

A Classification of Interactive Map Software

ABSTRACT

Map software programs can be different in a number of ways. This paper reports on the classification of interactivity produced as a result of surveying forty map applications. Specific examples from the survey are referenced as we describe different navigation styles, different levels of collaboration support, and various data options. Unique combinations within the classification are also discussed as we explore ideas for new interaction techniques.

1 INTRODUCTION

People use paper maps for a number of different activities. Atlases and other maps are often used when traveling in an unfamiliar area, such as driving in a city or hiking in a wilderness area. An adventure novel may include a map so that the reader has a reference for the characters' travels, and most shopping malls have a map to list stores and indicate their locations. Considering all of the different uses for maps, numerous map software programs have been written to simplify and automate some of the many map tasks. Route planning software is frequently used when going on a trip and looking at a computer-generated weather map on the Web is a common task.

Our interest is to design and evaluate map applications to support multiple users collaborating on a spatial task. For example, MOOsburg is an online, collaborative environment based on the town of Blacksburg, Virginia (Carroll *et al.*, 2001). Community members use this environment to communicate with their neighbors. The application allows them to collaborate synchronously or asynchronously through chat, a whiteboard, and other objects. The structure of the environment consists of distinct places that parallel real locations in the Blacksburg. Visiting one place at a time, users can interact with the different objects and contribute to the different discussions associated with each location. A map widget supports these collaborative activities as it provides a way to navigate and develop the environment. It displays a map of the town's roads and buildings and marks the "visitable" locations. Users can click on the existing locations or add new locations for other users to visit. The map widget also enables users to find one another as it incorporates awareness information, such as indicating where the current users are located.

Yet, this map widget in MOOsburg can be improved and there are other examples where map software can support a collaborative task. Different interaction techniques could make the map easier to use or enable the software to support different tasks. Currently, users just navigate and click on the place they would like to visit. Additional interactions might allow users measure distances using the map or store personal information on the map display. New features could also enable different forms of collaboration. For example, the map itself could become an object for users to collaborate with, allowing users to share ideas on a map display.

We can easily differentiate between different map applications, such as the MOOsburg map widget and a map program on the web, based on the tasks they are intended for, but this does not show how the software programs are fundamentally different. A classification of map software will allow us to make these distinctions. It will enable us to compare software that may seem very similar and contrast software that appears very different. It will also reveal different modifications we could make to the MOOsburg map widget and encourage new types of map software.

Map software programs can be different in a number of ways. For example, we could differentiate between the applications' hardware and software requirements or the usability of the user interfaces. Our classification focuses on the interactions the map supports. Supported interactions define what the user

can do with the map display. This, in turn, enables different map-based tasks. For example, a map application that supports multiple interaction techniques could possibly be used for a variety of tasks. Creating a classification of interactivity not only gives us a way to categorize existing map programs in terms of their interactions, but it provides a means to explore new interaction combinations that can reveal novel map-based tasks and unique applications that have yet to be developed (Ellis *et al.*, 1991).

This paper reports on the classification of interactivity produced as a result of surveying forty map applications. An explanation of the classification follows along with specific examples from the survey. Unique combinations are also presented, each of which warrant further investigation.

2 CLASSIFICATION OF INTERACTIVITY

Forty interactive map applications were surveyed in order to create a classification of map software (see Appendix A). This survey consulted web-based map programs, map software developed for various research projects, and off-the-shelf software products. The map applications were found from a combination of Web searches, personal references, and a research literature search. The set of map programs surveyed provide a good cross-section of interactive map software as the user tasks range from sharing travel information to viewing hydrographic data to creating a military plan. A description of the possible user interactions was recorded for each application, which was then generalized into a classification of interactivity.

The classification consists of three dimensions: navigation techniques, support for collaboration, and data sources available (see Figure 1). Navigation techniques refer to the way a user can change the viewpoint of the map, such as through zooming and panning. Support for collaboration refers to an application's ability to allow multiple people to communicate ideas. For example, the map software may allow users to chat in real-time or write comments on the map for later viewers. Data source availability refers to the options available for displaying different data on the map, such as displaying different layers.

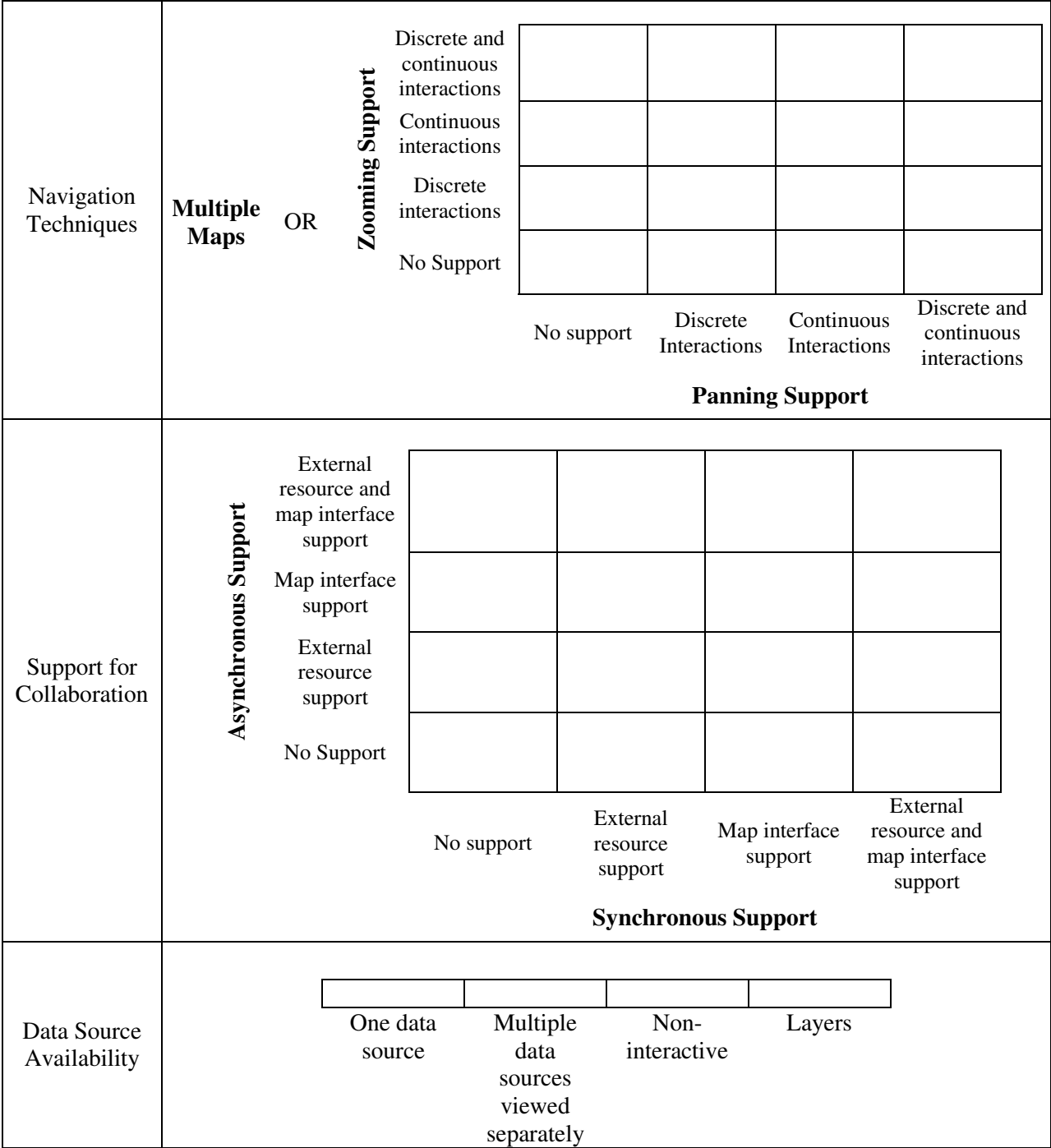


Figure 1. A diagram of the classification of interactivity for map software.

2.1 Navigation Techniques

Navigation with an interactive map program can occur in two different ways. The software can use multiple maps, each with one view, or it can use one map with multiple views. In the first case, the user has little control over how the map is navigated. One chooses between distinct locations that cause a new

map to be displayed. A map on a web page that uses an imagemap configuration is a good example. The map contains hotspots that link you to another web page that can contain another map image.

When navigation does not occur through multiple maps, users navigate one map with multiple views using some form of zooming and panning. Maps using this type of navigation are classified using two distinct aspects: panning support and zooming support. Panning refers to the way a user can change the area displayed with the map. For example, one might shift the map to the left in order to view something that was hidden off to the right. Zooming refers to the different magnification levels that can be viewed. For example, one might want to zoom out in order to view the entire map area on their display. Within both the panning and zooming components a map application can exist at one of four levels. At the first level, the map software does not allow this type of navigation (panning or zooming). The next three levels incorporate the different ways for supporting navigation: through discrete interactions, continuous interactions, or both.

When navigation occurs through discrete interactions, using either panning or zooming, the map display refreshes after each interaction. So if a user decides they want to pan or zoom, he/she would interact with the interface in order to issue the command and then wait for the map to refresh. A common implementation is to use buttons in the interface that relate to the viewpoint changes. For example, a user may click on a magnifying glass to increase the zoom or click on a compass to change the area displayed. Discrete zooming can also occur through drawing a box around an area to zoom into. After drawing the box, the user waits for the display to refresh. Another discrete panning design uses clicking and dragging. Users click on the map and drag it to pan, but the newly exposed areas are not rendered while dragging. Again, once the interaction with the interface is complete, the map display is refreshed and the exposed areas are rendered.

On the other hand when navigation occurs through continuous interactions, using either panning or zooming, the display provides continuous feedback to the user. So if a user changes the viewpoint using continuous navigation, the display changes while he/she is performing the interaction. This is commonly implemented with some form of dragging. For example, a user might change the zoom level by clicking and dragging on the knob on a slider widget. Each drag movement will cause the map display to update with every zoom level encountered. Similarly, continuously panning might be performed by clicking and dragging the map, where the display is continuously rendered with each movement.

Map applications that use both discrete and continuous interactions for either panning or zooming incorporate multiple techniques for navigation. For example, a map program might support zooming using a discrete interaction, such as clicking on zoom levels, and using a continuous interaction, such as dragging a slider through the zoom levels. Using both forms of navigation, the map enables many different interactions to take place.

Typically a map application uses either multiple maps or panning and zooming, although both could be employed. For example, a map application might use multiple maps, each of which could be navigated with multiple views. In this case, navigation primarily occurs through panning and zooming and such a map would be classified in terms of its panning and zooming support. Taking the multiple maps possibility into consideration along with the four levels of zooming and panning support, there are seventeen different possible combinations for navigation.

2.2 Support for Collaboration

The support for collaboration dimension has a similar classification scheme to that of navigation techniques. It consists of two distinct components, asynchronous support and synchronous support, each of which contain four possible levels of interactivity (Ellis *et al.*, 1991).

A map application provides asynchronous support if the software allows multiple users to exchange information over time. For example, one user might leave a comment for their colleagues to see the next time they use the map software. Users involved in asynchronous communication do not have to be at different locations, but this is usually the case as many map programs are accessed from a personal workspace rather than a common area. Synchronous support is provided when the software enables multiple users to work together at the same time. Two users holding an online discussion about a map is a good example. Again, users do not have to be at different locations, but this is often the case.

Within the two components of asynchronous and synchronous support, a map application can exist at one of four levels. At the most basic level, there is no support for this type of collaboration (synchronous or asynchronous). The next three levels incorporate the different means for supporting collaboration: collaboration using an external resource, collaboration using the map interface, and collaboration using both an external resource and the map interface.

If multiple users communicate using a tool other than the map interface than an external resource is supporting collaboration. For example, many web-based map applications have an email feature that sends a URL for a particular map display. Recipients of the email message might simply view the map or they might change the display through navigation, adding content, etc. and then send another message. In this case, collaboration is supported through the external resource of email. Many other examples occur when the map software is embedded in a larger application that includes collaboration tools. For instance, a synchronous chat feature is a common collaboration tool and a good example of an external resource.

The map interface supports collaboration if multiple users can work directly with the map display. When this is the case, the map software itself includes a means for users to communicate and share ideas. For example, a map program might have a collaborative editing tool so that multiple users can contribute to the data set and its representation. Another good example is a map application that includes a shared navigation feature. This would allow multiple users in different locations to see the map from the same viewpoint and watch the same navigation transitions.

Map applications that support collaboration both through an external resource and through the map interface incorporate multiple techniques for collaboration. For example, a map application might support collaboration using both a synchronous external resource, such as chat, and a synchronous map feature, such as shared navigation. Using both forms of collaboration support, the map software enables many different interactions to take place.

Taking the two components and four levels of collaboration into consideration, there are sixteen different possible combinations.

2.3 Data Sources Available

The third dimension of the classification characterizes the available data sources for the map software. In particular, this dimension looks at whether or not the user's actions can have any effect on the data displayed and if so, how much control is given to the user. For example, a map application may only have one data set and so none of the user's actions can result in different data sets to be used. On the other hand, the map software may include numerous data sets and require that the user specify every data source that is to be displayed.

Under the data source dimension, there are four different levels at which a map application can exist. The first level is the most basic and does not give the user any data options. The map uses only one data source and always displays that same data source. A map image on a web page is a good example. It

displays one data source and do not provide any data options. At the next level, a map application uses multiple data sources, but can only display one at a time. For example, a display with a state map could allow users to see different county statistics such as population and density of people. The third level is termed non-interactive data sources. In this case, the user does not have any data options, but the software incorporates different data sets and has an underlying algorithm for their use. This is commonly viewed when zooming with map software, as more data and details are often displayed when the magnification increases. At the last level, the user has total control over the data sources used as he/she chooses which data sets to display. This is commonly referred to as layers and is widely used in Geographic Information Systems (GIS).

2.4 Survey Results

By looking at the survey results, we can provide some validity to the classification. Examining the three dimensions individually, we see that the forty map applications were dispersed across the different combinations (see Figure 2, 3, and 4). Out of the possible seventeen combinations for the navigation dimension, the survey examined seven different combinations. Discrete panning and discrete zooming was the most common navigation technique observed, as many web-based applications were examined. All web browsers support a discrete model of interaction, but most require extra software to support continuous map interactions, resulting in many web-based maps that use discrete navigation.

Similarly, the map survey identified maps in seven of the sixteen types of collaboration support. Many of the map applications surveyed did not support collaboration, but again, many applications were located on the Web and required extra software in order to support collaboration. For example, posting a website that uses multiple maps for navigation is much less complicated than a web-based application that supports synchronous collaboration on the map interface. In terms of the data sources available dimension, all four levels were observed.

The entire classification has a possible 1,088 different combinations. Our map survey examined twenty-nine of these combinations. This means that most of the map applications surveyed were different in some way. Some of the maps were classified the same though showing that the classification does provide an abstraction.

Navigation Results

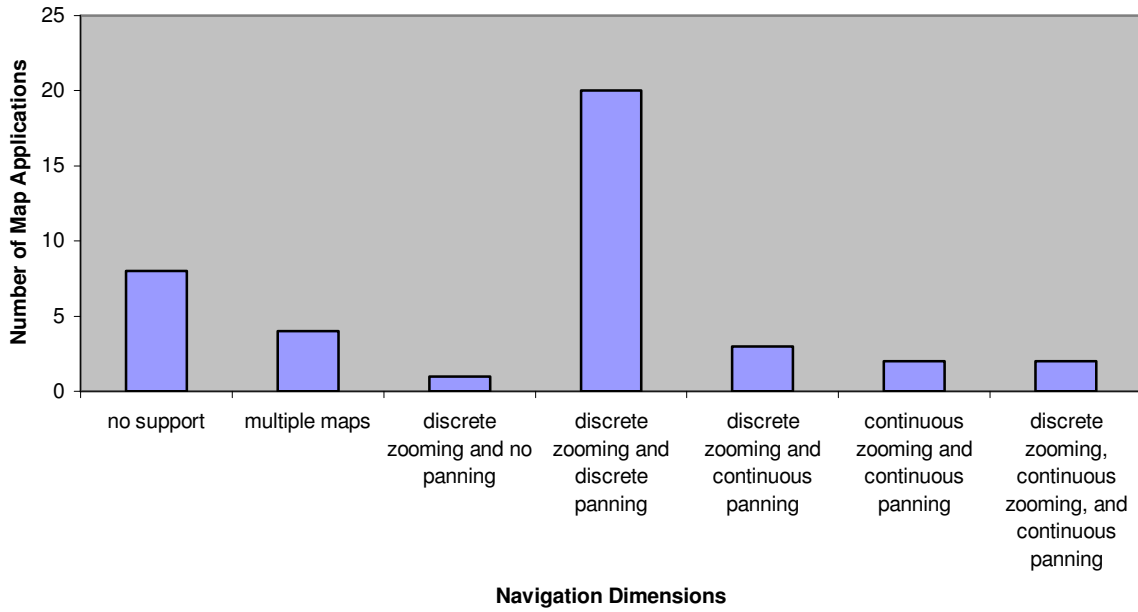


Figure 2. Map survey results from the navigation dimension of the classification.

Support for Collaboration Results

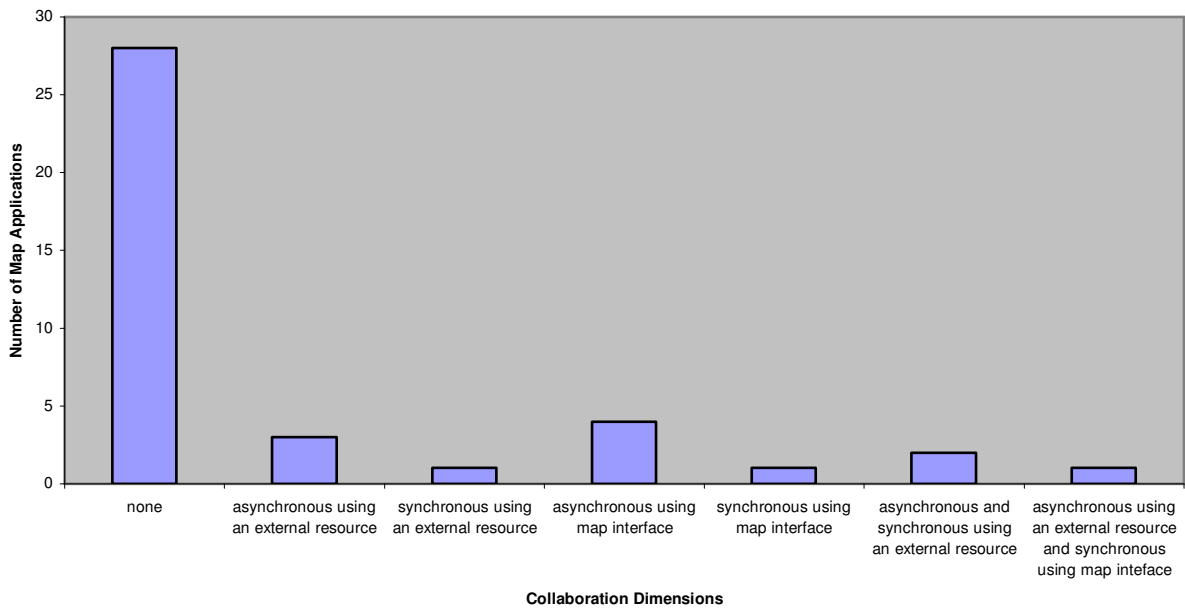


Figure 3. Map survey results from the support for collaboration dimension of the classification.

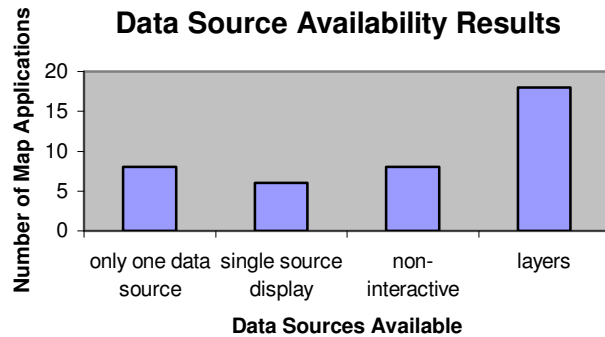


Figure 4. Map survey results from the data source availability dimension of the classification.

2.5 Other Possibilities

While establishing this classification, a handful of other dimensions were considered but not included. These dimensions focused on other interactions that map applications commonly support. For example, many map programs provide customization features, such as changing the color scheme or modifying an icon. Another interesting feature is the ability to add user-defined content to the map. On the one hand, some programs simply allow a user to mark a location with a pinpoint, while others include a range of drawing and annotation tools. A feature that is less frequently implemented is a transformation tool. Such a tool enables users to apply projections and rotations to a map.

Each of these interactions was considered to be part of the classification, but they did not provide very interesting distinctions. These interactions simply modify the appearance of the map as opposed to the interactions included in the classification. The dimensions examine more complex issues such as how users can collaborate with one another, how users can alter the map's viewpoint, and how users can modify the data sources displayed. For example, if we compare two maps that have the same navigation techniques, the same collaboration support, the same data source availability and different combinations of the appearance modifying interactions the combinations produced are not that interesting. In essence, each combination has a different set of neat features and including these combinations in the classification is not advantageous.

3 MAP SOFTWARE EXAMPLES

Having described the classification of interactivity, we will now go through a few examples. Each of these examples comes from the survey that was used to create the classification. They are some of the more interesting map applications examined and each exhibits different aspects of the classification.

3.1 Town of Blacksburg GIS

The Town of Blacksburg, Virginia includes a Web-based GIS system on their website. This map application allows town's citizens and visitors to access local GIS data. It provides information regarding the town's street system, property boundary lines, bus stop locations, zoning, and public locations, such as parks and libraries. The map is primarily used for reference and most tasks involve using the map to find a specific piece of local information (see Figure 5).

Looking at the software in terms of the classification, the map supports a fairly common set of interactions. The most prominent feature is the maps use of layers. Users can turn layers on and off through a series of checkboxes and an "Apply" button, where clicking on the button causes the map to update. Layer choices include area-based information such as zoning, line-based information such as roads, and point-based information such as libraries. This use of layers is particularly unique in that more layer choices appear as the zoom magnification increases.

In terms of navigation, panning occurs by clicking on the triangles on the edges of the map or by setting the next click to be the new map center. Zooming occurs in three increments, 2x, 4x and 8x, and happens through a drop-down menu and a click on the map. Alternatively, clicking on the "Location Map" and the zoom scale will change the area displayed and the magnification, respectively. This map suffers from a common web problem in that all interactions require a message to be sent to the web server so that the screen can refresh.

The map supports a couple of other interactions such as searching for an address, listing public places, and identifying different aspects of the display, but it does not support any collaborative activities. If two people want to look at this program together they need to be physically located at same computer at the same time. The software does not include a way for multiple people to know that they are using the application at the same time, nor does it support multiple collaborators using it over a period of time.

In terms of the classification of interactivity, this map application uses a common combination. It has no support for collaboration, navigation occurs through discrete zooming and discrete panning, and data sources are accessible through layers.

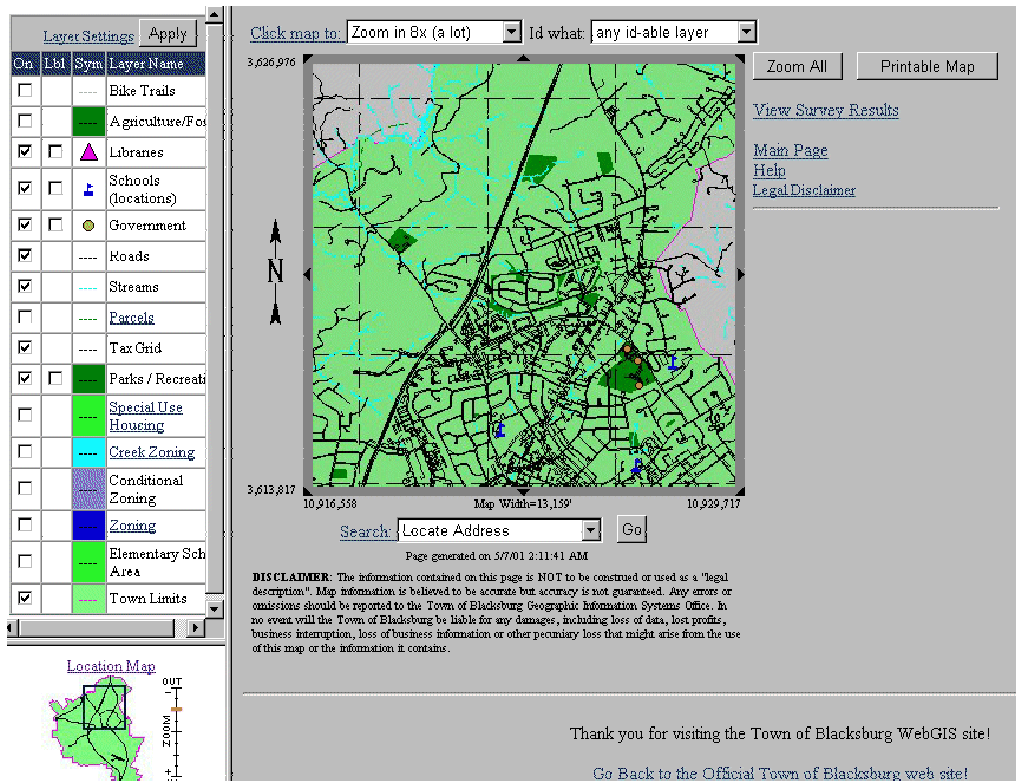


Figure 5. A screenshot from the Town of Blacksburg's WebGIS, a map application that uses discrete zooming and panning and a layers data source.

3.2 Triscape Map Explorer

Triscape is a company founded in 1997 whose mission is to develop virtual reality software that solves real world problems. Their first product, Map Explorer, is a unique software application involving road maps, web pages, and user-created annotations. One focus of the map software is to allow companies to publish web pages and paintings spatially, in order to sell a product or service. Customers enjoy a unique experience as they navigate this spatial layout and learn about the company. The other goal is provide an alternative to tradition on-line map programs. As a result, the map software is designed for three basic tasks: creating a company space, customizing an on-line map, and exploring these creations (see Figure 6).

The map software supports a range of interactions including continuous zooming, continuous panning, annotations, virtual links, and displaying live web pages. Using the standard navigation mode, the compass widget is used to continuously zoom and pan the map interface. Holding the mouse down on the arrows and the plus and minus symbols causes the map to pan and zoom, respectively. Alternatively, clicking and dragging the mouse on the map allows user to zoom and pan simultaneously. A left click corresponds to zooming out, a right click is mapped to zooming in, and the middle button provides free form continuous panning.

The map also supports navigation through virtual links and common Web browser interactions such as "Back" and "Forward". If a user clicks on a virtual link the map automatically navigates to a new location using continuous interactions. Using the "Back" and "Forward" buttons, one can retrace their steps.

Changing the magnification affects the amount of detail displayed on the map. Zooming in results in data being added and zooming out results in data being removed. The application uses multiple levels of detail with each building upon the last. They include major highways and major cities, important roads, and minor roads. Labels are also added at different levels of magnification.

This map software has a different approach than traditional on-line map applications such as Mapquest and MapBlast. It provides a range of annotation features so that users can customize their maps. One can add a wide highlighting line, a local road, a pond, a link to a live web page, a user-specified line or area, etc. Once the map is customized, the map can be saved on the web and referenced through a static URL for a year. This allows a user to have other people review their annotations and add new ones.

In terms of the classification of interactivity, this map application uses a unique combination. It has asynchronous support for collaboration using the map, navigation occurs through continuous zooming and continuous panning, and data sources are not accessible but rather used non-interactively.

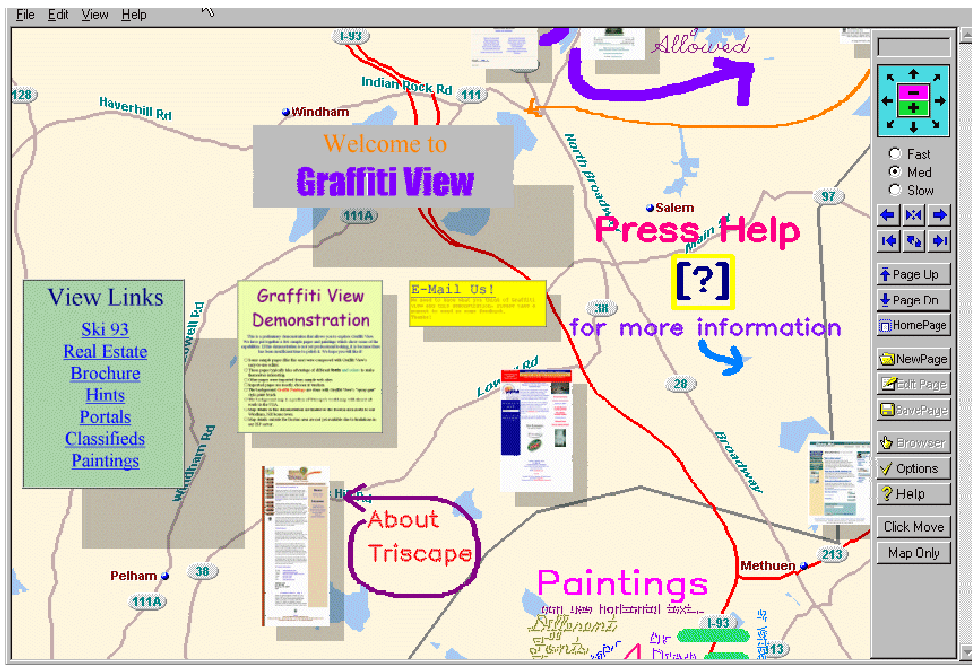


Figure 6. A screenshot from Triscape's Map Explorer. This map application supports continuous zooming and panning, asynchronous collaboration using the map interface, and non-interactive data sources.

3.3 VirtualTourist

VirtualTourist is website for travelers to share information. The website includes a range of activities to participate in as well as various travel tools such as currency converters, time zone maps, and current travel warnings. Over 146,000 people from 223 countries use this site to meet other travelers and share experiences. People share pictures, travel tips, travel stories, and reviews of destinations. The web site is organized so that each continent, country or territory, state, and city has a web page. On these pages, one can read user-posted comments relating to general tips, restaurants, accommodations, must see activities, nightlife, tourist traps, transportation, and so on. These pages also list registered users who have created their own page dedicated to the location. Typically, registered users create their own set of web pages that follow the same structure as the general use pages. These pages allow them to add travel experiences and pictures and give them a homepage for others to learn about their interests.

VirtualTourist uses a map interface for navigating their web pages. A map is included at the top of every web page so that users can choose to navigate to a subsection or read about the current area. For example, on the web page for the United States, a map of the US with state boundaries and state labels is displayed and each of the states are linked to the web page about that state. Using the maps, a user can easily drill down to the location they are interested in. Reversing the process is less intuitive as one has to either use the back button or recognize the other navigation aids on the WebPages (see Figure 7).

The maps used on the general use WebPages always look the same and there are no options to modify them. Personal web pages are marked with a color-coding based on the information provided by the user. Areas and places where the user claims to have been are colored with red, places the user plans to go are colored with green, and places where the user has been before and plans to go again are colored purple. This makes for a colorful map, but there is no real control over what data is displayed.

Using the VirtualTourist, users can also participate in one of the many discussion forum or chat online in real-time. The discussion forum organization parallels that of the web pages. Each continent, country or territory, state, and city has a separate discussion associated with it. Initial postings are typically questions, which are then followed by a series of replies. The online chat contains about 40 distinct rooms that relate to different travel topics, such as California, German cheese, and cafes. Other

interesting activities include sending an electronic postcard with a picture from almost anywhere in the world and searching for people with similar interests or with specific attributes in their profile.

In terms of the classification of interactivity, this map application uses another unique combination. It has synchronous and asynchronous support for collaboration using an external resource, navigation occurs through multiple maps, and only one data source is used.



Figure 7. A screenshot from the VirtualTourist website. This map application uses multiple maps for navigation, synchronous and asynchronous collaboration through an external resource, and only one data source.

4 EXPLORING THE CLASSIFICATION

A classification of interactivity enables us to do more than just classify existing maps. It also encourages the exploration of different interaction combinations. Given our multiple component classification, we can explore different combinations within each dimension as well as between dimensions. This section focuses on combinations within the dimensions of navigation techniques and support for collaboration.

It is interesting to look at the advantages and disadvantages of each unique feature within a dimension. This allows us to attribute the different features to different map characteristics, which can be used to

analyze new interaction designs. Some combinations of features are complementary and provide more power or flexibility than simply the sum of the two features, while others are simply additive.

4.1 Navigation Techniques

The dimension of navigation techniques has seventeen different possible combinations using multiple maps and four levels of panning and zooming support (none, discrete interactions, continuous interactions, and both discrete and continuous interactions). We examine only some of these combinations.

The use of multiple maps is a good approach when there are a small number of views to see. One possible scenario is a map application that displays the approximate locations of a collection of landmarks. The map display might include major roads and a clickable icon for each landmark, where clicking on an icon would bring up a new map focused on the landmark and the nearby roads. On the other hand, the use of multiple maps has the distinct disadvantage that navigation is very limited.

A map application that only uses zooming or panning has restricted navigation. With just zooming the map is limited in the area that can be viewed and with just panning the map is limited in the details that can be viewed. This is the case for both discrete and continuous panning and zooming.

Many systems that use discrete interactions suffer from slow refresh rates. For example, using a map program on a webpage often involves waiting for a map image to refresh. These slow refresh rates can be frustrating to a user. On the other hand, discrete interactions enable precision. For example, discrete panning might allow a user to shift the map in respects to a distance measurement or discrete zooming might allow a user to magnify the map by exactly 2x.

Discrete zooming is unique in that different implementations can have different consequences. For example, if the user can indicate a rectangle area to zoom into, then the interaction supports a form of panning as well as zooming. This implementation also gives the user greater control over zooming as it allows one to specify an area to magnify as opposed to a design that zooms in towards a particular point.

In comparison, continuous interactions have an advantage in that users get continuous feedback about the action they are performing. This feedback supports a closed-loop interaction; it enables them to stay oriented as well as evaluate their decision and potentially alter the interaction. The feedback also helps a user to quickly learn how the map responds. For example, using a continuous zoom and magnifying the map as much as possible, one can easily see how the magnification and the associated levels of detail can change. Another advantage of continuous interactions is their use of free-form movement. A user can use any number of zoom levels using continuous zooming as opposed to the fixed number available with discrete zooming. On the other hand, continuous interactions may be difficult to control. It is possible for a user to have trouble with the movement associated with continuous interaction resulting in the map changing undesirably.

While exploring the different combinations of discrete and continuous panning and zooming, two combinations stood out as being particularly interesting. First, a map application that implements both discrete zooming and continuous zooming can be useful. Both approaches have distinct advantages, which can be combined to produce a more versatile map application. As mentioned earlier, discrete zooming where the user specifies a rectangle area gives the user more control over what is magnified and continuous zooming offers a better feedback technique. When used in the same application, users can better specify their navigation with two unique techniques, although the interface is more complex.

The combination of discrete panning and continuous zooming is also interesting to consider. This combination could be helpful in tasks that are more detailed-oriented. One scenario might be where a user wants to learn about the area around a particular place and get a perspective on that place's location within a larger context. Such a task involves minimal panning and extensive zooming.

4.2 Collaboration

The dimension of collaboration has sixteen different possible combinations resulting from the four levels of asynchronous and synchronous support (none, support for collaboration using an external resource, support for collaboration using the map interface, and both support for collaboration using an external resource and using the map interface). We examine only a few of these combinations.

A map application that only supports asynchronous or synchronous collaboration can be restrictive. With just asynchronous collaboration the map software does not allow for chance encounters. For example, if two people happen to be using the map software at the same time, the lack of support for synchronous collaboration could limit their communication and even prevent them from identifying their simultaneous use. On the other hand, if a map application simply supports synchronous collaboration, the software is limited in its use. In order for one user to share their ideas, another user has to be using the application at the exact same time. If this is not the case, then the user is forced to remember it until someone else is using the application or share the idea using a different asynchronous tool. The second alternative may seem like a reasonable solution, but it can be difficult to specify a spatial idea without using the map application that generated the idea.

When the only support for collaboration is directly through the map interface, all communication must be conveyed on the map itself. This might be sufficient for some map intensive activities, but external resources could also be helpful. For example, a user might want to leave a message that does not relate to the spatial display. Collaboration support using the map interface forces the user to post the message on the map, whereas an external resource would allow the message to part of a different information representation. Placing all communication on the map interface also can make the map cluttered and difficult to read.

In comparison, when collaboration is only possible through external resources, no communication can be conveyed on the map. This could provide sufficient support for activities that are not map intensive, such as discussing general trends in the display, but communicating on the map might also be useful. For example, a user may want to illustrate their idea by physically pointing out an area on the map or annotating on the map for others to see. Collaboration using just an external resource does not allow these interactions to occur.

One combination that is interesting to consider is support for synchronous collaboration using both an external resource and the map interface. This provides good support for many synchronous activities where people can collaborate using a range of tools. But using multiple tools could be overwhelming, as one has to pay attention to many activities during a session.

5 NOVEL COMBINATIONS

Based on our survey, it seems that maps applications that do not support some form of collaboration are the majority. This makes it interesting to explore the classification with a focus on collaboration support. Using different combinations of support for collaboration along with different instances of navigation techniques and data sources available, we examined many points in the design space. Most of the combinations were not that different from an existing map application, but some of instances were novel.

One of the novel combinations identified uses asynchronous and synchronous collaboration support through an external resource and a layers data source. This is unique because most map applications that feature layers offer no support for collaboration, and those that do often focus on asynchronous collaboration using the map interface. In contrast, this particular combination allows multiple users to share ideas and explore different combinations of data sources. It enables users to work independently with the map and then contribute their ideas either in real-time or over time.

One scenario that uses this combination occurs when multiple people in different locations are planning a trip together. The users would carry on a discussion about the different places they want to visit, when and where they could meet up, the amount of time they want to spend at each location, different route possibilities, etc. The map would aid their decisions by displaying different data sources such as transportation terminals, major hotel locations, historical sites, interstate highways, and so on. The users would collaborate when everyone was using the application, when a subset was using the application, and when only one member was contributing ideas.

This combination has the disadvantage that it can be considered too similar to the VirtualTourist example to be truly unique. With the VirtualTourist, users discuss travel destinations by creating web pages with their comments and by using an online chat tool. The map displays an image of the place being discussed and it is navigated through multiple maps. With this combination the activities and interactions are similar, as users would use the map application to discuss different views of the data.

Examining a slightly different combination, the similarity is not present. Take for example a map application that supports asynchronous and synchronous collaboration using an external resource, synchronous collaboration using the map interface, and a layers data source. This is identical to the previous combination only now we have added support for synchronous collaboration using the map interface. This allows users not only to discuss the different views of the map but also to collaborate on the map display itself. For example, the software might allow users to share annotations on the map or enable users in different locations to view the same layers but navigate the map independently. Adding this extra component opens up a range of possible interactions and makes the map application different from that of the VirtualTourist.

This combination could be particularly useful for the field of GIS. For example, one scenario involves a collection of users analyzing the best place to put an interstate toll collection barrier. Layers would allow environmentalists, town's people, and commercial traffic companies to express their individual views as well as see each other's points (Gallo, 1996). Users could discuss the matter at the same time adding annotations to the map in order to express their points. Alternatively, users could view the data on their own at different times and become abreast of the different positions.

Along the same lines, extending the last combination to include asynchronous collaboration through the map interface adds even more interaction opportunities. With this combination, multiple users can communicate spatial ideas in real-time as well as over a period. This means that two users do not have to be using the application at the same time in order share ideas directly related to the map display.

This combination seems particularly useful in a community application, such as MOOsburg. Unlike a traditional work setting, people contribute to community-based activities at all hours. For example, someone may log on to MOOsburg late at night to add his or her comments to a town discussion forum. This type of environment requires both synchronous and asynchronous collaboration support. A map combination that includes asynchronous and synchronous collaboration through the map interface and external resources provides this. Also, the use of both the map interface and an external resource allows for a variety of discussions to occur.

Looking at these last two combinations closer, we can generalize our results in that all maps that include synchronous collaboration support using the map interface and a layers data source are novel. Most map applications that feature layers do not support collaboration and those that do offer asynchronous collaboration through the map interface. Our map survey included two examples of synchronous collaboration using the map. Both of them used layers and yet both of them can be further qualified. The Collaborative Map Annotator uses an interactive map on a large screen display for same place collaboration. Users can add and remove different terrain data, route maps, surveillance and intelligence information, and archived GIS data. This example is interesting because it allows users collaborate in the same location, but if we explore the use of remote collaboration we find a novel combination.

Similarly, MapsOnUs is a web-based map program that allows people to draw maps, plan routes, and search yellow pages. Two users can synchronously use this map by clicking on a link that makes the two views identical. In order to stay abreast of the other person's interactions, the link must be clicked repeatedly. This system does not support real-time synchronous collaboration, which would be desirable when working with a map.

6 CONCLUSIONS

This paper has described a classification of map software based on interactivity. It has provided three examples as well as discussed the classification. Also, we have explored some of the unique combinations that were revealed by the classification.

Creating such a classification encourages us to analyze map programs in terms of their fundamental characteristics. It causes us to think beyond the software's users, tasks, and work environment. This paper presented one way to analyze map programs. We looked at the software in respects to its navigation techniques, support for collaboration, and data source availability. This analysis technique serves as an example and encourages other means for analysis to be developed.

In particular, this classification enabled us to explore new interaction possibilities. It allowed us to go beyond what has been implemented and consider the map activities that are possible through different interaction combinations. These activities are still ideas, but they can be evaluated and supported in new map software applications.

APPENDIX

This is a listing of the forty map software applications surveyed during the creation of the classification of interactivity.

Name	Location	Navigation Technique	Support for Collaboration	Data Sources Available
ActiveMap (McCarthy <i>et al.</i> , 1999)	Andersen Consulting	continuous panning and discrete zooming	synchronous using an external resource	one data source
The map serves as an at-a-glance awareness tool that shows where people are within an office space.				
ArcData Online	www.esri.com/data/online/	discrete zooming and discrete panning	no support	non-interactive
A web application that allows users to create maps using data for sale at ArcData Online				
ArcView GIS 3.2	ESRI product	discrete zooming and discrete panning	no support	layers
A GIS produce that provides data visualization, querying, analysis, editing, and integration capabilities.				
Autodesk MapGuide LiteView Extension	www.mapguide.com	discrete zooming and discrete panning	no support	layers
An on-line application that serves maps without having users download and install a special viewer.				
Autodesk MapGuide Viewer	www.mapguide.com	discrete zooming and discrete panning	asynchronous using the map interface	layers
Software that delivers custom-specific maps and design data easily across the Web.				
Bay Area Rapid Transit (BART) Schedule Animation	www-itg.lbl.gov/vbart/homepage.html	no support	no support	multiple data sources viewed separately
A simulation that provides an infrastructure visualization of San Francisco's transit system.				
City of Tucson ArcIMS demo	www.ci.tucson.az.us/ed/ed.htm	discrete zooming and discrete panning	no support	layers
An on-line application to find and compare vacant commercial properties in Tucson, Arizona.				
Collaborative Map Annotator (Jedrysik, 2000)	www.rl.af.mil/tech/programs/ADII/adii_cma.html	no support	synchronous using the map interface	layers
A demonstration application for the Interactive Data Wall research project.				

EPIC Web Browser	www.epic.noaa.gov/epic/ewb	discrete zooming	no support	multiple data sources viewed separately
An on-line tool to provide access to EPIC hydrographic data sets.				
EtakGuide Map	www.etakguide.com	discrete zooming and discrete panning	no support	non-interactive
A demonstration of geocoding, a procedure to find and display any address on a map.				
Geophysical Fluid Dynamics Lab Data	www.cdc.noaa.gov/cgi-bin/DataMenus.pl?dataset=gfdl	no support	no support	multiple data sources viewed separately
An on-line tool to visualize global climate variable data from the Geophysical Fluid Dynamics Lab.				
GeoMedia Web Map	www.intergraph.com/gis/gmwm	discrete zooming and discrete panning	no support	layers
Commercial software produce that places GIS data on the Web.				
GRASSLinks	www.regis.berkeley.edu/gldev/regis.html	discrete zooming and discrete panning	no support	layers
A Web interface to a GIS system that facilitates data sharing between environmental planning agencies, public action groups, citizens, and private entities.				
Hourly/Daily Rain Data	precip.fsl.noaa.gov/hourly_precip.html	discrete zooming and continuous panning	no support	layers
An on-line tool to display daily and hourly precipitation totals from various locations all over the US.				
Houston Real-Time Traffic Map	traffic.tamu.edu/incmap/incmap.asp	no support	no support	multiple data sources viewed separately
A web-based application to convey real-time traffic conditions in Houston, Texas.				
Interactive California Environmental Management, Assessment, and Planning System (ICEMAPS)	icemaps.des.ucdavis.edu/icemaps2/ICEMapInit.html	discrete zooming and discrete panning	no support	layers
A Web interface to an environmental, California GIS.				
Interactive Web-Mapping Tool	atlas.geo.cornell.edu/ima.html	discrete zooming and discrete panning	no support	layers
Cornell's Geoscience Information System tool on the Web.				

Image Web Server	www.earthetc.com/ecwcounty/ecw_county_frame.asp	discrete zooming, continuous zooming, and continuous panning	no support	one data source
A demonstration of Image Web Server technology – county assessor data is provided on-line.				
JShape Software	www.jshape.com/index0.html	discrete zooming and discrete panning	no support	layers
A Java software package that supports fast and easy creation of interactive, web-based, GIS applications.				
Macromedia Shockwave FreeHand maps	www.stmaartenstmartin.com/freehand	discrete zooming and discrete panning	no support	one data source
This software displays a FreeHand file on the web.				
MAPBLAST!	www.mapblast.com	discrete zooming and discrete panning	asynchronous using an external resource	layers
An on-line application to drawn maps of anywhere in the US and provide routing information.				
Map-It	crust.er.usgs.gov:80/mapit	no support	no support	one data source
A demonstration of the free, open source software package GMT. This on-line tool draws a map of user-supplied latitude and longitude pairs.				
MapQuest	www.mapquest.com	discrete zooming and discrete panning	asynchronous using an external resource	layers
An on-line application to drawn maps of anywhere in the US and provide routing information.				
Maps.com	www.maps.com/learn	discrete zooming and continuous panning	no support	layers
Education resources to make learning fun. Maps are animated and interactive.				
Maps On Us	www.mapsonus.com	discrete zooming and discrete panning	asynchronous using an external resource and synchronous using the map interface	layers
An on-line application to drawn maps of cities and yellow page listings in the US and to provide routing information.				
MOOsburg map widget	moosburg.cs.vt.edu	continuous zooming and continuous	asynchronous and synchronous using an external	non-interactive

		panning	resource	
A navigation tool, awareness tool, and end-user developer tool for MOOsburg.				
MyWay.com's javamap	www.zip2.com	discrete zooming and discrete panning	asynchronous using an external resource	non-interactive
An on-line application to draw maps of anywhere in the US.				
NOAA Real-time TAO Buoy Data Display	www.pmel.noaa.gov/toga-tao/realtime.html	no support	no support	multiple data sources viewed separately
An on-line tool to display real-time data from ocean buoys in order to analyze El Niño and La Niña.				
Pacific Century Systems Limited's GIS Map	lps.pcgsys.com/wml/elpas/html	discrete zooming and discrete panning	no support	layers
A password-protected website to track co-workers' locations at PCS.				
Portland State University Child Welfare Partnership Thematic Mapping Program	www.ncn.com/~riling/Mapper/ore.htm	no support	no support	multiple data sources viewed separately
A web-based tool that provides child welfare data for the state of Oregon.				
Puget Sound Traffic Conditions	www.wsdot.wa.gov/PugetSoundTraffic	multiple maps	no support	one data source
A webpage that displays the current traffic conditions for the Puget Sound area in Washington state.				
Race Track Locator	chasinracin.net/track-locator	multiple maps	no support	non-interactive
A website to locate race tracks around the US.				
Ramonamap (Bartlett, 1994)	Western Research Lab	no support	asynchronous using the map interface	one data source
An application to share office information spatially.				
Rand McNally TripMaker Deluxe 1999 Edition	Rand McNally	discrete zooming and discrete panning	no support	layers
A commercial software product to plan road travel.				
Town of Blacksburg WebGIS	www.webgis.net/blacksburg	discrete zooming and discrete panning	no support	layers
An on-line tool that provides information regarding the town's street system, properties, parks, bus stop locations, zoning, etc.				

Taiwan Map	peacock.tnrc.edu.tw/ADD/maps/taiwanmap.html	multiple maps	no support	non-interactive
A primitive interactive map website.				
Triscape Map Explorer	www.triscape.com	continuous zooming and continuous panning	asynchronous using the map interface	non-interactive
An on-line application that provides an alternative approach to on-line mapping.				
Virtual Slaithwaite (Evans <i>et al.</i> , 1999)	www.ccg.leeeds.ac.uk/slaithwaite	discrete zooming and discrete panning	asynchronous using the map interface	one data source
A demonstration of a local, environmental decision-making, public participation tool.				
Virtual Tourist	www.virtualltourist.com	multiple maps	asynchronous and synchronous using an external resource	only one data source
A web-based application that allows people from all over the world to share travel plans.				

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