A Method of Analyzing Credibility based on LOD Control of Digital Maps

Daisuke Kitayama
Graduate School of Human Science and Environment
University of Hyogo
1-1-12 Shinzaike-honcho
Himeji, Japan
ne07p001@stshse.u-hyogo.ac.jp

Ryong Lee
School of Human Science and Environment
University of Hyogo
1-1-12 Shinzaike-honcho
Himeji, Japan
leeryong@shse.u-hyogo.ac.jp

Kazutoshi Sumiya
School of Human Science and Environment
University of Hyogo
1-1-12 Shinzaike-honcho
Himeji, Japan
sumiya@shse.u-hyogo.ac.jp

ABSTRACT

Digital maps are widely used and appear on all types of platforms for integrating content. Users can change display region and scale by panning, zooming in, and zooming out on a digital map. Level of detail (LOD) control for a given region at a given scale is decided by the designer of the digital map. Therefore, rules for displaying objects have limited credibility. For example, it is possible that equivalent objects do not display consistency, or nonequivalent objects do display consistency, even if users believe equivalent objects are displayed consistently. We propose a method to calculate the display validness on LOD-controlled regions and scales for increasing the credibility of digital maps. In particular, our method determines the equivalence of objects based on the display pattern at each scale and the size of the region determined to be the object's territory. In addition, we calculated the display validness using the equivalence of objects. In this paper, we describe our prototype system.

Categories and Subject Descriptors

H.5.1 [**Multimedia Information Systems**]

General Terms

Human Factors, Management

Keywords

Information Credibility, LOD control, Territory, Digital map, Spatio temporal DB

1. INTRODUCTION

Digital maps are widely used and appear on many types of platforms for integrating content, for example, Google Maps [3] and Yahoo! Maps [12]. These provide not only map content but also various services in conjunction with map content such as driving directions and photo viewers. Digital maps control the objects displayed based on the level of detail (LOD). LOD controls are subjective. Therefore, at some scale levels of a digital map, an object that should be displayed may not be displayed. On the other hand, an object that should not be displayed may be displayed. For example, Kobe is the prefectural capital of Hyogo. However, Kobe is not displayed in figure 1, even though other prefectural capitals are displayed.

We propose a method of calculating display validness in the LOD-controlled region and scale for increasing credibility of digital maps. In particular, we determine the equivalence of objects based on the display pattern for each scale and region size as an object's territory. We use digital map metadata for the display pattern at each scale and web search results for detecting the size of the region that should be considered an object's territory. In addition, we calculate the display validness using the geographical equivalence of objects.

The advantages of our proposed method are as follows

- This method can operate at a reasonable cost because it uses only digital map metadata in the displayed region and web search results.
- This method can extract equivalence relationships. The concept of "equivalent objects" can be used in object clustering for categorization of geographic information or in navigation to sightseeing spots.
- This method can analyze the credibility of digital maps. Digital maps are subjective about display control. This method can detect the validness of display condition relative to surrounding objects.

This paper is structured as follows. Section 2 explains our approach and Section 3 explains digital map metadata and how it detects equivalence with LOD control, and describes how territory is determined according to web search results. Section 4 explains the calculation of object equivalence and display validness. Section 5 discusses the prototype system, and Section 6 reviews related works.

2. OUR APPROACH

Rules for displaying objects based on LOD control differ by designers of digital maps. We think that there is not a

WICOW'09, April 20, 2009, Madrid, Spain.

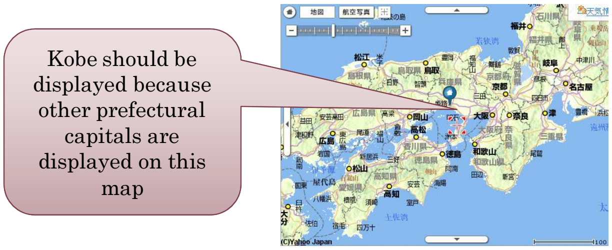

Figure 1: The credibility of digital maps

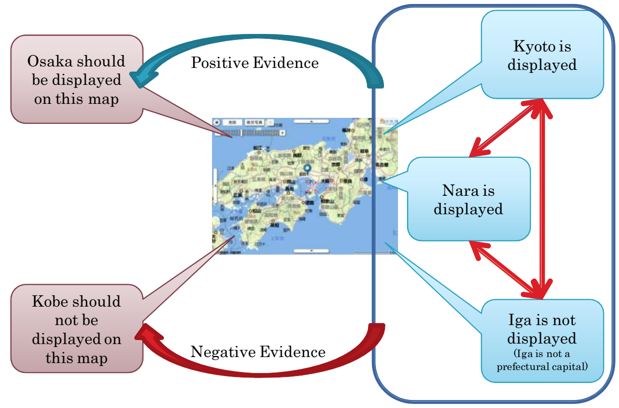

Figure 2: Concept image of analyzing credibility of digital maps

single correct answer for LOD control because LOD control is decided based on various factors. However, when rules of displaying objects change at different scales within a single map, the digital map has less credibility because users cannot trust the validness of the displayed objects. Table 1 shows display condition of Great Lakes and famous government buildings on Yahoo! Maps. Superior, Erie, Michigan, Huron, and Ontario are considered equivalent objects. However, these are not the same display pattern on the LOD control. Superior displays small scale map of 1/24,000,000. Ontario does not display halfway scale map of 1/6,000,000. White House and The Pentagon are considered equivalent objects. However, White House displays smaller scale than The Pentagon. We considered rules of LOD control are not consistency. But, equivalent objects are similar display pattern. Therefore, users need a method of analyzing the credibility of digital maps. In our proposed method, we calculate the display validness of geographic objects in a given region and at a given scale to determine the credibility of a digital map. In other words, we determine whether an object should or should not be displayed at a given scale. In particular, we determine the equivalence of objects based on the display pattern at each scale and the size of the region defined as the object's territory and we calculate display validness using the equivalence of the objects. Figure 2 is a concept image of our proposed method. Figure 3 shows the equivalence of objects based on LOD control and the object's territory.

We used the following procedure to calculate display validness.

1. We detected object equivalence based on LOD control of map scale for extracting equivalent objects. The LOD control of map scale is subjective. Therefore, equivalent objects are displayed at the same scale by the map's designers. We thought that credible map consists of consistent LOD control. In other words, equivalent objects should be display on same scales. We detect object equivalence by similarity of the display scale pattern.

2. We detected object equivalence based on map region as the territory of geographic objects for extracting equivalent objects. Geographic objects have a region of impact that is considered their "territory." Therefore, equivalent objects have similar sized territory. We thought that the territory of the target object could be determined by the co-occurrence of the target and other objects on web search results. If the target object has a large territory, the target object should co-occur with other similar objects, even if they are far from each other. We defined an object's territory as including objects that co-occur in the region on web pages. In addition, we calculated the similarity of the size of an object's territory to determine the equivalence of objects.

3. We calculated display validness using the equivalence of objects. We defined the object's equivalence as the equivalence of the LOD control and the equivalence of the territory. The display validness was calculated by object equivalences and display conditions. We calculated display validness as follows. First, we calculated object equivalences between other objects as the evidence value for the displayed target object. Each object has a positive or negative evidence value. Next, we calculated the display validness using other objects' equivalence as the evidence value. The display validness was calculated by multiplying each object's evidence value and the object equivalence by the target object and another object. When the display validness is negative, the display condition of the target object is not credible. The credibility of a digital map is estimated by a ratio of the valid display condition of each object to all objects on a region and a scale.

3. DETECTION OF OBJECT EQUIVALENCE

3.1 Object equivalence based on LOD control of scale

Our proposed method uses digital map metadata. A digital map consists of multiple sizes of scales. Each layer shows different geographical objects. For example, local authority names are shown at a small scale (e.g., scale of 1/21000), building names are shown at a large scale (e.g., scale of 1/3000). We use the geographical objects displayed at each scale as the digital map metadata. Figure 4 shows the scale structure of a digital map.

We defined metadata of digital maps by the following vector.

$$S = [s_1, s_2, s_3, ..., s_n] \quad (1)$$

$$s_i = \begin{cases} 1 \text{ (Object displayed at scale } s_i) \\ 0 \text{ (Object not displayed at scale } s_i) \end{cases} \quad (2)$$

Table 1: Example of LOD control based on scale size

	1/24,000,000	1/12,000,000	1/6,000,000	1/3,000,000	...	1/75,000	1/40,000	1/21,000	1/16,000	1/8,000	1/6,000
The Pentagon	0	0	0	0	...	0	0	0	0	1	1
White House	0	0	0	0	...	0	1	1	1	1	1
Ontario	0	1	0	1	...	1	1	1	1	1	1
Huron	0	1	1	1	...	1	1	1	1	1	1
Michigan	0	1	1	1	...	1	1	1	1	1	1
Erie	0	1	1	1	...	1	1	1	1	1	1
Superior	1	1	1	1	...	1	1	1	1	1	1

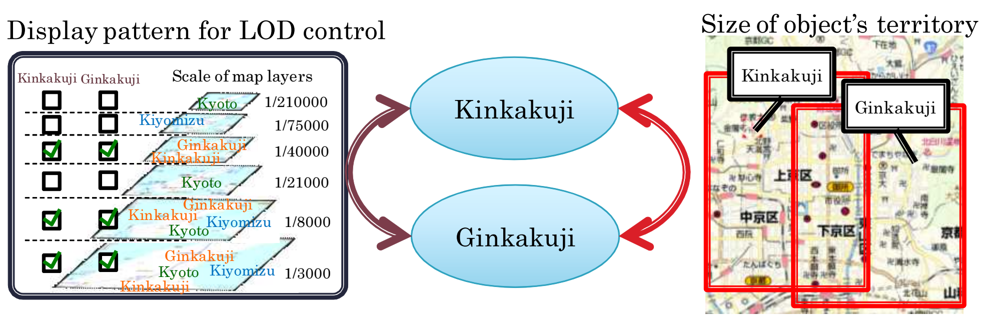

Figure 3: Equivalence of objects based on LOD control and object's territory

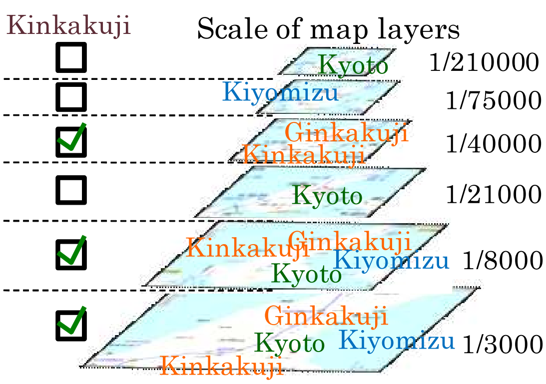

Figure 4: Scale structure of a digital map

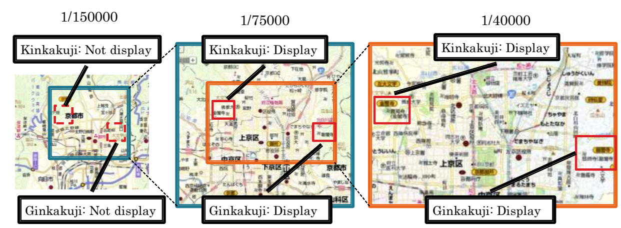

Figure 5: Object equivalence based on LOD control of scale

s_i is the displaying or non-displaying value of a geographic object at scale i of a digital map. 1 means a geographic object is displayed at a scale, 0 means the geographic object is not displayed at a scale. S is a vector that determines the display or non-display value of a geographic object at each scale.

We describe extracting equivalent geographic objects using the LOD control of scale. We define the object equivalence based on the LOD control of scale as geographic objects that are treated as the same type of object by the designer of the digital map. In other words, the object equivalence between similar types of objects has a high value. For example, because both Kinkakuji and Ginakuji temple are sightseeing spots in Kyoto, Japan, they have high object equivalence. We considered objects together displayed at many scales to have high object equivalence. In other words, objects given the same display pattern by the map's designer are considered to be the same type of object. Figure 5 shows how object equivalence is determined based on LOD control of scale.

We calculated equivalence of scale using the following formula.

$$scale\_eq(o_i, o_j) = sim(S_i, S_j) \tag{3}$$

When o_i is a target object, object o_j is a candidate to be an equivalent object. Similarity of LOD control is calculated using cosine distance by the function sim. In figure 5, object equivalence of LOD control between Kinkakuji and Ginkakuji is 1.0 because these are the same display pattern.

3.2 Object equivalence based on object's region

We detect object equivalence based on map region as the territory of geographic objects. We describe how an object's region can be used to extract objects' equivalence.

The area we consider to be the geographic "territory" of an object can be determined in part by the object's impor-

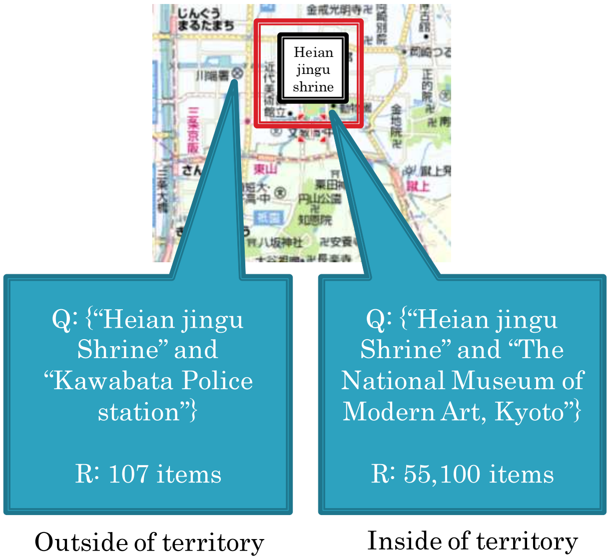

Figure 6: Object’s territory and web search results

Figure 7: Example of territories of Kinkakuji and Ninnaji

tance or impact. For example, Kinkakuji temple has a large territory because it is a famous sightseeing spot. In a web page, a famous sightseeing spot is often described as a landmark for navigating to other objects, and is often described collectively with other sightseeing spots, even those that are far away from it.

We thought that the territory of a target object could be determined by the co-occurrence of the target and other objects in web search results (See figure 6). If the target object has a large territory, the target object co-occurs with other objects even if they are far from the target object. We define “territory” as including objects that co-occur in web searches and are located in the same region as the target object. We define an object’s territory with the following formula.

$$terri(o_i) = region(C(o_i)) \tag{4}$$

$$C(o_i) = \{c_j | \frac{cooccur(o_i, c_j)}{dist(o_i, c_j)} > \alpha\} \tag{5}$$

when c_j is an object in the territory of o_i. Function *cooccur* returns the number of web search results of $\{ o_i$ and $c_j \}$. Function *dist* calculates the distance between o_i and c_j. The threshold of influence of territory is α.

Table 2 shows $cooccur(o_i, c_j)/dist(o_i, c_j)$ of Kinkakuji, Ninnaji, and around objects. Figure 7 is territories of Kinkakuji and Ninnaji when the threshold α is determined 4000. Kinkakuji’s territory shows solid line, and Ninnaji’s territory shows dashed line. In this example, Kinkakuji has larger territory than Ninnaji. Kinkakuji is famous sightseeing object therefore it is often described with far other objects as Ginkakuji, Kiyomizu Temple, and Kyoto station in web pages. On the other hands, Ninnaji is not famous object. It is often described with near other objects as Kitano Tenmangu and Kinkakuji, however less described with far other objects.

In this time, candidate objects c_j are very large amount of number. At maximum, this method checks all objects in the world. Therefore, we set two types of filter candidate

Table 2: Territory of Kinkakuji and Ninnaji

	Kinkakuji	Ninnaji
Kinkakuji	-	10,839.2
Ninnaji	10,839.2	-
Bukkyo University	11.9	1.4
Kitano Tenmangu	29,033.4	6,646.9
Kyoto Palase	12,159.9	3,316.1
Kyoto University	1,373.4	182.7
Kitayama	6,435.9	1,528.4
Kyoto Station	8,306.6	2,638.8
Kiyomizu Temple	9,988.3	3,031.5
Ginkakuji	8,635.1	1,624.3
Hozukyo	126.9	186.0
Arashiyama	7,639.4	4,489.1
Ryukoku University	1.2	0.5

objects for reducing calculation number. One filter is the object equivalence of LOD control because object equivalence is low when the object equivalence of LOD control is low enough. Object equivalence of LOD control is reasonable calculation because this calculation method use only bit pattern as display pattern. Other filter is the distance between target object and candidate object because candidate object is not selected as inner territory object when distance is very large. We set threshold of distance based on display region when the target object is center on the map. We considered that we should check all objects in a display region at minimum.

We extracted equivalent geographical objects using an object’s territory. We considered equivalent objects to have similar sized territories. On a digital map, objects are displayed to be easily viewable at different scales. Displayed objects are selected by the map’s designer. Displayed objects should have similar sized territories. If displayed objects have different sized territories, users cannot understand

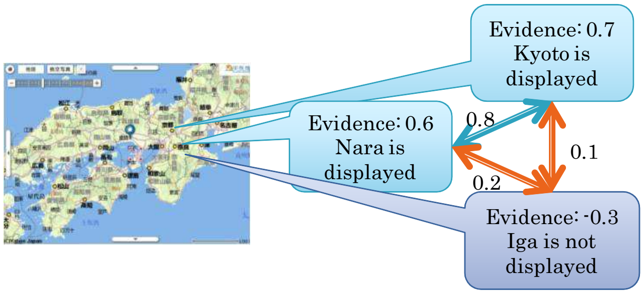

Figure 8: Calculating evidence value using object equivalence

the rules for displaying objects, and cannot understand the relationship between the displayed objects.

We calculate similarity of territory size for determining the equivalence of objects.

$$terri\_eq(o_i, o_j) = 1 - \frac{\big||terri(o_i)| - |terri(o_j)|\big|}{|terri(o_i)| + |terri(o_j)|} \quad (6)$$

In this formula, equivalence of territory is high when the difference between the size of o_i's territory and the size of o_j's territory is small.

4. CALCULATING DISPLAY VALIDNESS USING OBJECT EQUIVALENCE

We describe how to calculate display validness using object equivalence for improving the credibility of digital maps. First, we defined object equivalence as the equivalence of LOD control and the equivalence of territory. We considered object equivalence to be high when the equivalences both of LOD control and territory are high. Therefore, we defined object equivalence with the following formula.

$$equivalence(o_i, o_j) = \frac{scale\_eq(o_i, o_j) + terri\_eq(o_i, o_j)}{2} \quad (7)$$

The display validness is calculated by object equivalence and displayed condition. We calculated display validness as follows. First, we calculated object equivalence between other objects as the evidence value of the target object's display condition. We considered that displaying equivalent object is evidence that a target object should be displayed at this scale. The evidence value means a target object should be or should not be displayed. Each object has a value of object equivalence as evidence. When their display conditions are the same, the objects' values are positive. When the objects' display conditions are different, the objects' values are negative. Figure 8 shows calculation of evidence value. We calculated evidence values using following formula.

$$evidence(o_n) = \sum_{m=1}^{M} equivalence(o_n, o_m) \times condition(o_m) \quad (8)$$

when o_n and o_m are objects in the displayed region on the digital map. M is a number of objects. The function *condition* returns 1 or -1. When o_m is displayed, *condition* returns 1. On the other hand, when o_m is not displayed, *condition* returns -1.

Next, we calculated display validness using other objects' equivalence as the evidence value. The display validness was calculated by multiplying each object's evidence value and object equivalence by the target object and another object. When the display validness is positive, the display condition of the target object is credible. When the display validness is negative, the display condition of the target object is not credible. The credibility of the digital map is estimated by a ratio of the credible display conditions of each object in the region and at the same scale to all objects. Figure 9 shows the determination of display validness.

We calculated display validness using the following formula.

$$validness(o_i) = \sum_{n=1}^{N} equivalence(o_i, o_n) \times evidence(o_n) \quad (9)$$

In this formula, the display validness is considered to be high when there are many equivalent objects with positive evidence values.

5. PROTOTYPE SYSTEM

5.1 System architecture

We developed a prototype system using C# in Microsoft Visual Studio 2008 based on our proposed method. This prototype system consists of a map-viewing interface and a function that calculates display validness. For the map-viewing interface, we used Yahoo Maps API as the source for digital maps. Users can freely navigate around the maps by zooming in, zooming out, and centering. This system displays icons, which represent geographic objects and their display validness. The icons change color depending on the display validness. When the icon is red, the display validness is positive even though the object is not displayed. When the icon is blue, the display validness is negative even though the object is displayed. The geographic object database was developed from the metadata of the digital maps used.

In calculating display validness, our system calculates the display validness of geographical objects in a displayed region. It displays results consisting of objects calculated to have strong display validness and names of the top five equivalent objects. We used the Yahoo! Web Search API, SlothLib[11], for collecting current web pages.

5.2 Example of display validness

In this section, we explain example of calculating display validness. Figure 10 shows police stations as Kamigyo, Shimogamo, Kawabata, Gojyo, and Horikawa. Kamigyo, Shimogamo, and Kawabata police stations are displayed in this scale. On the other hands, Gojyo and Horikawa police stations are not displayed in this scale. We hypothesize their equivalence as showing table 3.

We calculate display validness as follows. First, we calculate evidence values according object equivalence. Next, we calculate display validness using evidence values of each object (See table 3). In this result, Gojyo and Horikawa police stations are high display validness even though not displayed in this scale. We considered that LOD control of this digital map is not consistency because some objects between display condition and display validness are different. In other words, Gojyo and Horikawa police stations are objects that should display in this scale.

Table 3: Display validness of police stations in Kyoto

		Equivalence					Evidence	Validness
		Kamigyo	Kawabata	Shimogyo	Gojyo	Horikawa		
Displayed object	Kamigyo	1	0.8	0.9	0.6	0.5	0.6	1.86
	Kawabata	0.8	1	0.8	0.5	0.7	0.4	2.02
	Shimogamo	0.9	0.8	1	0.7	0.4	0.6	1.88
Non-displayed object	Gojyo	0.6	0.5	0.7	1	0.8	1	1.62
	Horikawa	0.5	0.7	0.4	0.8	1	0.8	1.62

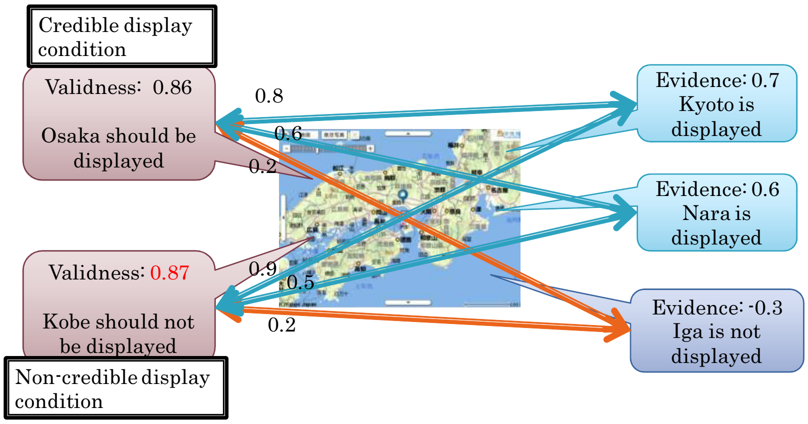

Figure 9: Determination of display validness

6. RELATED WORKS

6.1 Extraction of relationships between geographic objects

Methods for extracting relationships between multiple words have been extensively researched. Luo et al. [8] proposed a method for extracting relationships between two words using Web search results. However, we detected the relationships of geographical objects using metadata of digital maps and Web search results. Sagara et al.[10] proposed an efficient method for supporting findings and registering new shops from the web. This method can be used for detecting newly appeared objects. Newly appeared objects can be used for analyzing update validness of digital maps. We considered that update validness is basic level credibility[5]. We previously proposed[6] a digital map restructuring method based on metadata of digital maps. Our aim for this research was to judge map validity using a method different from our previous research.

6.2 Analysis of Web pages

Methods for analyzing temporal and geographical history have been extensively researched. Yamamoto et al.[13] proposed a validity calculation using web pages and temporal analysis. This method is used to judge the validity of input phrases using web search results. Our aim was to judge the validity of the display of real-world objects. Fukuhara et al. [1] proposed a system for collecting and analyzing blog articles to gain an understanding of people's concerns from collective and personal viewpoints. Their approach 1) analyzes relationships between blog articles and real temporal data, 2) extracts topics of interest, and 3) identifies trends. Glance et al. [2] proposed a system called BlogPulse, which extracts trends from collected blog articles. Using keyword occurrence rates over a given period of time, the system classifies current trends. Current analyzing methods of temporal tendency aim to detect trends. Our aim was to detect the territory of objects using web search results.

6.3 Information credibility

Methods of analyzing various types of information credibility are being researched. Lopes et al.[7] proposed a method of analyzing the credibility of Wikipedia entries using the concept of accessibility. They analyzed the influence on the credibility Wikipedia data based on accessibility as hyperlink of references. They proposed an article referencing the lifecycle model for improving the accessibility of references based on their analysis. In multimedia content such as digital maps, the accessibility of references is not relevant. Therefore, we propose determining display validness of objects using content-based analysis. Nakamoto et al.[9] proposed a method of tag-based collaborative filtering for improving the credibility of recommendations. They determined user similarity using social tagging for collaborative filtering. In the area of recommendations, user credibility is an important factor, and tag-based analysis is a reasonable method. However, detection of the display validness of objects is needed for content-based analysis of digital maps and web search results. Kawai et al,[4] proposed a method of using a sentiment map for visualizing the credibility of news sites. Their method analyzed sentiment about news articles and visualized the analyzed sentiment on a digital map. Their aim was to detect sentiment biases for determining the credibility of news sites. The digital maps were used

Figure 10: Example of display validness

only to visualize user sentiment. Our aim is to detect display validness of real-world objects using digital map metadata.

7. CONCLUDING REMARKS

We proposed a method for judging the validity of digital maps using LOD control and an object's territory. We determined the equivalence of geographic objects based on the similarity of LOD controls and the size of objects' territories. We also calculated display validness and evidence values using object equivalence. First, we extracted equivalence based on LOD controls of scale using digital map metadata. Next, we extracted equivalence based on the idea of an object's territory within a region using web search results. Finally, we calculated the object equivalence and display validness using geographic objects in a display region. With this method, users can determine an object's display validness on a digital map. Therefore, they can judge a map's credibility.

We developed a prototype system using our proposed method. In the future, we plan to evaluate a method of extracting equivalent objects, a method of calculating display validness, and a method for measuring the effectiveness of our proposed method for analyzing credibility using our prototype system.

8. ACKNOWLEDGMENTS

This work was supported in part by the National Institute of Information and Communications Technology.

9. REFERENCES

[1] T. Fukuhara, T. Murayama, and T. Nishida. Analyzing concerns of people using Weblog articles and real world temporal data. In *Proc. of WWW 2005 2nd Annual Workshop on the Weblogging Ecosystem: Aggregation, Analysis and Dynamics*, 2005.

[2] N. S. Glance, M. Hurst, and T. Tomokiyo. BlogPulse: Automated Trend Discovery for Weblogs. In *Proc. of WWW 2004 Workshop on the Weblogging Ecosystem: Aggregation, Analysis and Dynamics*, 2004.

[3] Google Maps. http://maps.google.com/.

[4] Y. Kawai, Y. Fujita, T. Kumamoto, J. Zhang, and K. Tanaka. Using a Sentiment Map for Visualizing Credibility of News Sites on the Web. In *Proc. of Second Workshop on Information Credibility on the Web (WICOW 2008)*, pages 53–58, 2008.

[5] D. Kitayama, R. Lee, and K. Sumiya. A Credibility Analyzing Method of Geographical Objects from Digital Maps. In *Proc. of 3rd International Conference on Ubiquitous Information Management and Communication (ICUIMC2009)*, 2009.

[6] D. Kitayama, T. Teratani, and K. Sumiya. Digital Map Restructuring Method based on Implicit Intentions Extracted from Users' Operation. In *Proc. of The Second International Conference on Ubiquitous Information Management and Communication (ICUIMC2008)*, pages 45–53, 2008.

[7] R. Lopes and L. Carrico. On the Credibility of Wikipedia: an Accessibility Perspective. In *Proc. of Second Workshop on Information Credibility on the Web (WICOW 2008)*, pages 27–34, 2008.

[8] G. Luo, C. Tang, and Y. li Tian. Answering Relationship Queries on the Web. In *Proc. of the 16th international conference on World Wide Web*, pages 561–570, 2007.

[9] R. Y. Nakamoto, S. Nakajima, J. Miyazaki, S. Uemura, H. Kato, and Y. Inagaki. Reasonable Tag-Based Collaborative Filtering For Social Tagging Systems. In *Proc. of Second Workshop on Information Credibility on the Web (WICOW 2008)*, pages 11–18, 2008.

[10] T. Sagara and M. Kitsuregawa. An Efficient Method to Support Finding and Registering New Shops from the Web (in Japanese). In *IPSJ Transactions on Databases*, volume 48, pages 49–57, 2007.

[11] SlothLib. http://www.dl.kuis.kyoto-u.ac.jp/SlothLibWiki/.

[12] Yahoo!Maps. http://map.yahoo.co.jp/.

[13] Y. Yamamoto, T. Tezuka, A. Jatowt, and K. Tanaka. Honto? Search: Estimating Trustworthiness of Web Information by Search Results Aggregation and Temporal Analysis. In *Proc. of a joint conference of the 9th Asia-Pacific Web Conference and the 8th International Conference on Web-Age Information Management (APWeb/WAIM 2007)*, pages 253–264, 2007.