Automatically Identifying and Georeferencing Street Maps on the Web

Sneha Desai, Craig A. Knoblock,
Yao-Yi Chiang, Kandarp Desai
University of Southern California
Information Sciences Institute
4676 Admiralty Way
Marina del Rey, CA 90292
[desai, knoblock, yaoyichi]@isi.edu, kandarpd@usc.edu

Ching-Chien Chen
Geosemble Technologies
2041 Rosecrans Ave. Suite 245
El Segundo, CA 90245
jchen@geosemble.com

Categories and Subject Descriptors
H.2.8 [Database Management]: Database Applications—Spatial Databases and GIS

General Terms
Algorithms, Design

Keywords
Street maps, map search engine, map georeferencing

1. INTRODUCTION
There are a wide variety of street maps available on the Web, but many of these maps cannot be easily located. In addition, many of these maps lack detailed metadata that describes important information, such as the geocoordinates and scale of the maps. Image search engines, such as Google Images can be used to find maps, but accurately and efficiently identifying street maps among different images remains a challenging task. This is because image sources might include images that are not street maps, such as photographs, icons, scanned documents, political maps and climate maps. Those images are not relevant for applications which seek only street maps. These sources provide data from their own spatial databases and stored information services. They are searched on the basis of context, for example, on the basis of filenames included in a query. It is important to find a method that does content-based searches for street maps and identifies them by image content, such as their unique patterns of roads and not just by their context.

In this paper, we describe an approach to efficiently retrieve all available street maps by integrating various sources and eliminating images that are not street maps. We explain the method to identify street maps among all the images retrieved by applying certain image processing techniques to identify unique patterns, such as street lines, which differentiate them among all other images. To identify street maps, we apply Law's texture classification algorithm [6, 7] to recognize the unique image patterns such as street lines and street labels. In addition, we exploit the utilization of our previous work of the automatic extraction of the road intersections to find the intersections on the street maps identified [9] as well as utilizing GEOPPM [1], an algorithm for automatically determining the geocoordinates and scale of the maps.

The rest of the paper is organized as follows. Section 2 explains the previous work. Section 3 describes the method of classifying street maps and finding intersections and geocoordinates of the maps. Section 4 reports our experimental results. Section 5 discusses the related work and Section 6 concludes and presents future work.

GIR'05, November 4, 2005, Bremen, Germany.

2. PREVIOUS WORK ON GEOREFERENCING STREET MAPS
In our previous work, we presented a technique to automatically extract road intersections on the maps and then determine the geocoordinates and scale of the maps. Considering the fact that road layers are usually unique patterns to identify the coverage of the map, we identify the road intersections on the street maps for extracting that unique pattern. We utilize the automatic image processing and pattern recognition algorithms [9] to identify the intersection points on the street maps. This section is utilized in our present approach and shown as module 2 in Figure 1.

After finding intersections, using the intersection patterns, we automatically conflate the street maps (whose geocoordinates are unknown in advance) and the imagery with known vector data utilizing the GEOPPM algorithm [1]. Using this technique, we can identify the geocoordinates and scale of the street maps. We describe a specialized point pattern matching algorithm to align the two point sets and conflation techniques to align imagery with maps. The work is utilized in our present work and shown as module 3 in Figure 1.

3. MAP FINDER – OVERALL APPROACH
The overall approach of the map finder is shown in Figure 1. The input is the query string of a city name. The final output would be all street maps of the city queried along with the geocoordinates and scales. We describe the whole process of map finder in three modules. The first module includes the automatic classification of street maps among images, which are retrieved from different image sources. In the second module, we automatically extract the road intersection points on the street maps identified by the first module. Using the set of road intersection points we determine the

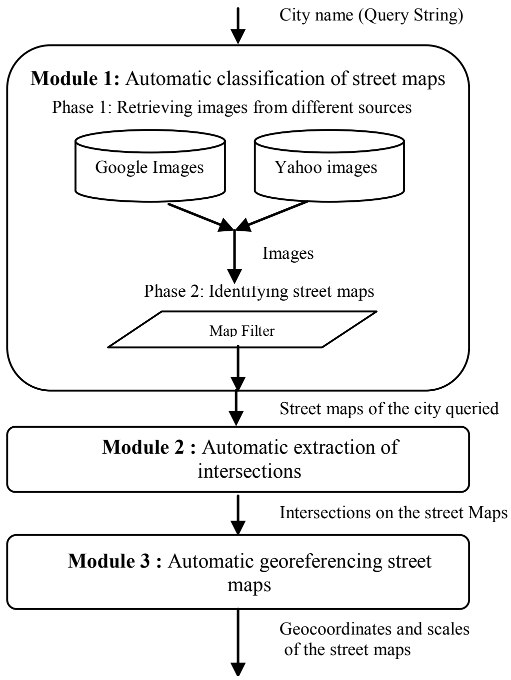


Figure 1. The overall approach of the map finder

geocoordinates and the scale of the maps in the third module. This section describes the details of the first module in Figure 1.

3.1 Retrieving All Available Street Maps on the Web

We retrieve all available street maps on the web by integrating image sources such as Google Images and Yahoo Images. Image sources have different images including photographs, icons, political maps and climate maps, which are not street maps. Therefore we focus on the images retrieved from the image sources. We used wrapper technology discussed in [4] to extract the image URLs from the sources. We check the availability of an image from the URL provided by the sources. Moreover, there might be some duplicate image URLs. We eliminate both nonworking and duplicate URLs. After finding available images from the total retrieved images, we identify the street maps among all the available images.

3.2 Identifying Street Maps

The primary task is to identify street maps that can be passed to the automatic extraction of road intersections (i.e., module 2 in Figure 1) and automatic georeferencing (i.e., module 3 in Figure 1). This process is shown in Figure 2.

First, we filter all the street maps from all different types of images. From those filtered street maps, we identify those street maps which are good for extracting road intersection patterns and conflating with known vector data. Each image has its own unique texture features, which are different and can be distinguishable from other images. We use Law's texture classification algorithm [6, 7] to find unique patterns of the street maps.

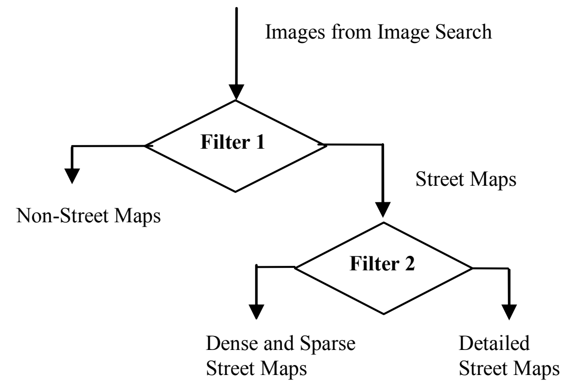


Figure 2. Identifying street maps among all different types of images

There are 25 attributes of street maps that are distinguishable for each image. We calculate these attributes for three color values (red, green and blue) thereby providing 75 different values to identify the street map. The algorithm identifies the textures such as lines and spots on the images. The measures are computed by first computing small convolution kernels of the digital image and then performing a nonlinear windowing operation as discussed in [6, 7]. For the automatic training and classification, we use SVM^{light} V2.0 support vector machine on a large scale training and classification [8]. We manually provide 1150 image examples including positive and negative examples to train the SVM and then do the automatic classification of the images.

3.2.1 Identifying Street Maps among All Images, Retrieved from Image Search

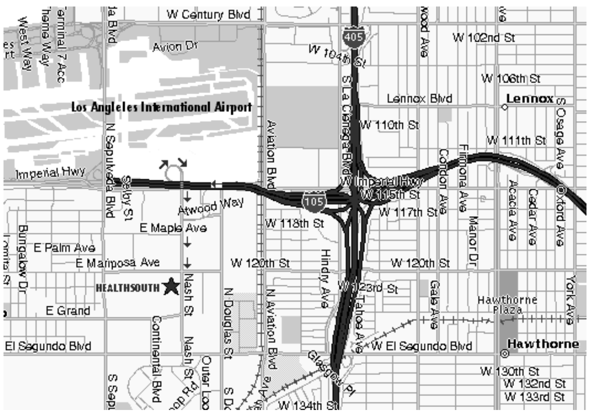
In the first phase, we automatically identify street maps having street lines and street labels, as shown in the Figure 3b, 3c, 3d. The image sources contain many different types of images. We distinguish all these images into two main categories. The first category includes the street maps, having the street information such as street lines and street labels. The second category includes images such as photographs, icons, logos, scanned documents, charts, graphs, commercial advertisements as well as economic maps, political maps, weather maps, etc., which do not contain any street information, as shown in Figure 3a. This filtering step is represented as Filter 1 in Figure 2.

3.2.2 Identifying Street Maps that can be Passed to GEOPPM to Find Geocoordinates

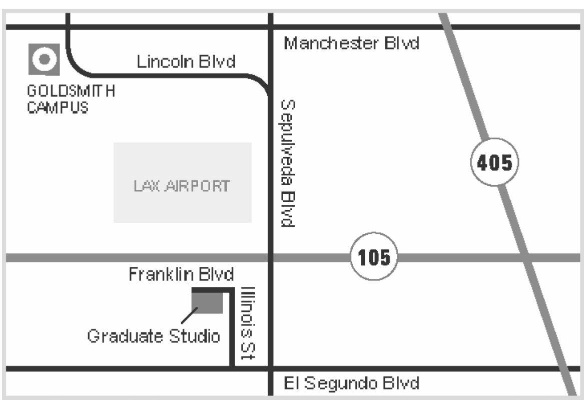
To get the geocoordinates of the map, the map image can be passed to the GEOPPM algorithm. GEOPPM does the matching of intersection points, thereby requiring an appropriate pattern of intersection points on street maps. For recognizing these types of maps, we define the measure of intersection point density as follows:

$$\text{Intersection Point Density} = \frac{\text{Total number of intersections found on the map}}{\text{Size of the map, pixel x pixel}}$$

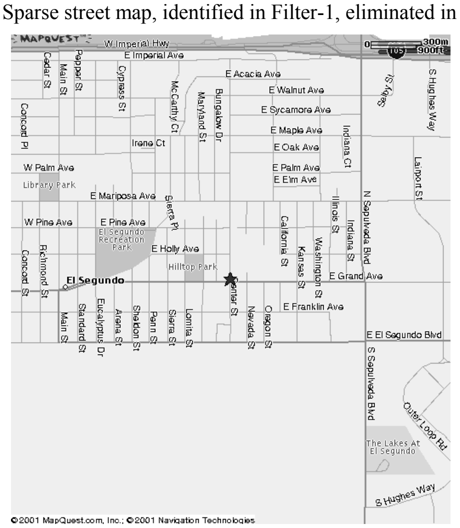
a. Images, which are not street maps, eliminated by Filter-1



b. Dense street map, identified in Filter-1, eliminated in Filter-2



c. Sparse street map, identified in Filter-1, eliminated in Filter-2



d. Detailed street map, identified by Filter-2

Figure 3 : Automatically classified example images

For dense maps (e.g., low resolution maps with resolution >= 7 m/pixel, having an intersection point density in the range of 0.01 to 0.02), we cannot find all available intersection points by the intersection detector [9]. This is because most of the street labels touch the street lines, so that when we remove the characters for extracting the road network from the maps we might loose the street line information. Without being able to detect a sufficient number of intersections, GEOPPM cannot determine the accurate geocoordinates. One of the dense maps found is shown in Figure 3b.

For the sparse maps (e.g., high resolution maps with resolution <= 1 m/pixel, having an intersection point density in the range of 0.00001 to 0.00008), though the intersection detector could find the intersections on these types of maps, GEOPPM would not be able to identify the matching pattern to the available vector data. This is because these maps would not have a sufficient number of intersection points on it. Figure 3c shows this type of sparse map.

The GEOPPM finds the geocoordinates of the street maps for which it can find an appropriate point pattern to match with the available vector data. Figure 3d illustrates this type of map. This step is represented as Filter 2 in Figure 2.

4. EXPERIMENTS

We experimented on two image sources: Google Images and Yahoo Images. We retrieve the images from these sources and apply map filtering techniques on the images. We used the city of El Segundo, CA as the query string input to retrieve all available street maps. We report our experiments in the form of a tree in Figure 4. In the tree, the result we achieve is shown without parenthesis and the recall and precision in parenthesis.

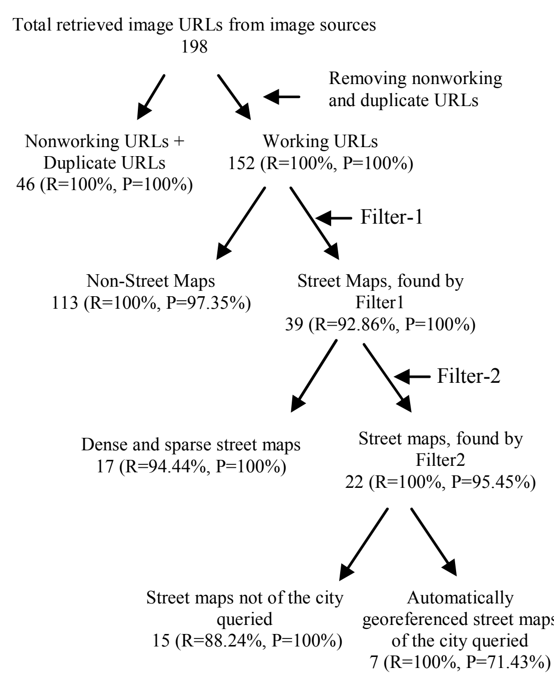


Figure 4. Experimental results

We define our recall as correctly identified street maps / actual street maps returned by the sources and precision as correctly identified street maps / total street maps returned. In the final stage we get 100 % recall and 71.43 % precision on automatically georeferencing the maps that cover the city queried.

The computation time primarily depends on the time consumed by the filtering technique, and it varies with the size of the image because the filter measures the unique texture features of the image pixel by pixel. The time it took for classifying the image ranges from 1.1 seconds to 72.93 seconds with the average of 29.65 seconds.

5. RELATED WORK

Although there is much research in the area of image retrieval and classification, we did not find any work related to identifying street maps and georeferencing them.

The approach described in [5] finds the image categories of news web sites and classifies the story, previews, commercial advertisements and logos. They focus on the combination of frequency domain and image and text features for the categorization, but they are not doing any kind of identification or classification of maps. In our work, we demonstrate a method of identifying unique street map properties like lines and labels with the help of distinctive image texture measures.

For compound images with text and lines, a new approach has been built in [3], which exhibits Transform Coefficient Likelihood (TCL) for identifying the text portion on the image. The approach could be used for the classification of map by text features. We are also identifying the street labels, which are text, but we are using pixel neighborhood and patterns for identifying street map texture properties.

The Web Seer [2], which is the image search engine for the World Wide Web, provides a way to locate the images on the web by using file name, file type, file size and color depth. They demonstrate the method to search images such as photographs and drawings by the image content tests such as band difference test, farthest neighbor test, color test and narrowness test. In contrast, we apply our method to identifying the street maps from different types of images retrieved from the image search. In addition, our work georeferences the street maps identified.

6. CONCLUSION AND FUTURE WORK

The main contribution of this paper is the design and implementation of the fusion of useful searching and integration technique as well as the identification of the street maps among all images retrieved from the image sources. In addition, we find intersection points on the resulting street maps and eventually determine the geocoordinates and the scale of those street maps.

We achieve a precision of 95.45 % in identifying the street maps. This demonstrates that our approach leads to remarkably accurate identification of street maps. The precision of 71.43 % for automatically georefececing the street maps illustrates that we are successful in finding geocoordinates and scale of the resultant street maps by utilizing the intersection detector and GEOPPM. The street maps classified by our filters could be used in a variety of applications and map search engines.

We intend to extend our approach in several ways. First we plan to further classify the images into different categories of maps such as political maps, weather maps, etc. We plan to minimize the use of additional image content to identify the image. We plan to develop OCR-related techniques to extract textual information from the identified street maps in order to label the detected intersections found and to support textual searching on maps.

7. ACKNOWLEDGEMENT

This research is based upon work supported in part by the National Science Foundation under Award No. IIS-0324955, and in part by the Air Force Office of Scientific Research under grant number FA9550-04-1-0105. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of any of the above organizations or any person connected with them.

8. REFERENCES

[1] C. C. Chen, C. A. Knoblock, C. Shahabi, Y. Y. Chiang, and S. Thakkar. "*Automatically and Accurately Conflating Orthoimagery and Street Maps*". *The 12th ACM International Symposium on Advances in Geographic Information Systems (ACM-GIS'04)*, Washington, D.C., USA, November 2004.

[2] C. Frankel, M. Swain, and V. Athitsos. "Webseer: an image search engine for the world wide web." Technical Report TR96-14, University of Chicago, Chicago, IL, 1996.

[3] I. Keslassy, M. Kalman, D. Wang, and B. Girod. "*Classification of compound images based on transform coefficient likelihood.*" In *Proceedings of the 2001 International Conference on Image Processing (ICIP'2001)*, Thessaloniki, Greece, October 2001.

[4] I. Muslea, S. Minton, and C. A. Knoblock. "*Hierarchical wrapper induction for semi structured information sources*". Autonomous Agents and Multi-Agent Systems, 4(1/2), 2001.

[5] J. Hu and A. Bagga. "Functionality Based Web Image Categorization." In *Proceedings of the Twelfth International World Wide Web Conference*, Budapest, Hungary, May 2003.

[6] K. Laws. *Textured Image Segmentation*, Ph.D. Dissertation, University of Southern California, Los Angeles, CA, January 1980.

[7] K. Laws. Rapid texture identification. In *SPIE (The International Society for Optical Engineering) Vol. 238 Image Processing for Missile Guidance*, pages 376-380, 1980.

[8] T. Joachims, "*Making large-Scale SVM Learning Practical*". Advances in Kernel Methods - Support Vector Learning, B. Schölkopf, C. Burges , and A. Smola (ed.), MIT-Press, 1999.

[9] Y. Y. Chiang, C. A. Knoblock, and C. C. Chen. "*Automatic Extraction of Road Intersections from Raster Maps*". In *Proceedings of the 13th ACM International Symposium on Advances in Geographic Information Systems (ACM-GIS'05)*, Bremen, Germany, November 2005.