The Geographer's Desktop: A Direct-Manipulation User Interface for Map Overlay*

(Extended Abstract)

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Abstract

Many spatially aware professionals use the manual process of map overlay to perform tasks that could be done with a GIS. For instance, they could be using GIS technology for work in environmental sciences and design fields, however, they are often not doing so because they lack the computer expertise necessary to run a GIS. The user interface of current GISs has been frequently cited as a major impediment for a broader use of GISs. Popularity and success of metaphor in other areas of human-computer interaction suggests that visual, direct manipulation user interfaces are especially attractive and easy-to-learn for non-computer experts. Many GISs use map overlay as a command-line based interaction paradigm. An interface to GIS that is a visualization of the map-overlay metaphor would enable experts in the spatially aware environmental sciences to more easily use GIS as a regular tool. To overcome this shortcoming, a new direct manipulation user interface based on the map-overlay metaphor has been designed and prototyped. It is well embedded within the successful Macintosh desktop and employs the particular characteristics of metaphor, direct manipulation, and iconic visualization. We create a *geographer's desktop* by replacing the familiar notions of files and folders with the concepts of *map layers* and a *viewing platform* on which layers can be stacked. A visualization of this user interface is presented. Particular attention is given to the way users can change the symbology of layers placed on the viewing platform.

Introduction

Many geographic information systems (GISs) attempt to imitate the manual process of laying transparent map layers over one another on a light table and analyzing the resulting configurations. While this concept of *map overlay*, familiar to many geo-scientists, has been used as a design principle for the underlying architecture of GISs, it has not yet been visually manifested at the user interface. To overcome this shortcoming, a new direct manipulation user interface for overlay-based GISs based on the map-overlay metaphor has been designed and prototyped. It is embedded within the successful Macintosh desktop metaphor and employs the particular characteristics of metaphor, direct manipulation, and iconic visualization. We create a geographer's desktop by replacing the familiar notions of files and folders with the concepts of *map layers* and a *viewing platform* onto which layers can be stacked. This goes beyond the concepts present in the user interfaces of popular

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GISs such as ARC/INFO and MAP II, as we build the user interface on a coherent metaphor *and* employ direct-manipulation techniques to perform actions, rather than circumscribing the actions by constructing sentences.

This paper presents the concepts and a visualization of this user interface in which each layer is represented by a single icon and the operations of modifying their content and graphical representation are achieved by double clicking on different parts of the icon. This differs from a previously discussed visualization (Egenhofer and Richards 1993), in which the information of a layer was split into two separate icons for its content and its graphical presentation to address individually what to retrieve from a geographic database and how to display the information (Frank 1992).

The remainder of this paper is structured as follows: The next section briefly reviews prior efforts in designing user interfaces for map-overlay based GISs and introduces as an alternative the concepts of the Geographer's Desktop. Subsequently, a particular visualization of the Geographer's Desktop is discussed, for which a sequence of interface snapshots are given. The conclusions point towards future research.

The Geographer's Desktop

The theoretical background of this user-interface design is based on a number of previous investigations. First, there is Tomlin's MAP algebra (Tomlin 1990), an informal collection of operations to be performed on layers of maps. A number of formalizations of the map-overlay concept have been given, e.g., as C++ code (Chan and White 1987) or as algebraic specifications (Dorenbeck and Egenhofer 1991). The idea of map overlay is complemented by investigations into GIS query languages and the recognition that there are two distinct issues to be addressed by a spatial query language (Egenhofer 1991): (1) the specification of what to retrieve (the *database retrieval*) and (2) the specification of how to present the query result (the *display specification*).

The second area influencing this work comprises several innovative studies of how to present map overlay at the user interface, that go beyond the typing of fairly complex commands (ESRI 1990) and the translation of commands into selections from pull-down menus (Pazner *et al.* 1989). For example, a graphical version of MAP II (Kirby and Pazner 1990) provides an approach to map overlay in which a user composes an "iconic sentence" through a sequence of icons that are dragged over the screen. At the same interaction level, GeoLineus (Lanter and Essinger 1991) allows a user to put together icons for layers, displaying on the screen the sequence of operations as specified in a command language—including the ability to track the composition of an overlay operation. These approaches are improvements over the typed version of a map algebra. They reduce the complexity of composing an overlay as the user need not remember a particular command, but can rather identify and select it from a set of given operations. On the other hand, both approaches retain the inherent structure of a map-algebra operation, which any user has to follow. As such, users are constructing sentences in the map algebra, but not necessarily performing a particular problem-solving task.

As an alternative to the command-line based languages for map-overlay, we pursue visual, direct-manipulation languages based on the map-overlay metaphor. In such a language, users perform actions much like the professional experts do in their familiar environment. They also receive immediate feedback about the status of operations being performed. This approach is superior to languages that describe operations verbally, because it reduces the "gulf of execution," e.g., the extra effort required of users to successfully complete a task) at the user interface (Norman 1988).

The *geographer's desktop* is a direct-manipulation user interface for map overlay (Frank 1992; Egenhofer and Richards 1993). The principal components of the geographer's desktop are (1) *geographic data* that a user can select and combine and (2) *presentation parameters* that apply to the data selected. The selection of data corresponds to a database query with which a user specifies which subset of the data is available to display. Geographic data can be combined with a variety of analytical tools, though initially the geographer's desktop will be restricted to the fairly simple combination of *graphical overlay*. A number of different analysis methods are available for geographic data, e.g., graphical (i.e., map-like) display of spatial information, tabular presentation (much like the common presentation of business data), or statistical charts.

The geographer's desktop manifests the map-overlay metaphor by adding a *viewing platform*, which is linked with a viewing window. The viewing platform represents the light table in the source domain. Users place layers onto the platform in order to see the contents of the layers as rendered by the appropriate visualization parameters, or remove them from the platform to erase them from the current view. The viewing platform has several functionalities: (1) It enables a direct-manipulation implementation of map-overlay and acts much like the trash can on the Macintosh user interface, which allows users to delete (and recover) files by dragging them into (and out of) the trash can. Likewise, selecting and unselecting geographic data becomes a direct-manipulation operation by dragging map layers onto and off the viewing platform, respectively. (2) The viewing platform allows a user to distinguish between a house-keeping operation on a direct-manipulation user interface and an operation to add spatial data to the set of viewable data, or to remove spatial data from the currently visible data set.

Layer Visualization of the Geographer's Desktop

Different direct-manipulation implementations of visualizing and interacting with the relevant objects are possible for the Geographer's Desktop. In one visualization, the database query and symbolization components have been treated as separate objects on the user interface surface (Frank 1992; Egenhofer and Richards 1993). Here a different approach is pursued as the database query and symbolization components are visually linked. This section introduces the two principal objects that comprise the *layer visualization* and details the operations that are typically performed on them. The objects are (1) layers and (2) viewing platforms. This is followed by a discussion of the visualization and interaction of the major operations. The user interface visualization presented is not merely a computerized version of map-overlay, but rather it exploits the primary concepts involved, while allowing for metaphor extensions to utilize advantages available in a computer environment.

Layers

The concept of *layers* is borrowed from the map-overlay metaphor, where physical maps exist as map layers. Generally, physical maps almost always have a legend and an area for map drawing. The legend shows the map reader what the various map symbols are, and the map drawing contains the graphic rendering of the map as defined by that symbolization. In a digital environment, the legend can correspond to the symbolization component and the drawing can correspond to the database query component as rendered by the symbolization rules. These concepts are brought together to form the *layer object* at the user interface (Figure 1).

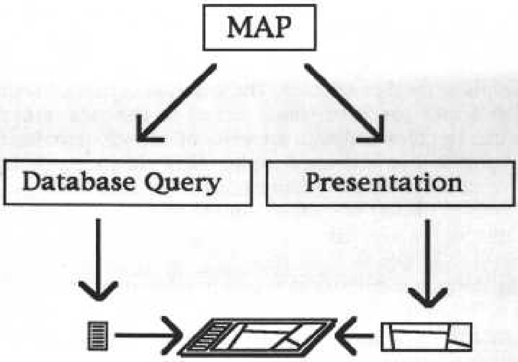


Figure 1: Visual integration of the components into a layer icon.

At the surface, the layer object is an icon that consists of two halves, with which the user can interact separately. Double clicking on either the legend for symbolization (Figure 2a) or the map for database query (Figure 2b) engages the user in a dialog for interacting with those parameters.

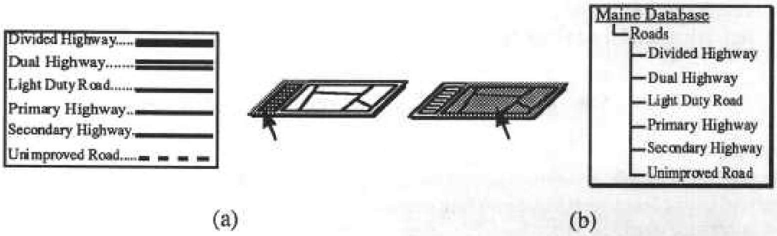


Figure 2: Double clicking on the left part of the layer icon (a) allows the user to manipulate the symbology, while double clicking on the right part of the icon (b) allows the user to modify the database selection.

Viewing Platform

When manipulating objects on the geographer's desktop, users must have a way of distinguishing between actions intended for "house cleaning" (i.e., moving things around), and actions meant to initiate operations upon the objects. The viewing platform is the object that enables users to differentiate these two fundamentally different kinds of actions (Figure 3).

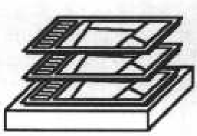


Figure 3: A viewing platform with three layers stacked on top.

Platforms are associated with a set of viewing windows in which the multiple views of the data may be displayed concurrently. New viewing platforms can be created on demand so that users may simultaneously compare several different overlays. Each platform can have multiple "hot linked" windows that correspond to the multiple views of the data. In a hot linked window system, different views of the data are displayed concurrently in different windows. Direct manipulation queries can be performed in one window with the results being shown in all.

Adding and Removing Layers

Initially, layers are located anywhere on the geographer's desktop (Figure 4).

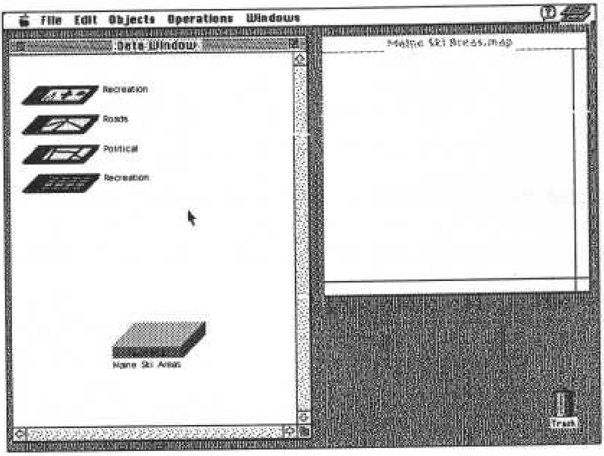


Figure 4: A snapshot of the layer visualization of the geographer's desktop.

A user selects the layer(s) of interest with a direct manipulation device and combines them by dragging them across the desktop onto the viewing platform in order to view them. Placing a layer on top of a viewing platform will initiate the rendering of its database query component as specified by its symbolization component. The result will then appear in the platform's appropriate view window. The layer may specify different kinds of renderings such as graphic, statistical, or tabular. The snapshot in Figure 5, for instance, shows the geographer's desktop after three layers with a graphic rendering and one with a tabular rendering had been put onto the viewing platform. The graphical and the tabular results are displayed in corresponding view windows.

Layers can be dropped onto the viewing platform by releasing the mouse in the zone above it and the platform will attract the layers, like a magnetic force, and stack them neatly on top of itself. During this process, users receive feedback about the status of their operation: the platform informs when the release of the mouse will result in the desired actions (i.e., before the mouse button is actually released) by highlighting when the mouse moving the selected layers is in the zone above the platform. The induced activity of attracting the layers once they are within the platform's area of influence is very similar to that of the trash can on the Macintosh desktop, which highlights when a file is dragged over it and absorbs that file when the mouse button is released. Reversely, when removing a layer, the platform's feedback informs the user that the selected layer or group of layers has been removed successfully or not. Removed layers remain at the location on the desktop where the user places them.

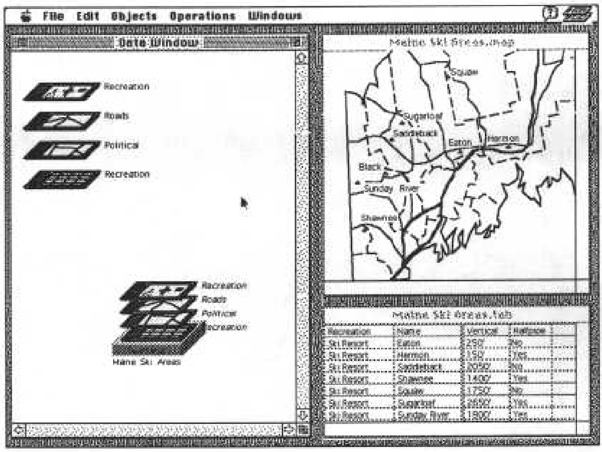


Figure 5: The geographer's desktop after four layers had been moved onto the viewing platform.

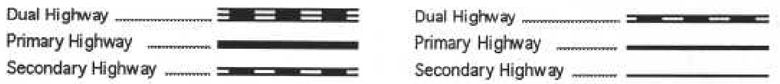
Modifying the Symbology

In addition to being the location where layers are placed to be viewable, the viewing platform includes the functionality of manipulating the symbolization components. Such symbolizations may form complex cartographic renderings according to a predefined map style such as "USGS 1:24,000."

The concepts that the implementation of this functionality is based on are similar to the feature known as *style sheets* in Microsoft Word (Microsoft 1991). Style sheets allow users to save specifications of how text should be formatted. There are interactive methods that users employ in order to create and use various style sheets. When a user first launches the application, there is a default font, size, and tab setup that is called the Normal style. A user who makes changes to Normal-styled text can then afterwards do two different things with a selection. First, the user can select some text whose style has been altered, and then choose "Normal" from the styles pop-up menu. At this point the user would see a dialog box asking whether to "Reapply the style to the selection," or "Redefine the style based on the selection." Choosing the first option would cause the selected text to reassume the default style "Normal," while choosing the second option would cause the definition of the style "Normal" to assume the form of the selected text's format. This, in turn, causes all text in the document that is styled "Normal" to assume the newly defined characteristics. Second, the user can select some reformatted text and choose **Style...** from the **Format** menu. This action produces a dialog box which allows the user to name this new style and add it to the list of styles available in the styles pop-up menu. After dismissing the dialog with an OK, the user could then select other pieces of text and reformat them by choosing the desired style from the styles menu.

The layers of this user interface visualization have similar features that can be explained easily via a comparison with MS Word. There are several default styles available to the user, which could include "USGS 1:24,000," "Rand McNally Road Map," user defined styles, and others. With the creation of a new layer, the user must choose both a default style and a database query. For example, a user may define a layer "roads" which uses the

USGS 1:24,000 roads symbolization (Figure 6a), with a database query that includes only Dual Highways, Primary Highways, and Secondary Highways. Alterations of the symbolization are possible via interaction with the legend portion of the layer. For example, if the user decided to make road symbolization smaller, it might look like Figure 6b.



(a) (b)

Figure 6: (a) USGS 1:24,000 roads symbolization and (b) a user-defined roads symbolization.

At this point the user could perform any of the same operations that are possible with MS Word styles. For instance, after choosing "USGS 1:24,000 Roads" from a styles menu, the user would be asked whether to "Reapply the style to the selection," or "Redefine the style based on the selection." Choosing the first option would revert the style back to its original form, while choosing the second would make all instances within the given document that used the USGS 1:24,000 Roads style assume the new symbolization. Second, the user could choose a **Styles...** command from a menu, allowing the naming, saving, and new availability of the style. It might be called "Minor USGS Roads," or something to that effect. After performing this task, the new style would then be available to any other layer with a roads database query within the current document.

In addition to styles within individual layers, the viewing platform can have an associated *Style Collection*, which is indicated by a name on the front of the platform. Default collections would consist only of the individual style components that make up "USGS 1:24,000," "Road Map," user defined styles, and others. For example, a USGS 1:24,000 collection would include "USGS 1:24,000 Hydrology," "USGS 1:24,000 Roads," etc.

Conflicts arise and must be resolved when a user drags a layer with a different style onto a platform. If, in the above example, the user had changed the roads symbolization of a layer and then dragged that layer onto a platform with a default "USGS 1:24,000" Collection, she or he would be presented with a dialog asking for clarification of the action. The first option would be to "Reapply 'USGS 1:24,000 Roads' to the user defined symbolization," and the second option would be to "Begin a new Collection." If the first option were chosen, the symbolization in the given layer would revert back to the default "USGS 1:24,000 Roads" style, and if the second option were chosen, the platform would begin accepting layers with different kinds of styles and putting them in a new Collection. Subsequently choosing the **Collection...** command from a menu would allow the user to name, save, and make available the new Collection. The user might give this new collection a descriptive name such as "USGS with Minor Roads."

The platform, with its many different Collections, allows the user the opportunity to quickly compare different renderings of the same layers. Changes in symbolization are easily accomplished by choosing a Collection from the pop-up menu on the front of the viewing platform—e.g., from USGS 1:24,000 to City Council (Figure 7). In addition, the viewing platform provides the user with feedback about the selection of the symbolization. With a pop-up menu on the front the user can manipulate style collections. The menu displays the current style collection of a given platform. When users change style collections by adding layers with different visualizations than the current collection, a new collection is started that is based on an extension of the first collection. This is visualized by adding a "++" to the end of the current style collection on the pop-up menu. Once the user has established a number of style collections, changing between them is as simple as selecting the desired style from the pop-up menu.

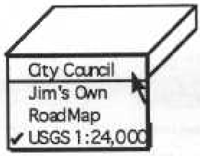


Figure 7: Changing the symbology by choosing a Collection from the viewing platform.

Conclusions

GIS user interface design has been established as a major topic in recent years (Mark et al. 1992). This paper contributes to this area with work in the visualization and interaction process of user interface design. This emphasis was possible because of the framework within which the work was done, where a formalization of data cubes and templates was already in existence (Frank, 1991). The geographer's desktop is a framework for visualizing a user interface to geographic information, in which map overlay was presented as the metaphor for interaction in the design.

The interaction concepts have been studied in a mockup created with the animation application MacroMind Director™ (MacroMind, 1991). The feedback we received from viewers was generally very positive. They stressed that the direct-manipulation visualization of the map-overlay metaphor is very intuitive. They also found it very appealing and powerful to have the flexibility of manipulating individually the database selection and symbolization components.

A number of questions are still open, some of which are currently under investigation. For instance, how can computational overlay be included within the framework of map overlay? The user interface as designed and visualized thus far addresses only graphic overlay; however, one of the strengths of GIS is its capability to perform such computational overlays as intersections and buffering operations. One viable solution would be to combine the map-overlay metaphor with a visualization such as grade school *addition*, which is a source metaphor with which virtually everyone is familiar (Figure 8).

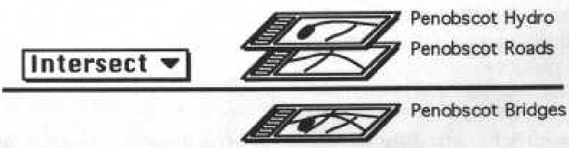


Figure 8: The simple *addition metaphor* applied to more complex geographic computational overlay.

When can certain metaphors be combined? Besides map overlay, there are other metaphors in use for such applications as panning and zooming in geographic space. Investigations into how these and other metaphors can coexist seamlessly in a GIS, are necessary in order to promote more metaphor-based interactions and implementations in commercial GISs.

Acknowledgments

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