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RETRIEVAL FROM A GEOGRAPHICAL INFORMATION SYSTEM

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The geographical information system presented in this paper, allows for pictorial retrieval by pictorial example, and textual retrieval by map content. In this aspect it differs from existing systems. The architecture and functions of the system are described and an example is discussed.

1.INTRODUCTION

When large quantities of geographical maps have to be managed by a computer system, the need arises for databases, in particular for image databases.

Current information systems deal almost exclusively with textual or numerical information. Relatively few databases deal with images. This is a remarkable fact as in every day life images play an essential role. Image information is essential in architectural drawings, electronic schemas, simplified cartoons of diagnostic observations, line drawings in biology books, piles of photographs in many shapes, etc. The information content of such an image database is very large, and, it is very difficult if not impossible to capture the contents of such a database in textual form. To illustrate this point, imagine that one has to describe the exact shape of a human body without the use of a drawing. Also, from digital image processing it is known that a complete and fully automatic interpretation of an image from an arbitrary source cannot be expected in the near future. So, when information systems are constructed, there is no alternative other then accepting images as such.

Accepting image databases as a part of a larger multi-media database, which also contains other forms of data, requires storage and retrieval of an image database in pictorial form. That is, for a true image (sub)database,

1. requests should be specified to the computer in a pictorial form, and,

2. the search should be based on pictorial correspondence.

Such a pictorial correspondence is opposed to a correspondence at the level of a textual description of the search request .

In the state of the art in databases as well as in image processing, methods of image indexing fulfilling both demands are very rare, probably due to the dominance of textual databases and the only recent general availability of sufficient processing power to make image databases feasible. An image typically holds 512^2 picture elements, each digitized in 1 bit (black and white images) or 8 bits (grey value images). In addition to those technical limitations, it can be observed that the state of the art in image processing until recently did not indicate methods to solve the image correspondence problem in more general terms either.

The query language and the access structures implemented in the database management systems are very powerful for textual retrieval. But in our case their potentiality is limited by the fact that the content of the images has to be described using models which are developed for database systems rather than for pictorial systems, and so they lack the expressive power needed for the manipulation of images as pictorial entities.

In fact, images are inherently different from database records. The record structure in database systems can be described at class (i.e. type) level. Since the ratio of instances per type is very high, the resulting storage structures and access methods are very efficient. In contrast, each image may have its own particular structure, and a whole semantic network [1] may be necessary to completely describe each image instance.

In the field of geographical data processing, several approaches have been reported. Some of them concern methods for building geographical database systems. A geographical road database project has been described by Olsson [2]. Siekierska [3] has presented an experimental graphic workstation with different cartographic functions, which allows the user to manipulate existing maps and to create new ones. Kasturi and Alemany [4] reported a project for a system that automatically extracts information from paper-based maps. Stanchev and Vutov [5] present an economic geographical data base system for maps of a particular region.

The problem of map recognition is also treated in the literature. An automated map recognition system has been studied by Ejiri et al. [6]. They apply a pattern matching technique to locate landmarks like a city hall or post-office. This works well when the image part is guarantied to hold a symbol, but as they state ".. finding candidate symbol areas is generally more difficult, and an effective algorithm to this end has yet to be developed".

Different database query languages are developed for geographical applications. A QBE-like language is described by Barrera and Buchmann [7] for a geographical database system. Roussopoulos and Faloutsos [8] proposed a SQL-like language to manage an image database system. Kasturi et al. [9] describe a natural language interface for geographic map queries.

In this paper we address the problem of pictorial retrieval by example, and textual retrieval by map content in a geographical information system. The system differs in this aspect from existing systems. The described system supports map indexing, in order to obtain the semantic content, and the retrieval of different kinds of geographical information.

2. SYSTEM FUNCTIONS

The main functions performed by the system are the following:

- data collection. This is realized in two ways. Beside the scanning of the map to acquire the pictorial representation, the user can interactively add textual information;
- map indexing; This is performed to obtain a semantic representation of the map image.
- storage of the map images in the Image DataBase, and the semantic representation in Logical DataBase;
- query management; This allows searching by textual description, by example image and by map features.

The global system architecture is shown in Fig. 1.

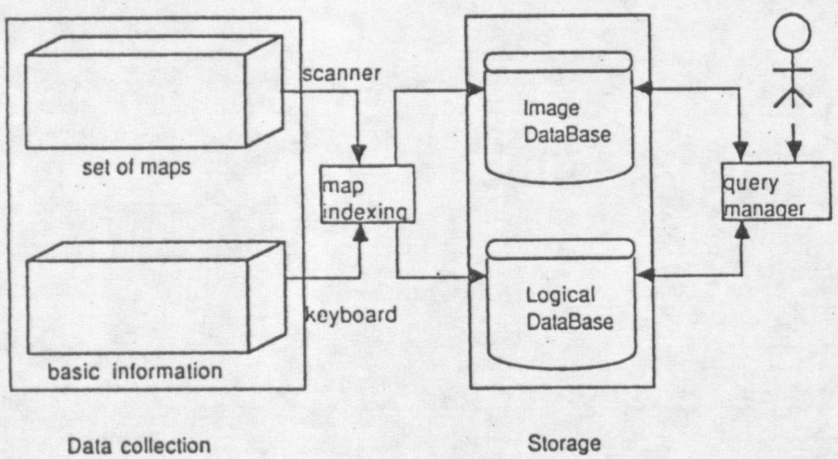


Fig. 1. The system architecture

2.1 Data Collection

The system requires the following data:

- the digitized map images
- the digitized image of the map legend as the formal symbol system to describe its content

Also the scale factor of the legend signs is needed. In the domain of geography three sizes of the legend signs are normally used to indicate the value of a quantity.

- basic information

This information is entered in the form of tables, which contain data such as: town names, population, area, geographical coordinates, road length, etc.

2.2. Map indexing

During the map indexing, a map is accepted and its legend signs are recognized, as well as their relative positions and their size to obtain a semantic representation of the map.

The map image indexing is based on digital image processing using fuzzy mathematical morphology [10], [11]. In particular the Hit-or-Miss transform is applied to find the positions in a particular map image where a legend sign is present. To be able to apply this transformation the legend signs have to be normalized to structuring elements. The resulting indexing process consists of two steps: entering of the legend signs and recognition of the legend signs in a particular map.

legend sign entering

The processing of the image of a legend sign is done to prepare it as a structuring element as known from Mathematical Morphology, where a structuring element is used later on to search for those places in the images of the database where there is an instance of such a legend sign. The image is normalized before entering a legend sign into the database. After the normalization positive values in the legend sign will indicate the image of the sign and the negative values correspond to the surrounding background. In addition, it is required that the sum over all elements of the normalized legends sign is equal to zero. This results in different weights for the positive and for the negative values of the structuring element to make the total sum zero.

search for legend signs

First a preprocessing is applied to the map image to correct for imperfections and noise introduced by the acquisition process. The preprocessing is based on [12]. Gaps in the components in the map image are filled by closing - an extension (dilation) of the components followed by a shrinking (erosion) operation.

The task for the pictorial component of a search for a specific legend sign is to find instances in the image database where the same sign is found. So, in order to find one, we need a measure which expresses the correspondence between the normalized legend sign, see above, and all places in all images of the database. The theory of mathematical morphology provides a measure to express such correspondence by considering the normalized detail image as a structuring element, S, in what is called a Hit-or-Miss operation [10]. The images in the database are valued +1 to indicate a black, sign pixel and -1 to indicate a white, background pixel. When, at a certain spot of an image, all positive pixels of S fit precisely in the detail, and all negative pixels fit precisely in the background, then the operation is said to yield a Hit. When either of the two fits fail, it is a Miss. It is clear that in this way instances of the detail image can be found by repeating the operation on every spot of every image in the database.

In practice, we prefer to use fuzzy mathematical morphology rather than the exact version. Fuzzy morphology permits for some inconsistency of the image with the detail or some noise in the image. At every neighbourhood of a locus (x,y) in an image, in fuzzy mathematical morphology, the point by point weighed sum of S with the image is taken. Some pixels of S are negative and when they weigh a detail value they will tend to lower the outcome. The same holds for positive values in S which hit on a background value. And these two options occur in most places where there is no correspondence between the image of the detail and the local configuration of the image of the database. But, when the local arrangement matches, then both types of pixels of S work to produce a strong positive outcome. In the ideal case, the outcome is equal to the absolute sum of all pixels in S. Taking the outcome as a percentage of the ideal value indicates a measure of correspondence between the local patch in an image and the specified detail image. The degree of correspondence is provided by the user and is usually in the interval [0.7, 1.0].

The pixels of high correspondence in a rectangular of the same size of the detail are reduced to one hit, because the fuzziness of the operation acts as an adaptive noise filter introducing more than one hit in images of good quality.

2.3. Map storage

Information is stored in two ways. Both the original image and the binary image, obtained after the preprocessing, are stored in the Image Database.

The basic information entered by manual interaction together with the information resulting from the image indexing of the maps are stored in the Logical DataBase. The

Logical Database includes Map, Legend sign and Relation DataBases. Also index tables containing specific features of the elements are generated and include coordinates of the legend sign centres, information extracted in topographical context of the legend sign, and the recognition degree.

2.4. Query management

The image query language in the system is a combination of retrieval by exemplatory image and by textual description of the image content. When a user's request can be expressed in terms of the extracted image description, there is no need to retrieve and process the original images. If however, the textual information is not sufficient, all images should be processed at the picture level to compare them with the image example.

Those images which fulfil the query make up the query answer set. In our approach, the query answer is presented by decreasing similarity to the specification, enabling the user to evaluate the quality of the matching. This is a typical advantage of the information retrieval techniques. In our approach, when we use retrieval by example image query, the recognition degree usually is higher then retrieval by textual description, due to the fact that the query describes the search image more precisely .

Since the image retrieval by content is not an exact process (there is no exact way of defining the image content), and even the user may forget to specify essential characteristics of the required search image, combining image retrieval by example with textual search is an essential moment in our system. It decreases the number of false ends.

Retrieval by example image

An example image map part is entered by a scanner, a camera or is extracted from stored images. The image query function includes:

- example image preprocessing
- indexing of the example image (i.e. transform the visually presented query in a semantic image description);
- translation of the query in a textual form (i.e. include in the query the relation between legend signs);
- binary search in the Logical DataBase;
- comparison between the example image and the set of images from the Image DataBase.

The resemblance degree between the example and the target is the recognition degree of the fuzzy Hit-or-Miss transform.

Retrieval by image content

In the image retrieval language the user specifies image conditions of the form: RETRIEVE IMAGES <element_clause>.

The <element_clause> includes combinations of <element description> and <position description>. The <element description> includes: legend sign name; attribute name; conditions for the attribute values such as "=", ">=", ">", "<", ">=", "<=" "<>" relations for numerical values, and with the MATCH operation for strings and for additional information, associated to the legend sign. The <position description>s are "E", "W", "N", "S", "NW", "SW", "NE", "SE", where "E", "W", "N", "S", denote the four cardinal directions. The position description is interpreted from left to right.

The resemblance degree between the query and the found images is defined as:

$$\frac{\sum \text{legend sign degree recognition}}{\text{number of legend signs}}.$$

Feature extraction

After finding the maps that satisfy the query specification a set of features can be obtained. These operations support the following set of functions.

DISTANCE measures the distance between two legend signs. DISTANCE_ROAD delivers the road distance between two legend signs. COORDINATE gives the coordinates of a legend sign. HOW_MANY gives the number of the requested legend signs on the map.

For the novice users, a query may be composed with the help of a menu-driven form. This enables an easy interaction, leads the user to the correct query and shows the result.

3. AN EXAMPLE

We will illustrate the functions of the system by an example of image databases for tourist maps of the Netherlands. Suppose, that the map presented in Fig. 2. is among the maps entered in the image database system. The legend signs and the parameters resulting from their normalization are given in Fig. 3. The result of the indexing of the map from Fig. 2. in given in Fig. 4. Note that this step performs the basic operations of the Hit-or-Miss transformations. The following operations on the semantic representation of the map have a standard nature.

Retrieving by textual query is shown in Fig. 5. The query is: show me the ma where the Vincent van Gogh museum and museum number 15 are. As a result of th query, a set of maps is retrieved from the Image DataBase. One of them is the map show in Fig. 2. Its recognition degree is 0.788. Retrieval by example image query is shown i Fig. 6. In this example the user enters an example image (the picture of Rijksmuseum and the resulting images are obtained. The recognition degree of the map from Fig. 2. i 1.

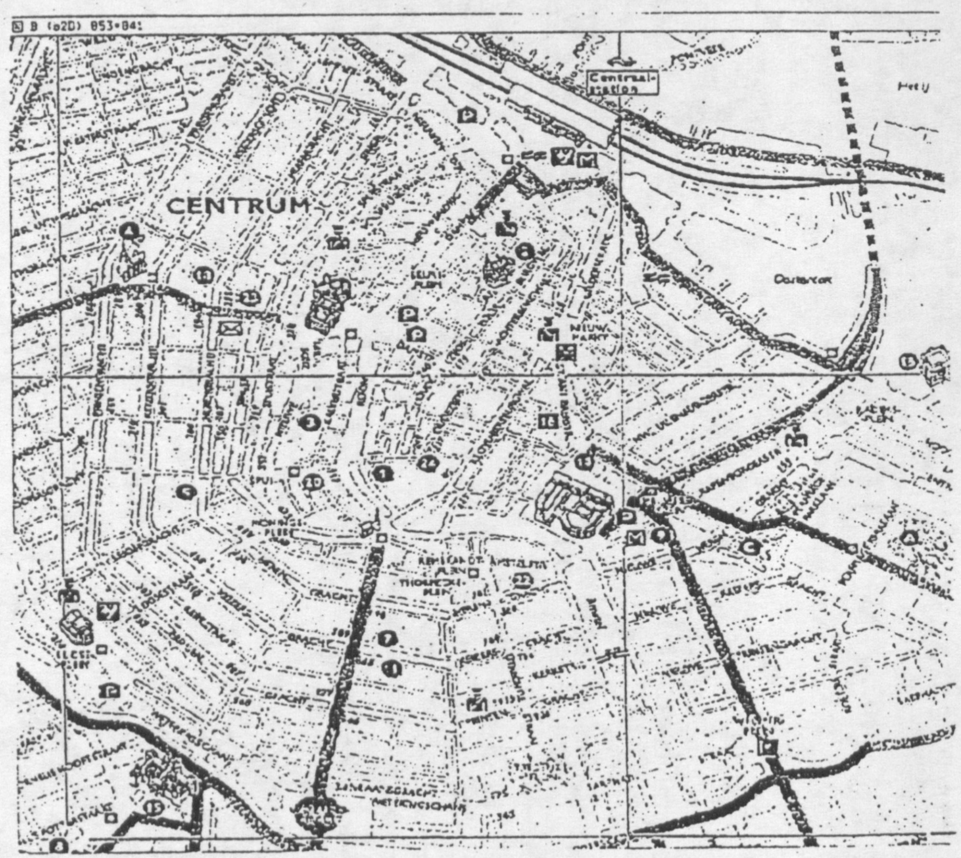
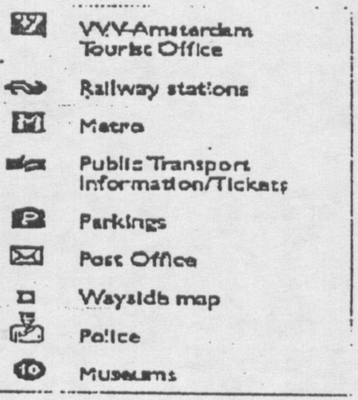


Fig. 2. Tourist map of Amsterdam centre



No.	detail_name	attribute_name		add_inf		t_val	m_num
. 1	tourist_office	street_name	- (	0.	0)	23192	25
. 2	railway_station	name	- (	0.	0)	22512	10
. 3	metro_station	station_name	- (	0.	0)	16668	40
. 4	transport_inf	street_name	- (	0.	0)	25676	50
. 5	parkings	street_name	- (	0.	0)	12388	100
. 6	post_office	number	- (	0.	0)	14476	50
. 7	wayside-map	street_name	- (	0.	0)	10154	10
. 8	police	street_name	- (	0.	0)	22558	50
. 9	museums	name	inside(	15.	15)	1567	50

Fig. 3. Legend signs and the result of their processing

No.	image_name	drt_name	x	y	att_name	att_value	a_inf	drg
1	map_Amsterdam_1	tourist_office	458	127	street_name	Damrak	-	0.894
2	map_Amsterdam_1	tourist_office	77	59	street_name	Leise_Plein	-	0.902
3	map_Amsterdam_1	railway_station	526	32	name	Central_station	-	0.863
4	map_Amsterdam_1	metro_station	499	132	station_name	Central_station	-	0.870
5	map_Amsterdam_1	metro_station	473	329	station_name	Nieuw_Markt	-	0.991
6	map_Amsterdam_1	metro_station	527	523	station_name	Visser_Plein	-	0.949
7	map_Amsterdam_1	metro_station	637	740	station_name	Weesper_Plein	-	0.965
8	map_Amsterdam_1	transport_inf	444	128	street_name	Damrak	-	0.897
9	map_Amsterdam_1	transport_inf	552	225	street_name	Hendrikkade	-	0.956
10	map_Amsterdam_1	parkings	387	86	street_name	Haarlemmerhoutuinen	-	0.901
11	map_Amsterdam_1	parkings	334	287	street_name	Damrak	-	0.869
12	map_Amsterdam_1	parkings	341	309	street_name	Damstraat	-	0.901
13	map_Amsterdam_1	parkings	521	501	street_name	Visser_Plein	-	0.938
14	map_Amsterdam_1	parkings	82	673	street_name	Leidse_Plein	-	0.978
15	map_Amsterdam_1	post_office	184	299	number	Central	-	0.876
16	map_Amsterdam_1	wayside-map	421	131	street_name	Damrak	-	0.901
17	map_Amsterdam_1	wayside-map	121	249	street_name	Wester_Mark	-	0.923
18	map_Amsterdam_1	wayside-map	296	307	street_name	Kalverstraat	-	0.945
19	map_Amsterdam_1	wayside-map	694	331	street_name	Valkenburgerstraat	-	0.944
20	map_Amsterdam_1	wayside-map	542	475	street_name	Visser_Plein	-	0.902
21	map_Amsterdam_1	wayside-map	711	537	street_name	Plantage_Kerklaan	-	0.899
22	map_Amsterdam_1	wayside-map	387	557	street_name	Rembrandt_Plein	-	0.890
23	map_Amsterdam_1	wayside-map	73	632	street_name	Leidse_Plein	-	0.923
24	map_Amsterdam_1	police	274	212	street_name	Voorburgwal	-	0.801
25	map_Amsterdam_1	police	421	198	street_name	Damrak	-	0.834
26	map_Amsterdam_1	police	455	309	street_name	Nieuw_Markt	-	0.893
27	map_Amsterdam_1	police	663	413	street_name	Ranenburgerstr	-	0.901
28	map_Amsterdam_1	police	47	576	street_name	Leidsegracht	-	0.876
29	map_Amsterdam_1	police	389	687	street_name	Prisen_Gracht	-	0.902
30	map_Amsterdam_1	museums	99	201	name	Anne_Frank_Huis	4	0.839
31	map_Amsterdam_1	museums	436	224	name	Amstelkring	2	0.903
32	map_Amsterdam_1	museums	166	244	name	Theater_Instituut	18	0.897
33	map_Amsterdam_1	museums	201	270	name	Spaarpotten	23	0.904
34	map_Amsterdam_1	museums	759	339	name	Scheepvaart	16	0.910
35	map_Amsterdam_1	museums	252	399	name	Amsterdams_Historisch	3	0.838
36	map_Amsterdam_1	museums	486	438	name	Rembrandthuis	14	0.900
37	map_Amsterdam_1	museums	343	442	name	De_Agnietenkapel	24	0.902
38	map_Amsterdam_1	museums	312	451	name	Allard_Pierson	1	0.889
39	map_Amsterdam_1	museums	253	459	name	Madame_Tussaud	20	0.877
40	map_Amsterdam_1	museums	147	467	name	Bijbels	5	0.877
41	map_Amsterdam_1	museums	550	519	name	Joods_Historish	9	0.884
42	map_Amsterdam_1	museums	431	565	name	Willet_Holthuysen	22	0.899
43	map_Amsterdam_1	museums	312	625	name	Fodor	7	0.866
44	map_Amsterdam_1	museums	317	655	name	van_Loon	11	0.799
45	map_Amsterdam_1	museums	114	733	name	Rijksmuseum	15	0.822
46	map_Amsterdam_1	museums	35	833	name	Vincent_van_Gogh	8	0.799

Fig.4. Semantic representation of the map from Fig. 2.

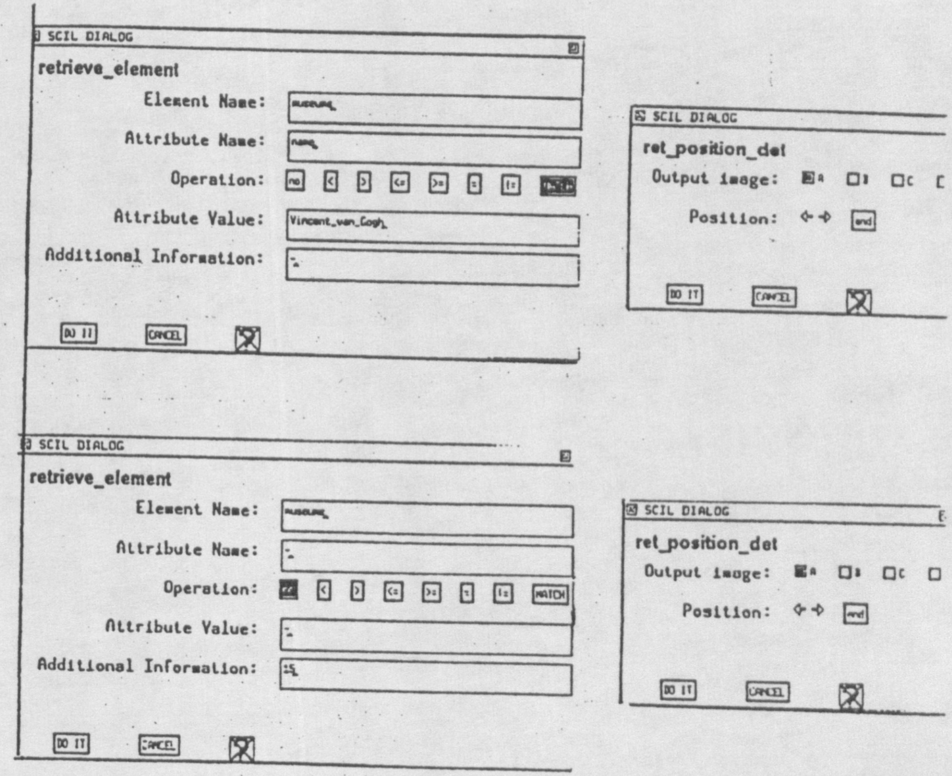


Fig.5. Retrieval by "textual query"

Fig. 6. Example image

The feature extraction capability is illustrated by the following examples concerning the map of Fig. 2.

Query 1: If the user wants to know how many museums there are in the region east of the Vincent van Gogh museum, the corresponding user query would be: HOW_MANY (museums WHERE museums.XCOOR E museums.name = 'Vincent_van_Gogh'). The result is: 16.

Query 2: If the user wants to know what is the distance between the Rijksmuseum and the Vincent van Gogh museum, the query would read: DISTANCE (museums.name = 'Rijksmuseum', museums.name = 'Vincent_van_Gogh'). The result is: 200m.

4. CONCLUSION

The main advantages of the proposed system are:

- query by text as well as by pictorial specification;
- the possibility to work with noisy map images;
- a fully automatic or interactive way of map indexing;
- calculation of a resemblance measure between the query and the retrieved map, expressing the goodness-of-search;
- mistakes by the indexing process are not crucial for the image retrieval.
- simplicity of the logical data representation. The representation of the information in tabular form is very comprehensive and easy to understand for the user;
- simplicity of the query language. The query language is available in two forms - menu driven and direct. The first one is very helpful for the novice users.

A prototype of the system has been implemented on a SUN workstation, under UNIX and written in C. It uses the SCIL_Image package [13], developed at the University of Amsterdam and the AMSTERDAM image database system designed for electronic schemes [14].

The method for image indexing discussed in this paper is applicable to image databases in other domains such as architectural drawings, electronic schemas and medical image databases. In particular the fuzzy Hit-or-Miss transform can be easily adapted to other kinds of (legend) signs.

REFERENCES

1. Tsichritzis D., Lochovsky F., "Data Models", Prentice-Hall, N.J. (1982).
2. Olsson L. "Development of Road Database from Map Overlays", Nat. Defense Res. Ins. (FOA), (Dec. 1984).
3. Siekierska E., "Toward an electronic atlas", Proceeding Sixth Int. Symposium Automated Cartography, Ottawa, Canada, pp. 464-474 (1983).
4. Kasturi R., Alemany J., "Information Extraction from Images of Paper-Based Maps", IEEE Trans. on Software Engineering, Vol. 14, No. 5, pp. 671-675 (May 1988).
5. Stanchev P., Vutov. V., "GAL: An Economic Geographical Maps DataBase System. Functional Description", Research in Informatics, Vol.3, Akademie Verlag, Berlin, pp. 197- 206 (1990).
6. Ejiri S., Kakumoto T., Shimada S., Matsushima H., "Automatic Recognition of Design Drawings and Maps", Proc. Seventh Int. Conf. Pattern Recognition, pp. 1296-1305 (1984).
7. Barrera R., Buchmann A., "Schema Definition and Query Language for a Geographical Database System", Proc. IEEE Conf. Computer Architecture for Pattern Analysis and Image Database Management, pp. 250-256 (1981).
8. Roussopoulos N., Faloutsos C.,"An Efficient Pictorial Database System for PSQL", IEEE Trans. on Software Engineering, Vol. 14, No. 5, pp. 639-650 (May 1988).
9. Kastruri K., Fernandez R., Amlani M. and Feng W., "Map Data Processing in Geographic Information Systems", Computer, pp. 10-21 (Dec. 1889).
10. Boomgaard R. van den, "Threshold Logic and Mathematical Morphology", Processing 5th International Conference on Image Analysis and Processing, Positano, Italy, pp. 111-118 (20-22 Sept. 1989).
11. Serra, J. "Image Analysis and Mathematical Morphology", London, Academic. (1982).
12. Groen F. and Munster R. van, "Topology based Analysis of Schematic Diagrams", IEEE 7th Int. Conference on Pattern Recognition, Montreal, Canada, pp. 1310-1312 (30.7 -2,8. 1984).
13. SCIL_Image package, University of Amsterdam. (1991).
14. Stanchev P., Smeulders A. and Groen F., "An Approach to Image Indexing of Documents", in Proc. 2nd IPIF Conference on Visual Database Systems, Budapest, Hungary, (Sept. 30 - Oct. 3, 1991).

(63.) Stanchev P., Smeulders A., Groen F., "Retrieval from a Geographical Information System", "***Computing Science in the Netherlands***", Stichting Mathematisch Centrum, Amsterdam 1991, 528- 539.