Automated Acquisition of Geographic Information from Scanned Maps for GIS using Frames and Semantic Networks

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Abstract

Data acquisition is the bottle neck for the introduction of Geographic Infor mation Systems (GIS). This paper presents a system for automatic extraction of semantic information from land register maps. The system uses explicit knowledge of the map, which is given by the legend of the map, the drawing rules, and the objects functionality. The knowledge is represented by frames and semantic networks. The system uses four levels of representation and processing: 1. raster image, 2. image graph of lines and junctions, 3. graphics and text objects, 4. semantic objects of the map. The interpretation of the map is performed by instantiation of the concept nodes of the semantic network. 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.

1 Introduction

The acquisition of the relevant information to fill a Geographic Information System (GIS) often is more expensive than the investment in the GIS. The use of existing paper maps is less expensive than photogrammetry or surveying. The main idea of the presented new system is to use an explicit model of the map in the domain of cartography. The objects are symbolized using the legend and drawing rules. Some information, e.g. roads or sidewalks in a land register map, is not symbolized in the legend. The semantic information is obtained from the functionality of these objects.The design and implementation of this work is specialized to land register maps of scale 1:1000 and 1:5000. Results of extraction of the legal parcel data as well as the topographic objects like parcels, roads and sidewalks are presented and discussed.

2 The 4-Level Model

The new model for large-scale maps is organized in four levels. The four levels are called image, image graph, graphics and text, and semantic objects. Each level consists of objects, operations to be performed on the objects and relations between the objects. In addition there are operations to be performed on and relations between objects in different levels, which is indicated by the arrows in Fig. 1. The model is represented by a Semantic Network. The nodes are given by frames, which are called concepts. Frames are prototypical object structures with slots, which are filled with attributes, relations or procedures. The arcs of the network are given by the Specialization (kind of) Relation and the Composition (part of) Relation. The main process in this conceptual network is the instantiation.

Level 1 represents the original raster image supplied by the scanning process. The basic objects are the pixels. Further objects are the connected components and skeletons. They are the output of the operators Connected Component Analysis and skeletonization. The operators are realized by procedures. The size of the Connected Components measured as circumscribed rectangle allows a coarse preclassification into dotsized, small and large objects. The dotsized objects are further processed by morphological operations to localize the dotted fill pattern of buildings (Fig. 2). This procedure however, is controlled by the semantic and graphics levels 4 and 3 (see below). The polygonal approximation (vectorization) also belongs to this level and can be combined with the line tracing, even on a contour or runlength representation of the image [Boatto 1992]. We postpone the vectorization to level 2 and 3. The remaining operators correlation, template matching and OCR are controlled by level 4.

Level 2 contains the line information of the image in an efficient graph repre sentation [Maderlechner 1988]. This so called image graph is a set of attributed undirected graphs, one for each connected component. The nodes of each graph represent the junctions or end points of the lines. The attributes are their position, radius, degree and angle. The degree is the number of lines joining in the node. The position and radius is estimated by a circle, which is fitted into the black area of the line junction. The arcs of the graph represent the lines. Their attributes are the line width and length.

Level 3 describes the well known world of 2-D computer graphics. The Basis Graphics (also called graphical primitives) are Point, Line, Area and Text. They are defined by their usual mathematical definition and have attributes, which define their graphical appearance on the image. Most graphical objects or symbols are composed of basic graphics objects. This is indicated by the part of relation from Composite Graphics to Basic Graphics. Complex composite graphics objects use a syntax, which is described in the concepts of the semantic objects level (e.g. parcel-ID).

In Level 4 we represent the knowledge about the investigated types of maps in an explicit and formal manner (Fig. 4). 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-ID has a defined geometric form and textual syntax. It is located inside of the parcel area if there is enough space, otherwise it is extended by a locator symbol (arrow), which points to the parcel area. The topographic objects are buildings, roads, sidewalks, garden or courtyard, polygon point, farmland, and meadow. In contrast to the boundary lines, the topographic lines are not necessarily straight lines between boundary stones, and may be curved.

As there are no symbols defined for roads in the legend, we have modelled the geometric and functional properties of roads: elongated shape, roughly parallel borders, and connections with other roads building a road network.

3 Control Strategy

The recognition process starts at the top level (Level 4). The end condition is the complete instantiation of the map concept. This is a top-down process. If the instantiation is not possible there are uninstantiated subconcepts (speciali zations, parts, or not successfully allocated slots). This induces new bottom-up and top-down processes (see Fig. 1 and chapter 2) which are controlled by several kinds of priority: (1) static dependencies given by the models in each level (specialization and part hierarchy), (2) fixed priorities of the concepts, and (3) measures of confidence resulting from procedures. The priorities are determined heuristically using the knowledge on the importance of the object, the visibility of the graphical objects, and the precision and time consumption of the procedures.

4 Implementation and Results

The concepts of the semantic network are represented as frames, which are implemented as Common Lisp Objects. The high level procedures are implemented in Common Lisp, the low level functions in Pascal. The OCR is a commercial product with an API. Fig. 5 shows the result of the parcel recognition. There are 6 parcels with corresponding parcel-ID. The remaining 3 parcel areas have their parcel-ID outside of the chosen region. The numbers corresponding to the buildings are of no interest in this investigation. By the criteria given in chapter 2 we get particular medial axes as road hypotheses. The roads are finally identified by building a road network across the (only legal) boundary lines (Fig. 6 and 7). For further examples and discussions see [Mayer 1993].

5 Conclusion and Future Work

With the proposed 4-level model and the mixed bottom-up and top-down strategy the legal land register information from large scale maps was extracted. The topographic information was accurate within the line width. The extracted road information is useful for traffic information systems or planning purposes. The generalization of the model to other maps is straightforward. The modelling of different kinds of drawings like engineering drawings requires a redesign of the semantic, syntactic and lexical models. An adaptation to analysis of aerial images for extraction of roads is planned.

References

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[Maderlechner 1988] Maderlechner, G. Jeppson, O., Representation, Classification and Modelling of Graphs for Efficient Pattern Recognition in Line Images, 9th ICPR, Rome, Italy, pp. 678-680.

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

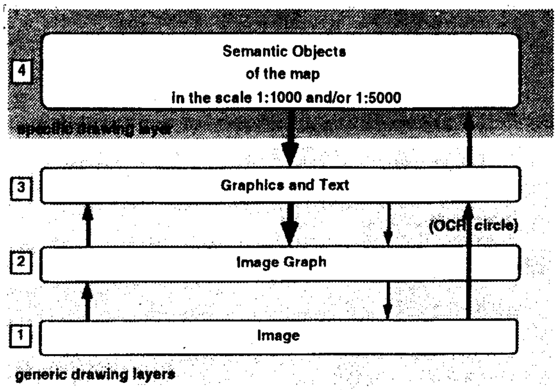

Fig. 1: The 4 levels of the representation of maps and the relations between the levels

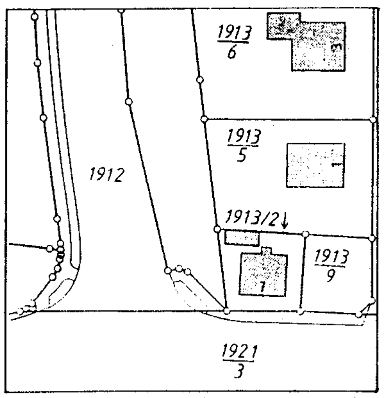

Fig. 2: Part of scanned Land Register map 1:1000

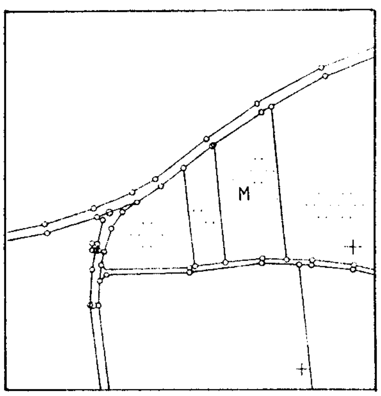

Fig. 3: Part of scanned Land Register map 1:5000

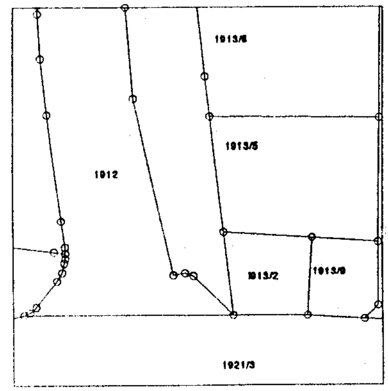

Fig. 5: Recognized parcels for map in Fig.3

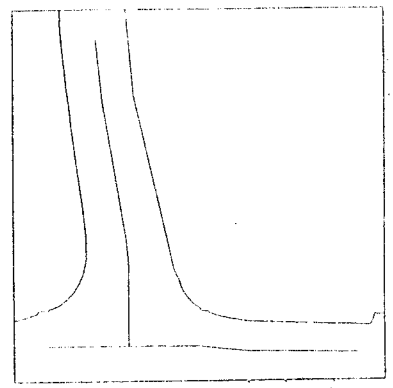

Fig. 6: Medial axes and borderlines of roads for map in Fig. 2

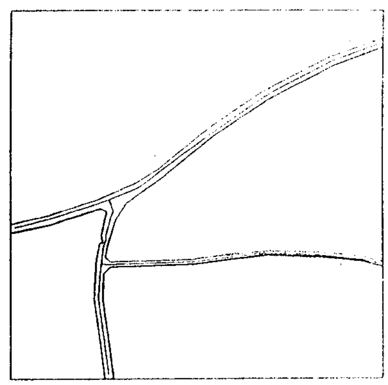

Fig. 7: Medial axes and borderlines of three roads (road network) for map in Fig. 3

Semantic Objects

- **Legal Objects**
  - **Parcel**
    - Parcel ID
      - main ID
      - sub ID
      - ID separator
      - ID-locator
    - Parcel Area
      - Boundary Line
      - Boundary Stone
  - **Polygonal Point**
- **Topographic Objects**
  - **Building**
    - Identifier
      - house number
      - name
    - Building Area
      - General Area
        - Topographic Line
  - **Road**
    - Identifier
    - Road Area
      - General Area
        - Topographic Line
  - **Sidewalk**
    - Sidewalk Area
      - Topographic Line
- **Basic Map Objects**
  - **Grid**
    - Grid Point
    - Coordinates
  - **Frame of map**
    - Frame Line
  - **Margin of map**
    - Map description
      - Map-ID
      - Map name
    - Version description
    - Scale
    - Legend

Fig. 4: Level 4 of the model. There are two relations between the objects: the class hierarchy (specialization, "kind of") is symbolized by solid lines or indentations between bold printed objects, the decomposition hierarchy (is part of) is indicated by indentations.