A Framework for the Visual Representation of Spatial Information on the Web.

Chun-Wen Chen
National Yunlin University of Science and Technology

Manlai You
National Yunlin University of Science and Technology

Sang-Chia Chiou
National Yunlin University of Science and Technology

A Framework for the Visual Representation of Spatial Information on the Web.

Chun-Wen Chen

Manlai You

Sang-Chia Chiou

National Yunlin University of Science and Technology

Map is a natural way to represent spatial information. Nowadays it's also very popular to get map service on the Web. Although such maps are mainly to provide information about places for people's daily life, they may not be well designed to fulfill the functions. Most electronic maps on the Web, or so-called Web maps, follow the forms of traditional topographic maps, not like the pictorial maps in our daily life. For the limitation of screen resolution and file size on the web, it's not even feasible to transfer large high-resolution illustration-like map to the Web. We would like to propose a framework to combine the concepts of geographic information system (GIS) and schematic maps to extend the possibility of visual representation of spatial information on the Web. The information management of GIS could handle the dynamic spatial information, and representation of schematic maps could satisfy the spatial cognition ability of people. We used interactive multimedia technologies to implement the interface of the Web map system. By the application of technologies, the map part on the Web map is not only a visual representation but also an interactive interface of the system. The framework for visual representation of spatial information could be applied on the Web and on the other handheld appliance platforms of limited screen size, such as PDAs or mobile phones, for users and designers.

A framework for the visual representation of spatial information on the Web

Abstract: Map is a natural way to represent spatial information. Nowadays it's also very popular to get map service on the Web. Although such maps are mainly to provide information about places for people's daily life, they may not be well designed to fulfill the functions. We proposed a framework to combine the schematic maps and information technology to extend the possibility of visual representation of spatial information. The framework mainly deals with the wayfinding problem of tourists to tour around a neighborhood. We adopted the concept of flow maps to formulate the framework of Wayfinding Flow Map (WFM). A weighted graph was used as the map model to compute the probability to select a specific path. According the numeric data computed, we could apply various styles of visualization to represent the wayfinding information. Such styles of visualization could be evaluated by usability engineering for their effectiveness and usability.

Key words: *Map, Wayfinding, Interface design, Information Graphics*

Introduction

Map is a natural way to represent spatial information. Nowadays it's also very popular to get map service on the Web. Although such maps are mainly to provide information about places for people's daily life, they may not be well designed to fulfill the functions. Most electronic maps on the Web, or so-called Web maps, follow the forms of traditional topographic maps, not like the pictorial maps in our daily life.

The ergonomics has been more and more important to the "cartographic design" -- design of maps -- for its help to make maps easier to use. Traditionally, cartographers were not so concerned with why symbols worked, but rather with determining which worked best. This was known as a behaviorist view, in which the human mind was treated like a black box. The trend today is toward a cognitive view, in which cartographers hope to find why symbols work effectively.

Wayfinding is a daily activity of solving spatial problems. Spatial information is necessary to solve such problems. Maps are used as an effective means to store and communicate spatial information. The artifact – maps are so often related to the human behavior – wayfinding.

Although technology of maps advanced rapidly in recent years, we still rely on our own basic spatial ability to find our way, even with maps. Some wayfinding maps help users not much. Mostly they just provide basic information, however wayfinding-related or not, and the main wayfinding tasks are left to users. The individual difference in spatial ability greatly affects the performance of map use. A lot of people feel frustrated while using maps to find their way. Many map designs take little consideration for wayfinding, although with their main purpose for wayfinding. Many map designs follow traditional styles and technological aspects without evidence from behavior and cognitive science.

The aim of this research is to design better maps for wayfinding, especially by the support of digital media. The dynamic and interactive characteristics of information technology could be utilized in the new interface of spatial information system. We would like to develop a map model for wayfinding maps. The visual representation of the map model could be utilized on different media to assist wayfinding behavior in the real world.

Wayfinding maps

We would like to focus on the range of geographic scale for people to tour around neighborhood. The maps we developed were operated on computer screens or handheld display. Our contribution emphasized on the innovative method of visual representation, but not on technological development.

Many kinds of maps can be used as wayfinding maps. General road maps may be the most common maps that we know and use for ordinary traffic and wayfinding. Most of them are common for their true-to-scale and north-up plan.

Let’s focus on the scale of local region people can travel around by walking. A site map can show the spatial structure in one site with simplified representations of roads and landmarks. Usually designers create it with more creativity. It could be represented in perspective view in many cases for tourism. For example, as shown in Figure 1, Milan’s landmarks are drawn as simplified blocks and commercial places as numbered labels. It’s easy to recognize the spatial relationship between landmarks and roads in the clear map.

Figure 1 A site map: a city map for Milan. [source: Holmes, 1991]

Route maps are also a kind of wayfinding maps with clearer form and function for their goals than general reference maps. They describe the path from one location to another. They are useful tools for visualizing and communicating wayfinding information. We can see them in car navigation systems, site location maps, and mostly seen, hand-drawn route maps by friends or ourselves to guide the way to some places.

Agrawala [2001] analyzed five common types of route maps, two of which are representative:

1) *Route highlight maps*: general maps with the route highlighted (Figure 2). Them offer fixed scale and unnecessary information for the route. They also hide some important information for wayfinding because of their scale.

Figure 2 A route highlight map: a route in San Francisco. [source: Agrawala, 2001]

2) *Hand-drawn route maps*: maps created by hand from the wayfinding information in memory (Figure 3). They may be the most convenient way we tell friends where our homes are. They are simple and clear by keeping only the order of paths and turning points without background reference map. Angles and shapes are generalized in simpler manner from our spatial cognition. Hand-drawn route maps can provide sufficient wayfinding information as well as good understanding.

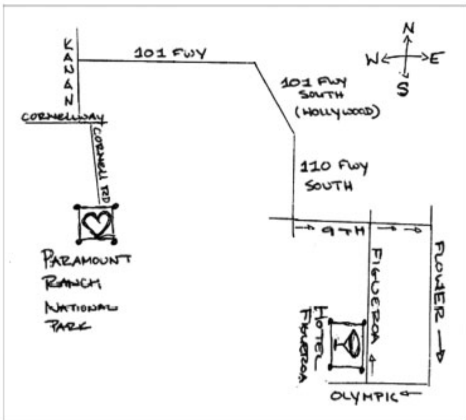

Figure 3 A hand-drawn route map. [source: Agrawala, 2001]

In most site maps, clear graphics are used to show the spatial structure of sites. They can help spatial orientation and construct cognitive maps well. But some wayfinding tasks are left to the users. If users' spatial ability is not good enough, tasks such as path selection and mental spatial transformation will be difficult and the experience of map use could be just frustrated.

By the help of a route map, users get enough wayfinding information about a specified route. It's not necessary to worry about the decision-making on path selection. Route maps are very goal-oriented and efficient. But they also limit the overall spatial understanding in a region and reduce the possibility to explore the neighborhood.

In the condition of traveling in neighborhoods, users need help to deal with the wayfinding information. With general reference maps or even clear tourism maps, they may get some information from them, but don't know what they mean and how to make decisions. Great spatial ability is necessary for fluent map use.

A route map is good solution for single route. Information technology may provide possibility for dynamic routes. In the previous study [Chen, You, & Chiou, 2003], we found people like the pleasure to explore unknown but safe world. It means we need a map that can provide possible routes to explore, even for the same destination. Such possible routes may have different importance and cost for users to choose.

Map model

Therefore we established a framework for wayfinding maps to visualize wayfinding information. The aim is to get a general method of visual representation for wayfinding. We introduced a strategy to use flow map as multiple route map. Flow maps present directions and paths of quantity [Slocum, 1999]. The trend in a flow map is represented highly visually. A flow map as a multiple route map could show the possible paths and the probability to select specific paths. The explanatory meaning of flow map now is transformed to directional use.

In the framework of Wayfinding Flow Map (WFM), a weighted graph was used as conceptual structure. The graph *G* consists of a set of nodes (*V)* and a set of directed edges (*E*). Nodes are denoted by $v_1, v_2 \ldots v_i, v_j \ldots v_n$, to represent location of features, and edges are denoted by e_{12}, e_{ij} , e_{in}, etc. to represent paths between features. Node v_1 is the starting point and node v_n is the destination. In the tour, important scenic features attract users much, and the resistance along the path such as distance and road condition prevents users to select the path. So weights are set for node v_i as *importance* p_i and for edges e_{ij} as *cost* c_{ij}. An example of graph is shown in Figure 4. The values of importance and costs can be set by users or experts of tourism, or can be gathered from users' real use records by a form of database.

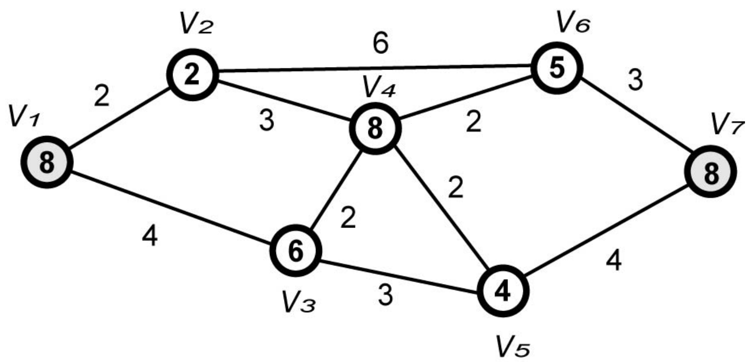

Figure 4 An example of graph as structure of a flow wayfinding map.

According that important spots attract users much and the resistance along the path prevents users to select the path, a simple rule, which is similar to that in electric circuits, is formed to compute the total effect on the trend to select the path. Another basic rule is, according the concept of flow branching and merging in flow map, that distribution of wayfinding probability should be equal to the ratio of wayfinding factors. We can set:

1) *Wayfinding factor* w_{ij} along the edge e_{ij} from node v_i to v_j,

$$w_{ij} = p_j / c_{ij},$$

where p_j is the importance of the node v_i and c_{ij} is the cost along the edge e_{ij}.

2) *Wayfinding probability* b_{ij} along the edge e_{ij} from node v_i to v_j,

$$b_{ij} = \Sigma\, b_{xi} * w_{ij} / \Sigma\, w_{ix},$$

where Σb_{xi} is the sum of edge width into node v_i and Σw_{ix} is the sum of wayfinding factor along edges from node v_i.

Sum of wayfinding probability by weight of edges connected from the starting node v_1, $\Sigma\ b_{1X}$ is set to 1 unit, i.e. 100%, where v_X is any node with connection to the node v_1. According the graph in Figure 4, an example of flow map is drawn as Figure 5, where size (width) is used to represent the wayfinding probability.

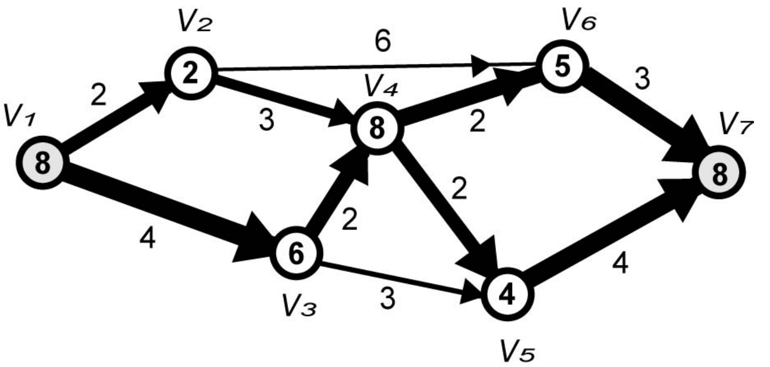

Figure 5 An example of wayfinding flow map without background map.

The criterion of the best path selecting is to find the route with min. of $\Sigma\ (1/b)$. In the field of artificial intelligent, A* algorithm for pathfinding can help to find the optimal route with the lowest cost [Nilsson, 1998]. In our case, a modified algorithm could be useful to fit our requirement.

In the original concept, the best route is not so necessary for visitors to explore the area. The visual trend it brings can provide sufficient guide for good enough routes.

Visualization

Map designers are used to taking width, a primary visual variable – size – of lines, as representation of quantity. For example, in Minard's flow map (Figure 6) [Tufte, 1993], the proportional variation of width between branches is a very important feature. It could show the relationship between each branch of flow. In Bertin's [1981] theory, size is the only visual variable can represent both the ordered and ratio relation well. That's why we can grasp the trend in flow maps easily.

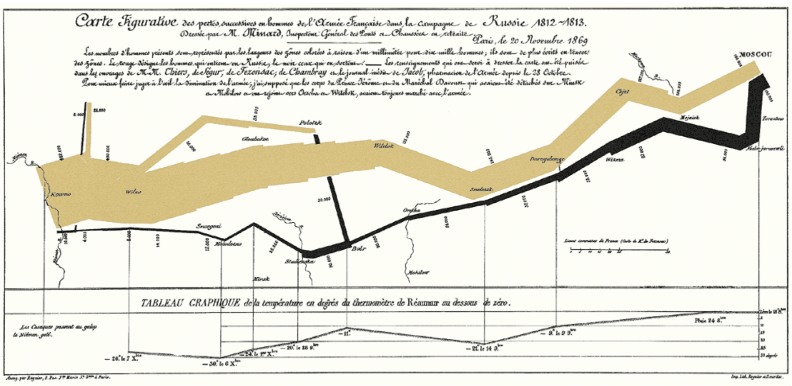

Figure 6 Napoleon's Russian campaign of 1812. [source: Tufte, 1993]

The wayfinding probability that its paths carry can be represented by width. A wayfinding flow map is visualized from 1) input: the original site map, to 2) graph structure of the site, to 3) weighted graph on nodes and edges, to 4) weighted flow added, and to 5) output: a wayfinding flow map. An example of processing is shown as Figure 7.

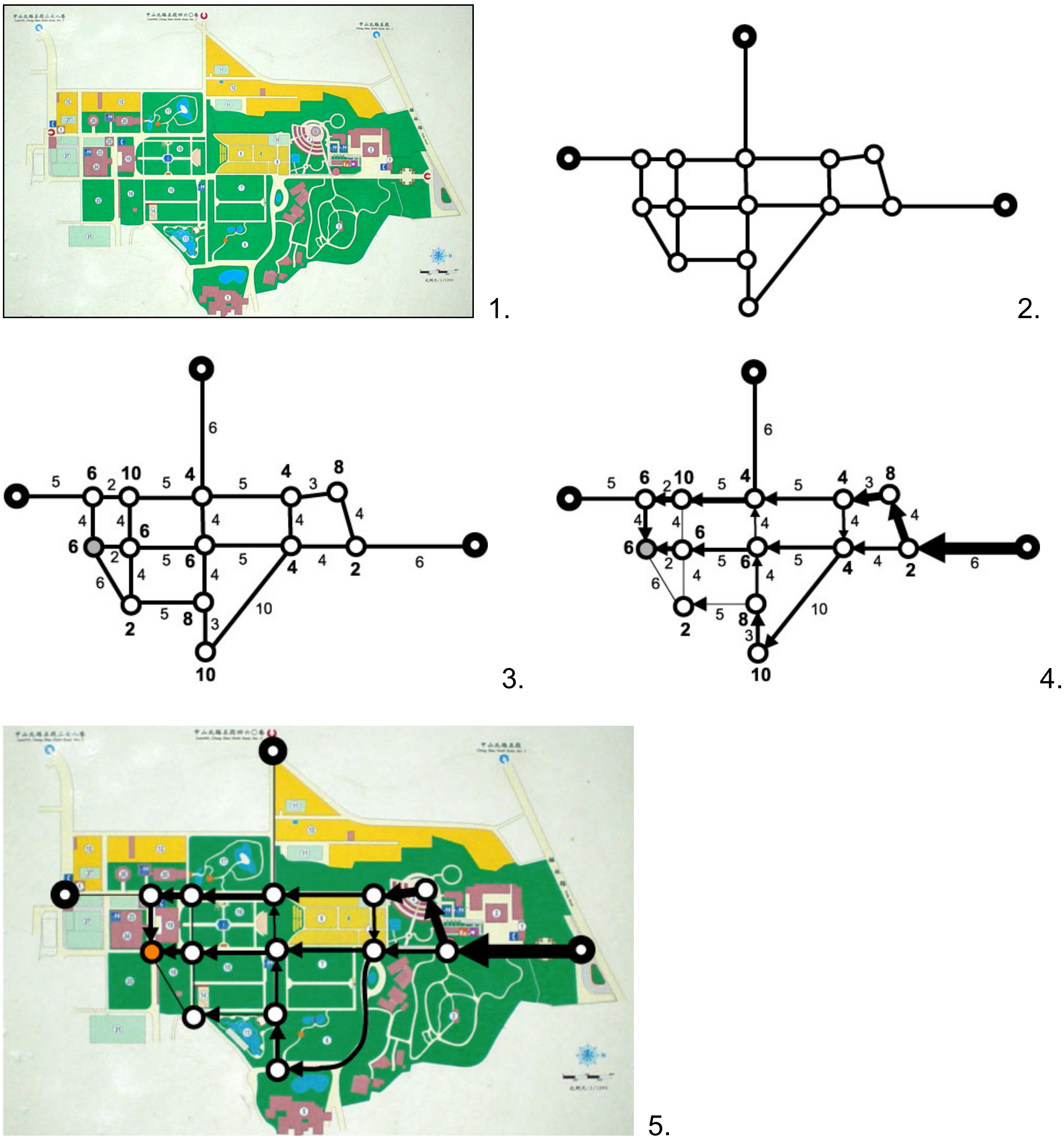

Figure 7 The processing of a wayfinding flow map: from 1) input: the original site map, 2) graph structure of the site, 3) weighted graph on nodes and edges, 4) weighted flow added, to 5) output: a wayfinding flow map with a background map.

The proposed wayfinding map would be evaluated by methods of usability engineering to test efficiency, learning, memory, error rate, and subjective satisfaction. A virtual environment would be built as the test site for such evaluation. Wayfinding tasks are given in the virtual environment. Statistic methods, mainly variance analysis, are used to compare the usability.

First, effectiveness of maps with or without directional representation of wayfinding flow map is evaluated. Then the usability of different quantization, such as size (width), color, and level (brightness), is compared. Examples are shown as Figure 8.

Finally the different visual representations are compared in compatibility with the wayfinding map. That is a 2x2 design to ask which representation is most compatible with the wayfinding flow map: 1) plan view or perspective view; 2) with background map or not.

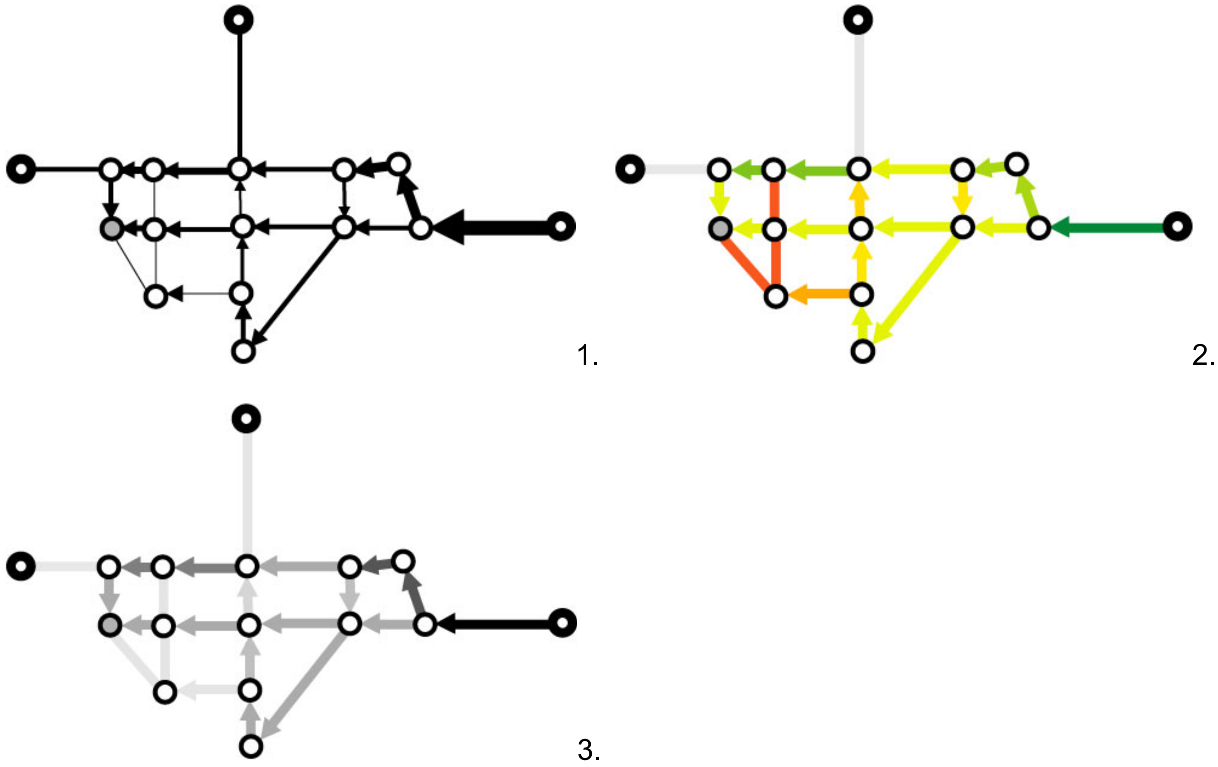

Figure 8 Examples of different quantization: 1) size (width), 2) color, and 3) level (brightness).

Discussion

The characteristics of the wayfinding map we proposed are:

1) *Independent of visual representation of background maps*: the wayfinding map can be a layer on an existing map. No matter how the background map changes its style, the wayfinding map can follow it.

2) *Free but reliable path selection*: the wayfinding map can provide guide like route maps and freedom like general maps to select path and to explore with suitable and sufficient information.

3) *Fitness for small display*: the simple representation of the wayfinding map could be easily displayed on the small screens in handheld devices or on the area of limited pixels in web pages.

The background map would provide the basic functions of map. The map model emphasize on the directional function for touring around.

Conclusion

Users hope the maps are the good mapping of the real world. That is, they can easily match the features between the maps and the real world. With good spatial ability, we can transform maps mentally to a comfortable way for human cognition -- a way of natural mapping. But a lot of people have difficulties in spatial transformation and map reading.

In the previous study on wayfinding behaviors of map users [Chen, You, & Chiou, 2003], we found users had some experience about the maps beyond usability dimension. The design of maps may influence the experience of users in spatial organization, maybe in the form of cognitive map. In this research, we try to provide wayfinding experience via a model of wayfinding map. The wayfinding maps may reduce the difficulties and frustrations of map reading in the limited area of web pages. They should fulfill the needs of users of different spatial ability by improved functions, usability, and pleasurability.

Acknowledgement

This study was partly sponsored with a grant, NSC92-2213-E-224-021 from the National Science Council in Taiwan.

Reference

[1] Agrawala, M., 2001, *Visualizing route maps*, PhD dissertation, Department of Computer Science, Stanford University.

[2] Bertin, J., 1981, Graphics and Graphic Information Processing, Walter de Gruyter, Berlin.

[3] Chen, Chun-wen; You, Manlai; and Chiou, Shang-chia, 2003, Psycho-pleasurability of maps for wayfinding, *Proceedings of the 6th Asian Design Conference: Integration of Knowledge, Kansei, and Industrial Power* (CD ROM), Oct. 14-17, Tsukuba, Japan, K-4, 8pp.

[4] Holmes, N., 1991, *Pictorial maps*, Watson-Guptill, New York.

[5] Nilsson, N. J., 1998, *Artificial intelligence: A new synthesis*, Morgan Kaufmann, San Francisco, CA.

[6] Slocum, T. A., 1999, *Thematic cartography and visualization*, Prentic-Hall, Upper Saddle River, NJ.