still legal information like boundary stones and polygon points. The topographic objects are buildings, roads, sidewalks (only in 1:1000), garden or courtyard, polygon point, farmland, and meadow.

Roads have no symbol in the legend in our maps in contrast to small scale maps with special line signatures (e.g. triple parallel line for highway). We have modelled the geometric and functional properties of roads: elongated shape, roughly parallel borders, and connections with other roads building a road network. The roads may have an identifier, which is a string of the road name in arbitrary orientation. We have postponed the modelling and recognition of the identifier. Therefore we use the same road model for both scales.

3 Results

We discuss the results for the two types of large scale maps shown in Figure 1 and Figure 2. The maps are scanned with 400dpi and the shown regions correspond to 1024x1024 pixels.

The starting point is the top level semantic object of the map (Level 4). The end condition is the complete instantiation of this map concept. This is a top-down process. If the instantiation is not possible there are uninstantiated subconcepts (specializations or parts). This induces new bottom-up and top-down processes (see Figure 3) which are controlled by relative priorities.

The application of morphological operations, connected component analysis and filtering yields a noise removal and identification of dot patterns as candidates for buildings. The cleaned image is thinned and transformed to the image graph. There are two line widths (thin with 0.18 and thick with 0.35 mm). The typical distortions of the skeleton near line crossings with small angles (two junctions instead of one) is acceptable, because our thinning process guarantees that the skeleton remains in the interior of the original lines.

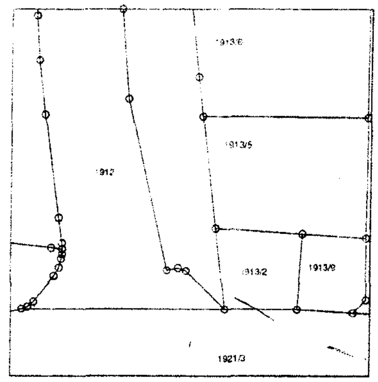

Figure 4: Recognized parcels with ID's and boundary stones

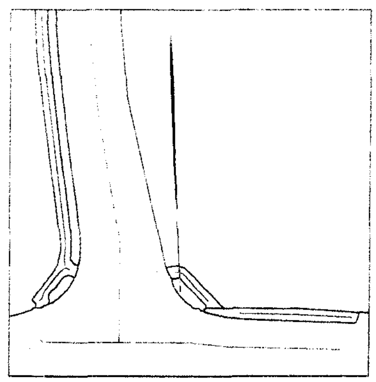

Figure 5: Recognized roads and sidewalks with their medial axes and borders

After finding the thick lines (hypothesis for boundary lines) we search for the circles corresponding to the boundary stones by template matching in the neighbourhood of the line ends. Figure 4 shows the result of the parcel recognition. There are 6 parcels with corresponding parcel-IDs. The remaining 3 parcel areas have their parcel-IDs outside of the chosen region. The parcel-IDs are determined. The parcel-ID 1913/2 is shifted into the correct parcel area. The numbers corresponding to the buildings are not shown.

For the extraction of roads we do not consider the line width. By the criteria mentioned in chapter 2 (elongation, medial axis, width) we get particular medial axes as road hypotheses. The roads are finally identified by building a road network. The roads are allowed to cross boundary lines which have no topographic meaning. With similar processing, i.e. instantiation of the concept sidewalks which depends on the determination of the roads the sidewalks are recognized (Figure 5).

The roads found in the map are plotted with their

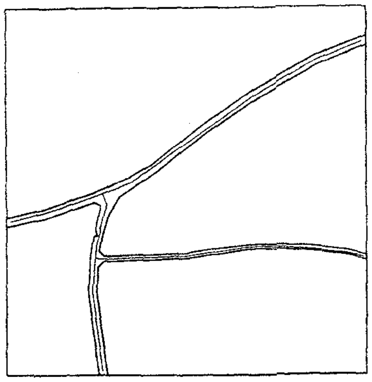

Figure 6: Recognized road network in map 1:5000

medial axes and the corresponding topographic border lines in Figures 5 and 6. The boundary stones, which covered the topographic lines, have been eliminated, so that the invisible parts of the lines could be reconstructed. The sharp corner in the left border of the vertical road in Figure 6 is caused by a tiny topographic area.

4 Conclusion and Future Work

With the proposed four level model and the mixed bottom-up and top-down strategy we could extract the legal land register information from large scale maps with high precision. The topographic information is accurate within the line width, if the covering of graphical objects could be resolved by the model. The extracted road information is useful for traffic information systems or planning purposes. As the generation of the semantic model of the drawing is expensive and must be made for every new application, an automation of this process will be investigated along the ideas of an information theoretic approach in [Kopec 1993]. An evaluation on a larger number of maps is necessary [Janssen 1993] to show the robustness of the approach with respect to lower quality or further topographic objects. The generalization of the model to other maps is straightforward. The modelling of other kinds of drawings like engineering drawings would require some redesign of relations between the layers and generation of new semantic, syntactic and lexical models [Dori 1993]. An extension of this method to the extraction of roads in aerial images is in preparation.

References

[Antoine 1991] Antoine, D., CIPLAN: A Model-Based System with Original Features for Understanding French Plats, Proc., 1st ICDAR, First Intern. Conf. on Document Analysis and Recognition, Saint Malo, France, pp. 647-655.

[Boatto 1992] Boatto, L., Consorti, V., Del Buono, M., Di Zenzo, S., Eramo, V., Esposito, A., Melcarne, F., Meucci, M., Morelli, A., Mosciatti, M., Scarci, S., Tucci, M., An Interpretation System for Land Register Maps, Computer IEEE, July 1992, pp. 25-33

[Ebi 1994] Ebi, N., Lauterbach, B., Anheiser, W., An Image Analysis System for Automatic Data Acquisition from Colored Scanned Maps, Machine Vision and Applications, Vol. 7, No. 3, 148-164.

[Dori 1993] Dori, D., Tombre, K., Paper Drawings to 3-D CAD: A Proposed Agenda, Proc. 2nd ICDAR, Tsukuba, Japan 1993, pp. 866-869.

[Ilg 1990] Ilg, M., Knowledge-Based Interpretation of Road Maps, Proc. 4th Int. Symposium on Spatial Data Handling, Zürich, pp. 25-34.

[Illert 1991] Illert, A., Automatic Digitization of Large Scale Maps, 1991 ACSM-ASPRS, Vol. 6, Auto Carto 10, Baltimore, pp. 113-122.

[Janssen 1993] Janssen, R.D.T., Duin, R.P.W., Vossepoel, A.M., Evaluation Method for an Automatic Map Interpretation System for Cadastral Maps, Proc. 2nd ICDAR, Tsukuba, Japan 1993, pp. 125-128.

[Kasturi 1992] Kasturi, R., O'Gorman, L., Document Image Analysis: A Bibliography, Machine Vision and Applications, Vol. 5, No. 3, pp. 231-243.

[Klauer 1993] Klauer, R., Untersuchungen zur Optimierung von Verfahren der automatisierten Digitalisierung von Flurkarten, Wissenschaftliche Arbeiten der Fachrichtung Vermessungswesen der Universität Hannover, Nr. 183.

[Kopec 1993] Kopec, G.E., Chou, P.A., Automatic Generation of Custom Document Image Decoders, Proc. 2nd ICDAR, Tsukuba, Japan 1993, pp. 684-687.

[Maderlechner 1994] Maderlechner, G., Mayer, H., Automated Acquisition of Geographic Information from Scanned Maps for GIS using Frames and Semantic Networks, Proc. 12th Int. Conf. on Pattern Recognition (ICPR), Volume II, Jerusalem, Israel, pp. 361-363.

[Mayer 1993] Mayer, H., Automatische wissensbasierte Extraktion von semantischer Information aus gescannten Karten, Dissertation, Technische Universität München.

[Mulder1988] Mulder, J.A., Discrimination Vision, CVGIP 43, pp. 313-336.

[Suzuki 1990] Suzuki, S., Yamada, T., MARIS: Map Recognition Input System, Pattern Recognition, Vol 23, No. 8, pp 919-933.