DESIGN PATTERNS OF WEB MAPS

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Abstract

Web maps have reached the level of depth and breadth that some academic generalization becomes practical. This paper outlines four design patterns of Web maps. These patterns are based on a task oriented grouping of Web maps and a design pattern framework developed in distributed processing. Web maps are grouped into *index*, *guide*, *narrative*, and *answer*, with four corresponding design patterns: *2D indexing*, *Dynamic spanning tree & visual association*, *thematic mapper*, and *single page query builder*. Each pattern is described following a template that includes the following elements: name, intent, primal forces, applicability, solution, benefits, and example.

Key words: Web maps, Internet, Design Patterns

Introduction

The World Wide Web has become an ideal media for maps. In less than a decade, Web maps have evolved from static raster images to dynamic, interactive, and multimedia representations of geography. Through the Web, maps are not only fulfilling their traditional roles as pictorial abstractions but also becoming a window to the wealth of information around the world. Maps find many innovative uses that were not possible before the widespread of the Web. The great number of Web maps and the rich variety of them warrant some academic generalization, which may help the further development and application of this technology.

This paper attempts to look at the design patterns of Web maps. A design pattern is a concise description of a common sense approach to a design problem (Mowbray and Malveau, 1997). The idea of design pattern was originated from Alexander, an architect and planner who wanted to summarize the common solutions in building architectural design (1977). Recently computer scientists have adapted design patterns as an approach to improving efficiencies in software design (Gamma, et al., 1995). Similar to architecture and software design, Web map development is clearly a design problem. There are choices to be made at different levels of a complex system of Web map making. Generalizing the common problems and the corresponding solutions in making Web maps seem to be a useful exercise.

In the following sections, we will describe the approach to identifying design patterns of Web maps. The methodological issue involves the categorization of Web maps, the structural levels at which we develop the design patterns, and the template we use to provide a relatively concise description of the patterns. We will then present the major patterns of Web maps.

Development of Design Patterns

The essence of a design pattern is a well-defined problem and a concrete solution. Consequently, the main tasks are identifying the problems, gathering the common solutions, and describing the solutions. Problems occur at different levels. In software development, there are problems at the object level, where the concerns are the definition and management of object classes. There are also problems at the microarchitectural level, where objects are combined. There are still problems at the framework level, where components are formed. Higher up, there are problems at the application level, where components are organized to provide application functions for the end user. For large applications, several application programs may be needed, resulting in problems at the level of system integration. Finally, when the problem is so large that it requires interoperations of individual systems, we have problems at the global level (Mowbray and Malveau, 1997). In this paper, we will focus on problems at the application, system, and global levels where the perspectives of application developers and project managers are dominant.

We begin the problem identification process with categorization of Web maps. Like any other problems of classification, there are many ways to group things. For example, Peterson put Web maps into three types, i.e., static maps, interactive maps, and animated maps (Peterson, 1997), reflecting a perspective of dynamic cartography. In this paper, we suggest a categorization that is task-based, i.e., the intended use of the Web maps. Finding out what Web maps are used for, in a scientific way, is not a trivial task. The Alexandria Digital Library Project conducted some studies on the subject with intriguing methods but the findings were limited to the uses of existing maps in the digital library, mostly *static* maps. While a systematic study on Web map use is clearly warranted, at this point, we consider an empirical categorization adequate for promoting a discussion on design patterns.

We propose the following four categories of Web maps, based on the intended uses.

Index
These are maps used as indices for spatial data libraries. Maps provide two to three-dimensional index to spatial or non-spatial data that the user can browse and download. The USGS US-GEO Data site[i] and the MIT Digital Orthophoto Browser[ii] (Ferreira, et al.) are two excellent examples.

Guide
These are maps that direct users to the points of interest in a region or locale. Campus maps, city maps, and park maps belong to this category.

Narrative
These are maps that tell stories about geographic events and processes. News maps and weather maps are narratives. Thematic atlases such as population atlas and economic atlas are mainly used for presenting thematic data.

Answer
These are maps that display results of spatial queries. Currently, typical queries are routing (how to get from A to B?), proximity (how far is my house from the contamination sites?), and locator (where is 1000 Mission St., Mount Pleasant, MI 48858?). Technically, there can be far more complicated spatial queries.

Another important aspect in developing design patterns is specifying the template to ensure a consistent format for pattern description. Mowbray and Malveau suggested some thirteen elements in their template for CORBA design patterns. With a much narrower scope, our description will focus on the following items:

Solution name: name of the pattern
Intent: Objectives.
Primal forces: The main issues to resolve.
Applicability: When the pattern should be used.
Solution: Concise description of the methods to resolve the primal forces.
Benefits: Highlights of advantage of the solution.
Example: How it is or can be applied to a particular problem.

In the following section, we will describe four design patterns for Web maps, with each corresponding to the types of map use on the Internet.

Design Patterns of Web Maps

2D Indexing

Intent: Provide a two-dimensional graphic index to digital data organized in specific geographic partitions.

Primal forces: Minimization of navigating steps and distractions.

Applicability

Using maps as indices to data is a common practice, which is naturally adapted to facilitating dissemination of data on the Web. Compared with text list and forms, index maps have the advantage of graphic display and direct manipulation (point and click). However, when the geographic extent is large and the partition unit for the data is small, e.g., the USGS 7.5 minute maps series, reference maps with different levels of details are needed. Navigating through the hierarchy of maps can be time consuming and distracting.

Solution

1. Provide optional input of geographic reference information at or near the location of interest. Such information should be very simple and require little time to enter. Zip code and well-defined place name are good examples. This optional input should be present throughout the navigational process.

2. At all levels of the map hierarchy, maintain the presence of the top-level index map in reduced size, with a graphic symbol indicating the current location. The reduced top-level index map should have the same interactivity as the one with original size.

3. Provide freehand panning or fixed-direction panning so that minor adjustment can be made and subsequent search may be improved if the location is nearby.

Benefits

Knowing the proximate location of interest makes it possible to skip several navigational steps. It may not save a lot of time because entering the information may take more time than clicking through the maps. However, reducing the steps (particularly repeated actions) has positive psychological effects. The presence of the reduced top-index map and the optional geo-reference input make it possible to begin another search with one step instead of a repeated "back page" operation.

The Map Finder[iii] maintained by the United States Geological Service facilitates proximate georeference information to locate its 7.5 minute maps. The user can enter either the Populated Place Name or the ZIP code as the search parameter. The result is the index map of the region center upon the ZIP code zone or the Populated Place. The index map has eight fixed direction panning buttons that lead to the neighboring regions. This design is more effective than the other map data server at the USGS that uses graduated zoom to reach the target. The Map Finder can be improved by adding a reduced index map showing the location of the current view.

Dynamic Spanning Tree, Mouse-over, and Visual Association

Intent: Achieve effective design for Web maps with horizontal and vertical partitions.

Primal forces: Expose the internal logics among the maps and supplemental contents.

Applicability

1. Place guides such as campus maps and city maps show relative locations and attribute information about selected geographic features. Typically, the coverage area must be partitioned into smaller pieces to fit the computer display as well as organized into map layers of different spatial resolutions. Maps resulted from such horizontal and vertical partitions, along with supplemental multimedia contents, need to be organized with an efficient hypermedia structure so that users can use the guide with minimum redundancy and navigational steps.

2. Instant feedback improves the effectiveness of the guide. The users often want to know where they are, what they are looking at (guided by the pointer), and how different contents on the screen are related.

Solution

The two key design considerations for interactive place guides are link-node structure and mechanisms for instant feedbacks. The nodes are individual guide pages that include maps and corresponding contents. Links are pointers that connect the nodes.

1. Use a dynamic spanning tree structure to expose guide pages at different levels of the hierarchy. The design is similar to the Windows Start menu except that individual items at each level (L1, …Ln) can be activated as a guide by themselves. For example, a tourist guide to China may have the provincial index map at L1, the city index map at L2, and the tourist site index map at L3. A user can choose to open a provincial guide, which have links to all the tourist cities; or, he/she can directly shift to the guide for a specific site. The dynamic spanning tree should be present at all the nodes so that the user can navigate to nodes at the upper levels.

Root   L1   L2   L3
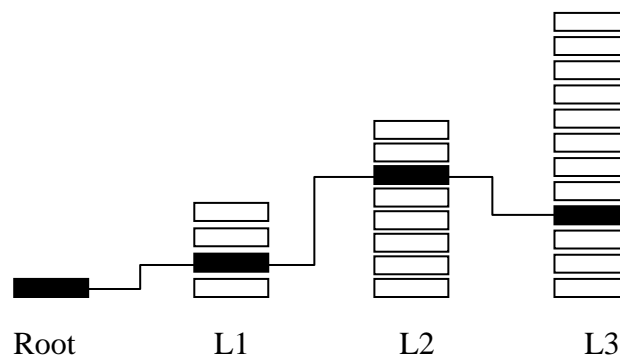
2. Use the mouse-over effect to give instant feedback. When the mouse cursor is over a "hot spot", the object changes its display state (different fill, size, for example), accompanied by a callout box nearby containing additional descriptive information.

3. Implement links among related objects on the same page so that when an object is activated by the mouse-over effect, all connected objects will be highlighted, creating a visual association.

Benefits

The dynamic spanning tree maximizes the linkages from one node to another. It eliminates the disruptions caused by the constant page changes during the navigating process. The mouse-over effect and visual association make multiple representations more effective.

Example

The figure below depicts how a dynamic spanning tree can be implemented for a country level guide to tourist sites.
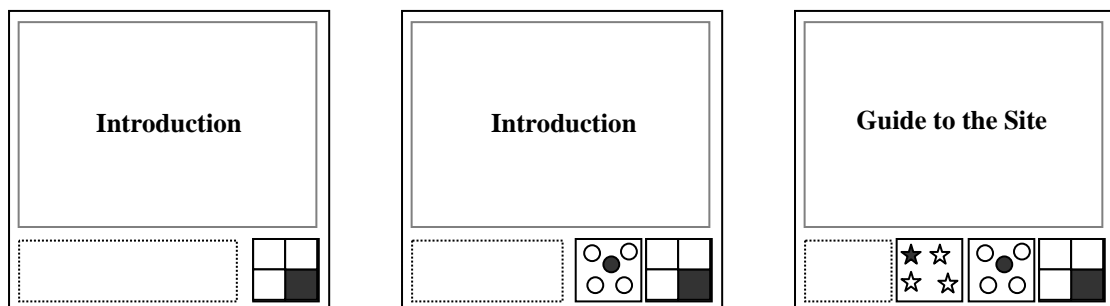
We assume the guide has three levels: provinces, cities, and tourist sites. On the first page, the user moves the cursor to the province of interest. The city index map appears on the left. The user points the cursor to the specific city, which brings up the tourist site index map. The user then clicks on the site of interest. The site page appears. The area outlined with dotted lines automatically adjusted and could be filled with complementary information. Note that at the provincial level, the user can click, instead of simply positioning the cursor over the province, a provincial guide would appear. This is the same with the city level.

To navigate to the other sites in the same city, the user simply clicks on another point in the site index map. To navigate to another city, the user places the cursor on the city index map. The site index map would be simultaneously updated. Similarly, the user can jump to another province. The city index map changes accordingly and the site index map disappears.

For an example of mouse over effect and visual association, please visit the campus map of Central Michigan University.[iv]

Thematic Mapper

Intent: Provide a coherent design for thematic map collections.

Primal forces: Accommodation of tools for data exploration with minimum navigational steps.

Applicability

Many Web-based thematic maps require stepping through several selections on different pages. When the map finally appears, the user has little control over what to see and how to show the data.

To realize the benefit of digital cartography, thematic maps on the Web should provide the user with the capability of selection by theme and/or attributes, symbolization, and classification. The user should be able to compose the map on the same page.

Solution

Provide the following interface elements next to the map area: theme selector, legend dialog, and query dialog. The theme selector can be implemented as slide menu (for main themes) and drop down menu (sub-themes). The query dialog box should include the attribute column, relational and logical operators, value frame, and the query statement frame (same as the ArcView query builder). The legend dialog box should include symbol type (graduated circle, fill, etc.), attribute item to map, classification method, and color schemes (similar to the ArcView legend editor).
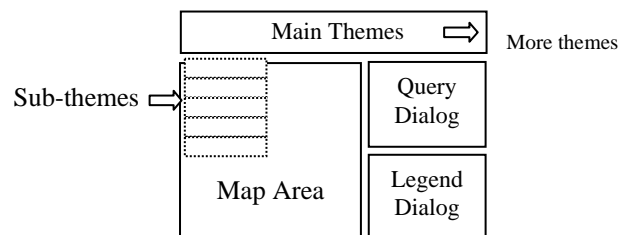
Benefits

The user has full control over what to see (theme and attribute) and how to show the data (subset and classification). The map and the control areas are on the same page, resulting in minimum distraction.

Examples

There are many good existing thematic maps on the Web can benefit from this design. A notable one is the Demographic Data Viewer[v] at CIESIN (Center for International Earth Science Information Network). The DD Viewer has a set of excellent mapping functionality so that the user can browse and customize the county level demographic data in the US. In order to make the map, however, the user must go through the following pages: select states, select geographic area (county), and map composition parameters (on one page, including: geography summary level, classification method, variable, mapping patterns, output formats, etc.). The submit button sends all the mapping parameters to the server which returns a page with links to the map image and descriptive information about the map. The DDViewer has many of the components this design pattern requires. Rearranging them would improve the service to a great extent.

Single Page Query Builder

Intent: Provide a concise and friendly interface for collecting user inputs.

Primal forces: Minimization of navigational complexity.

Applicability

Web mapping services often use excessive number of pages to obtain input parameters from the user. Moving from one input page to another requires additional communication between the browser and the server. Reviewing inputs from previous pages are often necessary for coordinating input parameters but will add time, cause distraction, and sometimes result in data lost.

Solution

Design a single page query builder to obtain input parameters. A variety of menus, buttons, and forms can be used. The resulting input page should be stored in temporary memory so that the user can revise the parameters after previewing the resulting map.

Benefits

This design eliminate the following operations in a typical mapping service: loading individual query pages, initiating (press the submit button) the next page, going back to a particular page to make revisions, generating the input summary page. One apparent trade-off of the single page query builder is the need to scroll up and down the side bar. Scrolling along the same page, however, is far less distractive than changing pages and does not cause additional communication between the server and client. For commercial sites that want to generate as many clicks as possible, this design would require different ways to put ads on the pages.

Example

While many non-geographic services, notably on-line customization of PC orders, use single page input, most of the current mapping services typically require one or two input parameters. Routing service, for example, requires only the starting and ending addresses. Contamination site search needs the location reference (address or zip code) and the radius. The trip planner from MapQuest.com[vi] is one that has slightly more complex input. The planner calculates the route based on the address of the stops the user specifies. The designer of the page decided to break down the input into four pages:

> Start
      Page 1, input: name of trip, round trip or one-way.
> Create route
      Page 2, input: address of start location.
      Page 3, input: address of destination (multiple destinations allowed; page refreshes after every new address).
> Route summary
      Page 4, summary of route and map.
> Associated search (hotel, destination guides)

One may find it reasonable to put minimum input request on the first page because the user may not want to continue with the query. Why, however, are the inputs for start location and destinations separated on two pages? The figure below shows a single page design can achieve noticeable improvement.

This design uses an identical box for creating the routes, as there is no inherent difference between the starting location and any other destinations except for the traveling orders. We added the column "order" to specify the sequence of the trip. We also added the "erase" column so that the user can delete a stop. The user can stay on this page and add as many stops as he wants without the distraction from page loading.

Summary

We have outlined four design patterns for Web maps. These patterns are based on a task-oriented grouping of Web maps and the pattern description framework developed in computer software design. Though not a thorough abstraction of current Web map designs, the patterns described in this paper should serve as useful references for Web map designers. Developers of Internet mapping software should also find ways to improve their products, as some of the design described here are fairly difficult to implement with existing commercial software packages. As we can see, it would be another useful exercise to generate design patterns at the lower scales.

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[ii] http://ortho.mit.edu/
[iii] http://mapping.usgs.gov/nsdi/
[iv] http://map.cmich.edu
[v] http://plue.sedac.ciesin.org/plue/ddviewer/
[vi] http://www.mapquest.com