A Deformation Analysis Method for Artificial Maps Based on Geographical Accuracy and Its Applications

Daisuke Kitayama
University of Hyogo
1–1–12 Shinzaike-honcho,
Himeji, Hyogo 670-0092, Japan
dkitayama@shse.u-hyogo.ac.jp

Kazutoshi Sumiya
University of Hyogo
1–1–12 Shinzaike-honcho,
Himeji, Hyogo 670-0092, Japan
sumiya@shse.u-hyogo.ac.jp

ABSTRACT

Artificial maps are widely used for a variety of purposes, including as tourist guides to help people find geographical objects using simple figures. We aim to develop an editing system and a navigation system for artificial maps. Artificial maps made for tourists show suitable objects for traveling users. Therefore, if the artificial map has a navigation system, users can get geographical information such as object positions and routes without performing any operations. However, artificial maps might contain incorrect or superfluous information, such as some objects on the map being intentionally enlarged or omitted. For developing the system, there are two problems: 1. extraction of geographical information from the raster graphics of the artificial map and 2. revision of inaccurate geographical information on the artificial map. We propose a deformation-analyzing method based on geographical accuracy using optical character recognition techniques and comparing gazetteer information. That is, our proposed method detects the tolerance level for deformation according to the purpose of the artificial map. Then, we detect a certain position on the artificial map using deformation analysis. In this paper, we develop a prototype system and we evaluate the accuracy of extracting information from the artificial map and detecting positions.

Categories and Subject Descriptors

H.3.1 [**Information Storage and Retrieval**]: Content Analysis and Indexing

General Terms

Human Factors

Keywords

GIS, Geographical Accuracy, Artificial Maps, Navigation System

WebQuality '12, April 16, 2012, Lyon, France

1. INTRODUCTION

Tourist maps, sketch-like maps, and rough maps are commonly used nowadays to support daily decision making, such as searching for the nearest restaurant or planning travel. We refer to such maps as "artificial maps." When we walk around a city, we often come across artificial maps such as a city guide map and or a map for navigating an advertising spot. Artificial maps are used not only in real spaces but also on the Web. For example, most Web pages of restaurants include artificial maps for route guidance, and those of cities include artificial maps to show sightseeing spots. In addition, user-generated content such as blogs may include artificial maps created for records of the user's travel. Artificial maps enable users to easily understand geographical information by showing specialized information. However, artificial maps contain different features, even when they are made for the same purpose. Therefore, maps with excess information or modifications that present inaccurate geographical information might lead users to the wrong destination. For example, a user using an excessively artificial map that shows too long a distance between landmarks for route guidance to a target restaurant may not be able to find that restaurant.

In contrast, online map services such as Google Maps and Yahoo! Maps show general geographical information. Therefore, users may have to manipulate the search objects, change regions, and so on many times to get the required information they desire. Bing Maps[1] is an online service that generates modified destination maps automatically. However, Bing's destination maps do not possess all the good points of artificial maps because this system reduces unimportant streets and objects based on general importance. We show the characteristics of artificial maps and online maps in Table 1.

Now, most navigation systems use online maps because the Global Positioning System (GPS) returns longitude and latitude coordinates. We consider that if longitude and latitude coordinates can be translated to X and Y coordinates on an artificial map, users can use a navigation system on an artificial map even when the artificial map has incorrect geographical information such as false object positions or inaccurate distances between two or more objects. When users want to see more objects, such as restaurants and sightseeing spots, on an artificial map that lacks such geographical information, then by the same technique of converting coordinates, we can show retrieved objects on the artificial

[1] http://www.bing.com/maps/

Table 1: Characteristics of online maps and artificial maps.

	Online maps	Artificial maps
Accuracy	Accurate	Inaccurate
Machine Readability	Readable	Unreadable
Human Readability	Difficult	Easy
Coordinates	Longitude and Latitude	X and Y
Purpose	General	Special

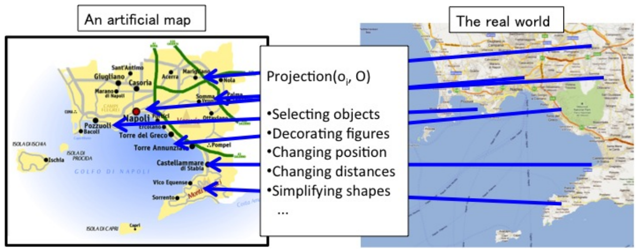

Figure 1: Real world and artificial map.

map. For developing this technique, we have two problems to address:

- Extraction of geographical information from the raster graphics of the artificial map
- Revision of inaccurate geographical information on the artificial map.

Therefore, we propose a deformation-analyzing method based on geographical accuracy using optical character recognition (OCR) techniques and comparing gazetteer information. In this method, we enhance OCR techniques by postprocessing for recognizing geographical object information and we check the correspondence of a point in terms of its coordinates on the artificial map and its longitude and latitude, using geographical accuracy.

This paper is organized as follows. Section 2 describes our approach and reviews related work. Section 3 describes how recognition is used in artificial maps. Section 4 presents a method for corresponding artificial maps to the real world. Finally, we evaluate the accuracy of our method in Section 5.

2. OUR APPROACH

2.1 Definition of artificial maps

Artificial maps show a certain purpose by containing selected geographical objects from the real world and transforming the shapes of the objects to enable users to understand geographical information. In other words, map makers generate artificial maps by selecting suitable objects for their purpose, determining object positions to show their purpose, and depicting object appearances to increase readability. Therefore, artificial maps are projected maps with added modifications, such as transformation, emphasis, and deletion of geographical objects that are included in the real world. The relation between the real world and an artificial map is shown in Fig. 1.

We define artificial maps using the following expression:

$$Artificialmap = \{o'_i | o'_i = projection(o_i, O), o_i \in R\}. \quad (1)$$

Here, R is a set of geographical objects with longitude and latitude coordinates in the real world, and o_i is a geographical object. The *projection* function adds modifications that convert the longitude and latitude coordinates to X and Y coordinates on an artificial map by using the relation between an object o_i and a set of shown objects O on the artificial map. This function determines the objects shown on the artificial map and how to show objects. o'_i is an object with some modifications.

Deformation analysis in this context is the evaluation of artificial maps by estimating the types of processing needed in the *projection* from the real world as input and in the artificial map as output. Therefore, we analyze deformation by extracting the positions of objects and representation of objects on artificial maps and comparing them with the positions of the objects in the real world and on an artificial map. We consider all maps to be modified ones with objects extracted from the real world and modifications made to the extracted objects. In this work, our target is to obtain artificial maps in which the spatial positioning of objects has been modified.

2.2 Overview of our research

We propose a method for analyzing the deformation of a map by using geographical accuracy for modifying the map, as shown in Fig. 2. First, we explain the problem of how we extract geographical information from the raster graphics of an artificial map. We extract geographical object information that consists of geographical object names and positions from artificial maps using OCR techniques. We correspond extracted data to gazetteer data for corresponding data of an artificial map and data from the real world. However, this corresponding process has three obstacles:

- Extracted data include some noise items such as incorrect characters and text pertaining to nongeographical objects.
- Geographical object names on artificial maps are different from geographical object names in the gazetteer.
- There are many candidate objects in the gazetteer.

We address the first and second obstacles by using the Levenshtein distance of geographical object names. Then, we address to third obstacle by finding outliers based on spatial dispersion.

Next, we describe the problem of how we revise inaccurate geographical information on an artificial map. For translating from real-world coordinates to coordinates on an artificial map, we have to take care of partial modifications. Artificial maps are modified such that some parts are enlarged and other parts are foreshortened. Moreover, modifications may cause errors in object positions, and the extraction step may lead to mistaken objects. Thus, there are two types of inaccurate geographical information:

- Modifications of an artificial map can be partial.
- Some objects have inaccurate positional relationships.

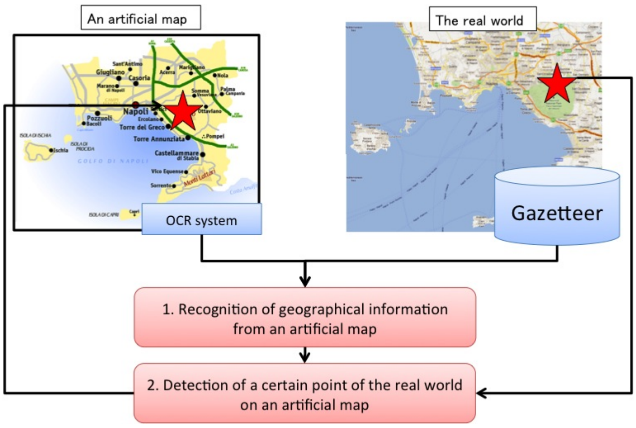

Figure 2: Concept image of deformation analysis.

A map's deformation can be analyzed from the standpoint of two geographical accuracies. The geographical accuracy of the real space is related to the accuracy of the approximate positional relations and the relative distances. We address this first obstacle by using the relative distance relations of a set of three objects in a bottom-up approach. We detect the consistency among each set of three objects and eliminate inconsistent sets of three objects as excessive deformation from the process of translating coordinates. Then, we address the second obstacle by using approximate positional relations of a set of three objects. In this way, we can translate positions in real-world coordinates to positions in artificial-map coordinates.

2.3 Related work

The PhotoMap[12] system has been proposed for user navigation with artificial maps. With this system, users can determine their current position on the artificial map. When the user relates a position on the artificial map with one on the real map two or more times prior to navigation, the system estimates the user's current position based on the relevant positions. Moreover, when the user relates the current position on the artificial map to one on the real map once before navigating, the system matches the artificial map with the real map based on the relevant positions. Then, the user can adjust the scale of the artificial map and the real map to determine the current position on the artificial map by using the GPS system. Schöning et al.[12] proposed a simple method for detecting certain points on the artificial map. However, using the artificial map results in quality problems such as inaccurate positional relations and distances. Therefore, we propose a detailed analysis method for addressing these quality concerns. We believe that Schöning et al.'s method can be smoothly combined with our method.

Methods for generating artificial maps, such as the destination map function of Bing Maps, have been extensively researched. These methods perform various operations, such as selecting objects, transforming the shapes of objects, and arranging the positions of objects. Grabler et al.[7] proposed a detection method for selecting objects that was based on the semantic, visual, and structural importance of objects. They used web site ratings of traveling spots as the semantic feature; the object's color, shape, and height as the visual feature; and the object's position as the structural feature. Arikawa et al.[2] proposed a method for detecting visible objects using the ontology of geographical objects for adaption to a user's needs. Shimada et al.[13] and Nakazawa et al.[9] developed a method for selecting objects using attributes such as type and position. Many methods for transforming the shapes and arranging the positions of objects have been proposed[8, 6, 14, 10]. A common approach is to simplify borders, such as roads, coastlines, and edges of buildings, into straight lines and right angles, based on the cognitive science of maps. Then, objects are arranged using morphing techniques to simplify the distortion. Agrawala et al.[1] proposed a method for transforming the shape of roads based on consistency and the theory of cognitive psychology. The proposed method could highlight important roads by maintaining consistency even when these roads were shorter than other roads. These studies aim to generate an artificial map that is desired by users. Our aim is to analyze artificial maps that are generated manually. If we can analyze the deformation of artificial maps, we can further develop various systems for purposes such as retrieving and ranking artificial maps based on effective deformation, replacing an artificial map on a Web page with a more useful one, and revising inaccurately modified parts to create better artificial maps.

We now describe conventional research pertaining to the extraction of geographical information from the raster graphics of artificial maps. Michelson et al.[11] proposed a map identification method using CBIR techniques and edge features. This method searches for similar edges between an input image and a map repository and a non-map repository. When the results include many images from the map repository, the input image is identified as a map. This method is aimed at simply detecting whether the input image is a map. Our method presumes that the input data is that of a map. Therefore, our method needs to use their method for preprocessing.

Spatial-query-by-sketch[3][4] is a well-known method for searching for a map by using a sketch map as a query. In other words, artificial maps are correlated with the real world using this method. This method uses as queries geographic topological relations that are extracted from a hand-drawn sketch map and defined as inclusion relations, overlap relations, and so on[5]. Then, this method retrieves suitable regions of the map by using the topological relations. In this method, an artificial map is correlated with the real world by the graphical structure and topological relations. In contrast, our method correlates an artificial map with the real world by using a set of points as geographical objects and their positional relations. Further, our method can analyze the artificial map's accuracy. We think that the spatial-query-by-sketch method and our method can complement each other.

3. RECOGNITION PROCEDURE FOR ARTIFICIAL MAPS

3.1 Extraction of candidate objects from a gazetteer

Recognition of artificial maps has two steps. First, we extract candidate objects that are described on artificial maps using OCR techniques and a gazetteer. Next, we narrow

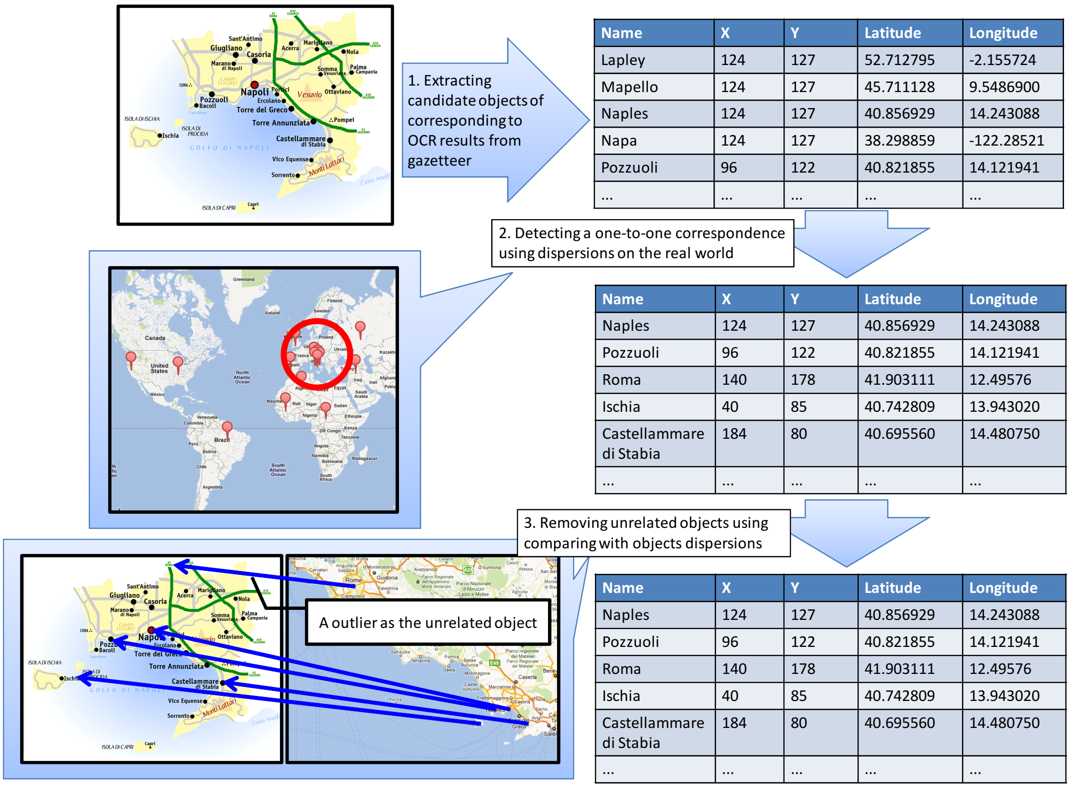

Figure 3: Procedure for recognition of artificial maps.

down candidate objects for detecting described objects on artificial maps. Figure 3 shows a recognition procedure for artificial maps.

In the extraction step, we use OCR techniques for just reading the characters on artificial maps. Therefore, we cannot know whether the extracted characters are geographical objects. Moreover, extracted characters include some noise items such as a few characters being read as other characters. From these facts, we extract candidate objects from the gazetteer. We use the Levenshtein distance between extracted characters and the names of geographical objects from the gazetteer because the Levenshtein distance can handle abbreviations and OCR noise. We set all insert, delete, and replace costs to 1.0. We use a threshold α of total costs n divided by the length of the extracted characters for extracting candidate objects. In this way, we extract a set of extracted characters, character coordinates on an artificial map, geographical object names, and coordinates in the real world as a data set for the candidate object.

3.2 Narrowing down candidate objects using spatial dispersion

For recognition of described objects on artificial maps, we have to select one candidate object from all possibilities. First, we filter out unrelated candidate objects based on outlier detection using spatial aspects in the real world. In this step, we detect a one-to-one correspondence with extracted characters from an artificial map and geographical objects in the gazetteer. However, there are unrelated objects that are not described on an artificial map. Therefore, we remove unrelated objects by comparing object dispersions in the real world with those on an artificial map.

We filter out unrelated candidate objects by the following procedure:

1. We calculate the center longitude and latitude coordinates by using a weighted average of all candidate objects. The weight of a candidate object is the inverse number of candidate objects from the same extracted characters.

2. We remove the furthest candidate object from the center coordinates. If the furthest candidate object is the last candidate object of a certain extracted set of characters, we redo this procedure without that object.

3. We repeat steps 1 and 2 until all the extracted characters have a one-to-one correspondence with a candidate object.

In this procedure, we assume that most artificial maps describe a narrow region: For example, a city map describes a narrow region of a city and a guiding route map includes only the narrow region between an origin object and a destination object. We cannot filter out unrelated candidate objects on artificial maps that encompass large regions such as the entire world. This is an inherent limit of the procedure outlined here.

After filtering, unrelated objects remain on the artificial map. For example, when a extracted character is not a geographical object or some geographical object names are similar to extracted characters, an unrelated object is included in the filtering results. Therefore, we have to remove unrelated objects. We consider that the positional relations of an extracted character to other extracted characters are similar to the positional relations of the corresponding geographical object to other geographical objects when a corresponding geographical object is described on an artificial map. However, we cannot use absolute values of distances because the coordinates used on an artificial map and in the real world are different (X and Y versus longitude and latitude). Therefore, we compare dispersions of object coordinates on both an artificial map and in the real world. We calculate the dispersion of object o_i using the following formula:

$$Dispersion(o_i) = \frac{1}{n}\sum_{o_j \in O}^{n} Distance(o_i, o_j)^2, \qquad (2)$$

where n is the number of objects O. The *Distance* function returns the Euclidean distance between object o_i and object o_j.

If the difference of dispersions on an artificial map and in the real world is large, we remove the object that has the largest difference of dispersions. We determine whether the difference of dispersions is large or not by using the Smirnov-Grubbs statistical test method. The detailed procedure is as follows:

1. We calculate all of objects' dispersions on both an artificial map and in the real world and the difference of each dispersion of corresponding objects.

2. We determine whether the difference of dispersions is large or not by using the Smirnov–Grubbs statistical test method.

3. If the difference of dispersions is large, we remove the object that has the largest difference of dispersions.

4. If the difference of dispersions is not large, we finish this process.

In this way, we extract an object's name, its X and Y coordinates, and its longitude and latitude coordinates as described objects on an artificial map.

4. TRANSLATING COORDINATES OF THE REAL WORLD TO THOSE OF AN ARTIFICIAL MAP

4.1 Finding corresponding coordinates using relative distances

In this section, we detect corresponding coordinates of a certain point in the real world. We use the extracted objects' coordinates in the real world and an artificial map (see Fig. 4). If there are three extracted objects, we can estimate the corresponding coordinates of a certain point in the real world using geometric calculations as follows:

1. In real-world coordinates, we extract a point of intersection between a side of two extracted objects and a perpendicular to the side and the target point. We then extract another point of intersection between another side of two extracted objects and the above perpendicular. In this way, we extract three sets of points from three sides of three extracted objects.

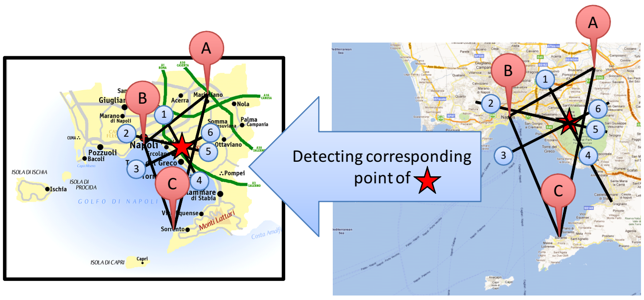

Figure 4: Translating coordinates of the real world to an artificial map.

2. We calculate a ratio of a distance between an extracted point and a point of intersection to a distance to another extracted point and the point of intersection. In this way, we calculate six ratios on the three sides.

3. In artificial-map coordinates, we place two points using the calculated ratios and the three extracted objects at every three sets.

4. We estimate the corresponding point using the above sets of placed points. We draw three lines based on each set of placed points. The estimated corresponding point is the point of intersection of their lines.

We perform this process using a set of three extracted objects. All estimated corresponding points are inaccurate because extracted objects include inaccurate modifications. Therefore, we calculate the corresponding point using estimated points based on the accuracy of the positional relations in the next section.

4.2 Detecting corresponding coordinates using approximate positional relations

In this section, we describe the accuracy of approximate positional relations. In this analysis, we focus on the relative positions of three objects. Therefore, an analysis of the approximate positional relations only focuses on the direction, irrespective of whether the target object is to the right or the left when one object is seen from another. We compare whether the directions are the same between the objects of an artificial map and of the real world. We consider that there are inaccurate modifications of positional relations when the positional relations in the real world and those in the artificial map are different; when the positional relations are the same, we consider that the modifications are more accurate. Therefore, we calculate similarity based on vectors of the signed degree of an angle using the following formulas:

$$\begin{aligned} deg(o_i, o_j, o_k, A) &= (o_j^x - o_i^x) \times (o_k^x - o_i^x) \\ &\quad + (o_j^y - o_i^y) \times (o_k^y - o_i^y) \qquad (3) \\ &\quad (o_i, o_j, o_k \in A), \end{aligned}$$

$$\begin{aligned} v(o_i, o_j, o_k, A) &= [deg(o_i, o_j, o_k, A), \\ &\quad deg(o_j, o_k, o_i, A), deg(o_k, o_i, o_j, A)] \quad (4) \end{aligned}$$

$$Sim(\ v(o_i,o_j,o_k,A), v(o_i,o_j,o_k,R)) = \frac{v(o_i,o_j,o_k,A)\cdot v(o_i,o_j,o_k,R)}{|v(o_i,o_j,o_k,A)|\times|v(o_i,o_j,o_k,R)|}, \quad (5)$$

where o_i, o_j, o_k are geographical objects. The function deg shows the signed degree of an angle by a numerical value. This function returns a positive value when o_i is on the right of the line drawn from o_j to o_k, and it returns a negative value when o_i is on the left of the same line. The function v returns a vector of three degrees. Argument A is a set of geographical objects on an artificial map, and R is a set of geographical objects in a gazetteer showing the real world. o_i^x means o_i's X coordinate on the artificial map and longitude coordinate in the gazetteer. o_i^y is o_i's Y coordinate on the artificial map and latitude coordinate in the gazetteer. We use X and Y coordinates when the argument is A; we use longitude and latitude coordinates when the argument is R. In this way, we detect inaccurate modifications of positional relations when function Sim returns a low value.

Finally, we detect a point using a weighted average of all estimated points. This time, we use the weight values from the above-calculated similarities because we decrease the effect of extracted objects that have inaccurate positional relations.

5. EVALUATION

5.1 Prototype system

We evaluate the accuracy of recognition and the accuracy of detecting current position using the following prototype system. We developed a prototype system using C# on Visual Studio 2010. The interface of the system is shown in Fig. 5. The prototype system made for showing "HERE" on an artificial map is based on deformation analysis. We substitute the online map (Google Map) on the right part for GPS when a user inputs the current position. A user can select an image of an artificial map on a Web page as input. The system shows the target artificial map on the left. When a user selects current position by a right online map, the system shows the icon "HERE" on the left artificial map.

We extract geographical object names from the image of the artificial map using the color OCR library.[2] We use a gazetteer that consists of geographical object names, longitudes, and latitudes, which are extracted from Yahoo! Local[3] and Geonames.[4] We preprocess an image by doubling its size to make it more readable by the OCR system.

5.2 Recognition of artificial maps

We evaluated the accuracy of the recognition of described objects on artificial maps. We used 20 artificial maps that show routes for accessing universities and famous sightseeing spots around Kyoto and Hyogo in Japan(see Table 2). We manually prepared correct descriptions of the objects on artificial maps. We calculated precision and recall by the number of described objects and the number of extracted objects for this evaluation.

Table 2 lists experimental results. A high precision means we can estimate a certain position correctly because noise objects are few. Recall is relatively low from precision; however, we can estimate a certain point even with only a few extracted objects. In our method, preprocessing involves only size expansion (with both vertical and horizontal dimensions being increased by 400%). If we use other combinations of size expansion (e.g., expanding vertically by 400% and horizontally by 200%) and divide layers into background color and character color, we can extract more characters from an artificial map for improving recall. We consider that precision is more important than recall for corresponding a certain position. From these results, we confirmed that our recognition can be used to detect the corresponding position on the artificial map.

[2]http://panasonic.biz/it/sol/ocr/sdk/
[3]http://local.yahoo.com/
[4]http://www.geonames.org/

Table 3: Experimental results of detection.

No.	# of correct detections	# of incorrect detections	Accuracy
1	24	16	60%
3	26	14	65%
5	14	26	35%
7	0	30	0%
9	7	13	35%
11	3	7	30%
13	0	10	0%
15	4	6	40%
17	1	9	10%
19	7	3	70%
Total	86	134	39%

5.3 Detection of corresponding point

We evaluated the accuracy of the detection of a point on the artificial map corresponding to a certain point in the real world. In this evaluation, we used an odd number of maps and several participants for determining whether the results are accurate. Participants could see the online map for confirming the position in terms of the details. Participants randomly selected a point in a region of the shown artificial map. This procedure was performed 10 times per artificial map. We evaluated the accuracy of our method by calculating the ratio of accuracy.

Experimental results are given in Table 3. In this table, the accuracy of detected corresponding points is indicated. The accuracy is 39%, with a correlation coefficient for the precision of recognition of 0.62 and a correlation coefficient for the recall of recognition of 0.38. Hence, we can detect a certain point from the real world on the artificial map when the precision of recognition is sufficiently high. However, our method yields some incorrect detections; for example, a detected corresponding point is at the bottom of a certain street when that point is located in the upper part of the street in the real world. The correct and incorrect results are shown in Figs. 6 and 7. Our method only considers point objects, not line objects such as streets and edges of districts. We need to extend our method to handle line objects in addition to point objects. Therefore, developing recognition techniques for line objects and enabling the detection of the corresponding position using line objects will be the aim of our future work.

6. CONCLUDING REMARKS

We defined novel concepts for analyzing map deformation and its applications. Then, we described how to extract geographical objects from an artificial map. Furthermore,

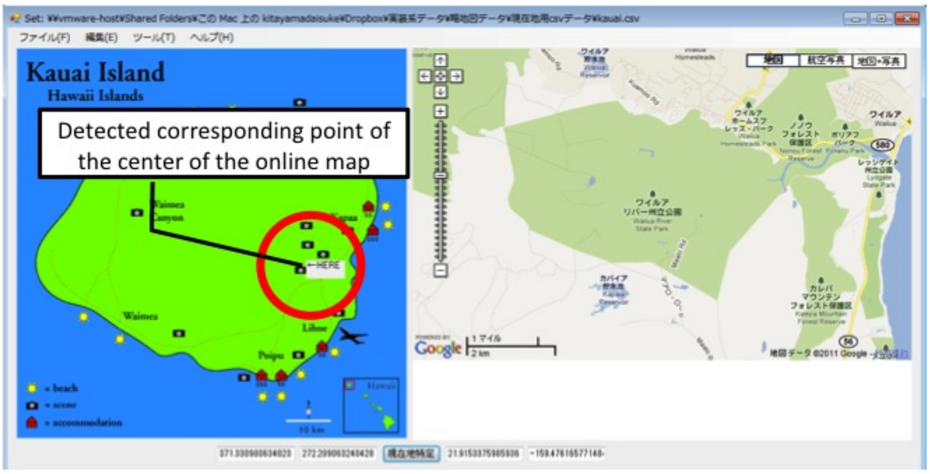

Figure 5: Screen image of prototype system.

Table 2: Experimental data and results of recognition.

No.	URL	#Described objects	#Extracted objects	Precision	Recall
1	http://www.kais.kyoto-u.ac.jp/japanese/access/accessmap.html	34	7	1.00	0.21
2	http://www.sal.tohoku.ac.jp/map.html	43	9	0.33	0.07
3	http://www.kyushu-u.ac.jp/access/index.php	49	13	0.85	0.22
4	http://www.med.tohoku.ac.jp/access/index.html	39	4	0.50	0.05
5	http://www.agr.kyushu-u.ac.jp/agr_08/access/	30	10	0.60	0.20
6	http://www.agri.tohoku.ac.jp/agri/ad2.html	27	4	0.75	0.11
7	http://www.hokudai.ac.jp/footer/ft_access.html	22	3	0.00	0.00
8	http://www.en.kyushu-u.ac.jp/jimu/access.php	17	6	0.67	0.24
9	http://www.sis.nagoya-u.ac.jp/access/index.html	29	6	0.50	0.10
10	http://www.hokudai.ac.jp/bureau/map/hakodate.html	15	1	1.00	0.07
11	http://www.hellokcb.or.jp/jpn/promoter/convention_facilities.html	7	4	1.00	0.57
12	http://www.sci.nagoya-u.ac.jp/access/access.html	25	2	0.50	0.04
13	http://kyoushujo.com/detail_t_06303.html	15	13	0.31	0.27
14	http://www.hellokcb.or.jp/jpn/access/index.html	3	2	0.50	0.33
15	http://www.toyo.ac.jp/himeji/access_j.html	17	17	0.71	0.71
16	http://www31.ocn.ne.jp/ himejikaho/gaiyou/himejiaccess.html	10	2	0.50	0.10
17	http://www.gin-basha.jp/	11	4	1.00	0.36
18	http://www.shosya-g.co.jp/map.html	11	6	0.50	0.27
19	http://www.eonet.ne.jp/ zenmaru/Tizu.htm	12	10	0.90	0.75
20	http://www.himejicastlehotel.co.jp/map2/index.html	16	2	0.00	0.00
Average				0.61	0.23

we explained how to detect where corresponding points of the real world map onto an artificial map. We showed the effectiveness of recognition of artificial maps and detection of corresponding points.

In this analysis, we developed a navigation system for use on artificial maps and an editing system for artificial maps. For the navigation system, when a user gets an artificial map from signs or leaflets, we can insert the icon "HERE" for their convenience at any time. Then, using the editing system we can also add and show user-requested objects (e.g., restaurants) on a tourist guide map that only describes sightseeing spots.

In our future work, we will enhance our method to treat not only point objects but also line objects. In addition, we will make use of the public developed applications and evaluate the effectiveness and coverage on variable artificial maps by user tests.

7. ACKNOWLEDGMENTS

This work was supported in part by a joint research project with Micware Co., Ltd.

8. REFERENCES

[1] M. Agrawala and C. Stolte. Rendering effective route maps: improving usability through generalization. In *Proceedings of the 28th annual conference on Computer graphics and interactive techniques*, volume 1, pages 241–249. ACM, 2001.

[2] M. Arikawa and Y. Kambayashi. Dynamic name placement functions for interactive map systems. *The Australian Computer Journal*, 23/4:133–147, 1991.

[3] M. Egenhofer. Spatial-Query-by-Sketch. In M. Burnett and W. Citrin, editors, *IEEE Symposium on Visual Languages (VL'96)*, pages 60–67, September 1996. Boulder, CO.

[4] M. Egenhofer. Query Processing in

Figure 6: An example of correct detection on map No. 3. The red circles on the online map and the artificial map are points that are detected correctly.

Figure 7: An example of incorrect detection on map No. 17. The bold red lines on the online map and the artificial map are the corresponding streets. The detected corresponding point is not detected correctly.

Spatial-Query-by-Sketch. *Journal of Visual Languages and Computing*, 8 (4):403–424, 1997.

[5] M. J. Egenhofer. A model for detailed binary topological relationships. *Geomatica*, 47:261–273, 1993.

[6] K. Fujii, S. Nagai, Y. Miyazaki, and K. Sugiyama. Navigation Support in a Real City Using City Metaphors. In *Digital Cities 2000*, pages 338–349, 2000.

[7] F. Grabler, M. Agrawala, R. W. Sumner, and M. Pauly. Automatic generation of tourist maps. *ACM Transactions on Graphics*, 27(3):1, Aug. 2008.

[8] H. Honda, K. Yamamori, K. Kajita, and J. Hasegawa. A System for Automated Generation of Deformed Maps. In *Proc. of IAPR Workshop on Machine Vision Applications (MVA 1998)*, pages 149–153, 1998.

[9] T. Inoue, K. Nakazawa, Y. Yamamoto, H. Shigeno, and K. Okada. Use of human geographic recognition to reduce GPS error in mobile mapmaking learning. In *Proc of. Fifth International Conference on Networking and the International Conference on Systems (ICN / ICONS / MCL 2006)*, page 222, 2006.

[10] T. Kitahashi, M. Ohya, K. Kakusho, and N. Babaguchi. Media Information Processing in Documents -Generation of Manuals of Mechanical Parts Assembling. In *4th International Conference Document Analysis and Recognition (ICDAR 1997)*, pages 792–797, 1997.

[11] M. Michelson, A. Goel, and C. Knoblock. Identifying maps on the world wide web. *Geographic Information Science*, pages 249–260, 2008.

[12] J. Schöning, A. Krüger, K. Cheverst, M. Rohs, M. Löchtefeld, and F. Taher. PhotoMap: using spontaneously taken images of public maps for pedestrian navigation tasks on mobile devices. In *Proceedings of the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services*, page 14. ACM, 2009.

[13] S. Shimada, M. Tanizaki, and K. Maruyama. Ubiquitous Spatial-Information Services Using Cell Phones. *IEEE Micro*, 22(6):25–34, 2002.

[14] K. Yamamori, H. Honda, and J. ichi Hasegawa. A method for arrangement of road network based on streetwise transformation. *Systems and Computers in Japan*, 34(3):20–32, 2003.