The availability of computer technology outpaces its usability. Faster and less expensive computer systems find homes on the desks of more students, teachers, researchers, business people, and average citizens than in the past. Despite this proliferation of computer hardware, the pervasive complexity of these systems impedes the promise of improved productivity. In response, the areas of cognitive science and human factors are being considered more in system design. Studies of human-computer interaction seek to improve the usability of computer systems by developing theories, guidelines, and methods related to the design and development of user interfaces.

These efforts have already yielded noticeable improvements in the user interfaces for certain business applications, such as word processors and spreadsheets. So popular are these user interfaces that they are now being ported to GIS software. Today, state-of-the-art GISs employ pull-down menus, dialog boxes, and push-buttons which allow users to execute commands without the need to memorize their names and particular syntax. Still, the differences between business software and GIS warrant new developments specific to GIS user interfaces. In particular, investigations of methods and guidelines for the design of GIS user interfaces are needed. Two fundamental guidelines discussed here are the use of metaphor and direct manipulation.

Metaphor-Based User Interfaces

There is no such thing as a "beginner" computer user. That is, these users have prior experiences, knowledge, and preconceptions that act as a framework for new experiences. Mental models for new systems are formed by mappings onto this framework. The term metaphor is generally used to describe the mapping process, which is fundamental and pervasive in human understanding.

User interface designers can exploit the metaphor process to shape a user's mental model of a new system.

Interface metaphors based on a physical office have enjoyed success. Visual icons representing files, folders, printers, fax machines, and even trash cans provide a comfortable environment for most business applications. The user knows what these icons represent because they look familiar. But looks are not enough. To complete the metaphor, these interface objects must also act familiar. This is the role of direct manipulation.

Direct-Manipulation User Interfaces

Direct manipulation is a metaphor for a user's physical activity. Actions that users would normally perform in their own environment, such as pointing and moving objects, are metaphorically mapped to direct manipulation, typically using a mouse or another pointing device. When accompanied by visual metaphors, direct manipulation creates a powerful interactive environment. Users see and recognize the object with which they want to interact. They physically select this object and the action they want to perform on it with direct manipulation.

The appearance of the object then changes to visually inform the user of the result of the interaction.

This form of human-computer interaction became popular with full-screen text editors and spreadsheets with which the users could move directly to the text they wanted to edit and effect changes. Desktop user interfaces dominate today's business-oriented applications. Operating systems such as Windows NT provide users with icons they can select with a pointer and move around on the screen to execute operations. For instance, to delete a file, a user selects it and drags it over a trash can icon where the file disappears.

Are these office metaphors appropriate for GIS user interfaces? Files, folders, and trash cans cannot adequately represent the objects and actions typically required for analyzing spatial information. The Geographer's Desktop, a user interface developed at the University of Maine, offers an environment tailored specifically for GIS. The design of this user interface began by focusing on a user group that performs exploratory spatial data analysis for scientific and commercial applications. These users are typically spatially-aware and familiar with fundamental concepts of spatial analysis. By constraining the design to those users and their application domain, new opportunities for user interface metaphors become evident. One such opportunity used here is the map overlay metaphor, creating a user interface that looks and behaves like the thematic map overlay.

Map Overlay Metaphor

This user interface design is based on the well-known concept of map overlay. Historically, transparent map sheets representing different data themes were stacked on a light table, allowing the examination of spatial relations between themes that would
not have been visible on a single sheet. The separation of geographic data into themes—frequently also referred to in the literature as layers or coverages—is commonly used by landscape architects, environmental planners, and other geo-scientists. This organization of data has influenced the design of many GISs, such as Intergraph's Grid Analyst.

This metaphor has visual and physical components. The objects of map overlay, thematic data layers, and the light table are visually represented by graphical icons. Direct manipulation of these icons replaces the physical action of stacking data layers. The map overlay metaphor creates a highly usable interface for creating maps and performing GIS analysis on the Geographer's Desktop.

Creating Maps on the Geographer's Desktop

To view thematic map layers, a user selects the desired icons and drags them, using the mouse, onto a viewing platform, an icon that represents a light table. The viewing platform is associated with a map window in which a cartographic rendering of the map layer is displayed. The viewing platform exhibits local gravity: A data layer icon released above the viewing platform will fall into place.

If more than one layer is placed on the viewing platform, the layer icons are stacked vertically on the viewing platform. At the same time, the thematic information is drawn in one map window in the same order as the stacked icons, bottom to top. This duplicates the behavior of a real light table where the data of the top transparency appears over all others. The layers can be reordered by selecting an icon and moving it to the top. The data represented by that icon will then be drawn last over the other data. To remove a theme, the user simply selects the corresponding layer icon and drags it off the viewing platform.

Interactions are defined for specifying the visualization parameters of each theme.

Performing GIS Analysis on the Geographer's Desktop

To perform more sophisticated analyses with map layers, the Geographer's Desktop has the computational platform. Again, the process of metaphor was used to create this user interface. It originates in the way basic additions are taught in grade school and handled in such tasks as balancing a checkbook. Adding some numbers is performed by writing them in a vertical arrangement, drawing a horizontal line, adding a plus sign above the line and writing the result underneath. By replacing the numbers with map layers and the plus sign with a GIS operation, one achieves an intuitive way of performing GIS analysis with thematic map layers.

The interaction to specify the inputs of an analysis is exactly the same as the viewing platform. Data layer icons are dragged and dropped onto the computational platform. The function to be applied to these layers is selected from a pop-up menu located on the platform. Interactions are also defined for specifying any required function parameters. The icon representing the output of the analysis can be manipulated as any other layer icon. It can be placed as an input to another computational platform to facilitate the nesting of operations. The output layer of a computational platform can be placed directly onto a viewing platform, creating an integrated environment for analysis and display.

Conclusions

This user interface embodies research being conducted at the University of Maine on GIS user interfaces where several masters degree theses have been completed in collaboration with this research. Jeff Jackson investigated different metaphors for panning and zooming on map views. Jim Richards investigated the interaction and visualization of the viewing platform. And Tom Bruns investigated the same aspects for the computational platform.

User interface design has many confounding factors. Information technology is experiencing rapid growth and change. The face of the typical user changes often. The presence of computer technology often changes the very nature of the user's task. As a result, many of the assumptions made by the user interface designers will be invalid when the product is shipped. Design methodologies must be carefully constructed to anticipate these changes. Unfortunately, design methodologies often conflict with the realities of commercial product development.

The techniques of metaphor and direct manipulation hold great promise for better user interfaces. The user interface presented here is just one of several possible implementations for the same underlying concepts. There are many challenges ahead for GIS user interface design. Design and evaluation methods specific to visual, highly interactive GIS user interfaces must be developed. One thing is clear: User interface design is not a task that can be tackled in isolation from an application domain. The design of GIS user interfaces must include contributions from the GIS community.