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The purpose of this study is to discover if there is a difference between user satisfaction with vector map images versus user satisfaction with raster map images. Many studies in the past have examined the advantages and disadvantages of vector versus raster images of continuous geographic data, but no one has previously looked at the effects that these images have on user satisfaction. The population sample was UNC School of Information and Library Science graduate students. Results show that for city, street, and building locations, UNC SILS graduate students have greater self-reported user satisfaction when viewing vector images on Google Maps. However, for topographic features such as mountains and lakes, students prefer raster format.

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RASTER AND VECTOR MAP IMAGES

by
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Introduction

With the advent of digital map imagery in 1967, an increasing number of websites are offering views of maps. These maps come in all shapes and sizes, and offer users several forms of data presentation options to choose from. Two of these options are raster and vector graphics. Raster graphics are scanned images composed of tiny dots called pixels. They are better at showing photographs and satellite images, and they cannot be scaled without loss of resolution. Vector graphics are drawn images composed of lines and curves. They are better at showing map outlines and contours, and they are highly scalable. Map librarians, in concert with the USGS (United States Geological Survey), currently offer both types of graphics to users seeking to investigate this issue. Few studies address issues of why an individual would or should choose one type over the other. A satisfaction-oriented HCI (human-computer interaction) and usability experiment explores the user's subjective opinions about a map interface, while the researcher examines the behavior of users who view maps online. The research goal is to make systems better; knowledge of user responses should make it easier for systems designers to satisfy map user needs by providing them with well-designed geographic data.

Readers must become familiar with several terms in order to fully understand this research study:

1. *Continuous geographic data* is defined as digital maps consisting of thin, curved, brown or black lines that portray elevation differences as “wrinkles” on the earth’s surface, randomly sampled from Google Maps, viewed by 18 graduate students.
2. The *maps* used in this study are defined as randomly sampled, two-dimensional, digital images (a mix of raster and vector) of portions of the earth’s surface—including coastlines, cities, and rivers—from the Google Maps website.
3. A *vector* graphic is a type of map image composed of connected lines; it can be scaled up or down (zoomed in or out) without any loss of quality.
4. *Raster* graphics are a type of map image composed of pixels; it cannot be scaled to a higher resolution without the loss of quality.

The research question is: when viewing continuous geographic data on Google Maps, will raster images or vector images produce greater self-reported user satisfaction for UNC SILS graduate students under varying criteria? Vector graphics produce a smooth image and can be resized without distortion. Because of this, the hypothesis is that vector images will yield greater self-reported user satisfaction. The null hypothesis is that there will be no difference in the self-reported user satisfaction with either the vector or the raster images.

Literature Review

Map librarianship is a specialty area, often perceived as mysterious to many information professionals. Nichols (1982) writes, “Traditionally, there is a division in libraries where maps are concerned; the generalist librarian often lacks knowledge of the characteristics of maps” (7). With the advent of the Internet and the ease at which map images are now available, it is important for librarians to gain an understanding of these valuable resources. Many users look for spatial information and spatial questions are commonly asked during reference interviews. Presenting the user a map only takes care of half of the problem. If the user does not understand the map, then the geographic data is useless. Včkovski, Brassel, and Schek (1999) state, “The traditional way to view geospatial data has been as a map. One of the ways publishers of geospatial data add value is the manner in which they are able to present the data visually” (24). Another option for presenting the user with spatial data includes maps on the Internet via computer. Nearly a quarter of a century ago, this information need was revealed by HCI (human computer interaction) experts. Nichols (1982) predicted that “Digitization of all spatial data will help meet the present and developing needs for correlation of data from a wide range of sources (ground surveys, air photography and remote-sensing satellites) and from a wide range of disciplines, and for the selection of a proportion of these data and their presentation in various forms” (253). In addition, it is easier to keep map sheets up-to-date in digital form.

In terms of map data, Larsgaard (1998) contends, “The data may be stored in such a way as to provide considerable flexibility, the response time is greatly decreased, and

maintenance of [information] is relatively quick and simple” (48). Along with the HCI literature on mapping, there is an abundance of literature from the field of psychology on mapping. Here is found the impacts of interactive geographic data on the user’s mind. MacEachren and Kraak (1997) reveal that “All mapping can be considered a kind of visualization...it is to the cognitive and decision-support functions that much of the new geo-information technologies are directed—particularly those technologies which include maps having dynamic and interactive components” (335). This was predicted years before the modern internet. Engelbart (1962) suggests, “[computers] can improve the intellectual effectiveness of the individual human being” (ii). A two-way communication between the user and the map is essential. As geographic data becomes more sophisticated, designers must find a way to get the user more involved in the process. Cartographers must remember that the map is created for the user, not the other way around. Andrienko, et al. (2002) argue that “[A] high degree of user interactivity is a general requirement for maps designed to support data analysis and decision making” (325). In order to assess as many examples as possible of map presentation data, we must go to the source.

As stated by the United States Geological Survey (2006), “USGS is the Nation's largest water, earth, and biological science and civilian mapping agency.” The United States Geological Survey has a main .gov website and several subsidiary websites that provide continuous geographic data to users around the world. Larsgaard (1998) claims, “[The] USGS is prominent in the production of cartographic digital databases” (57). Similar studies in this area include those by: Koussoulakou and Kraak (1992), who investigated animated versus static maps and found that animated maps resulted in faster

user response times; MacEachren, et al. (1998), who investigated map animation, focusing and classification and found that map animation facilitates visual thinking, pattern noticing, and hypothesis generation; and Harrower, MacEachren and Griffin (2000), who investigated map animation, temporal focusing and temporal brushing and found that “The level of the visualization system must be well matched to the knowledge users have” (279). According to Wise (2002), “Two [data] models are in common use—the Vector and Raster models. Each provides a model of a map in a form which can be stored on the computer, but without being tied to any particular software package or type of computer” (7).

Raster graphics are made up of tiny picture elements, called pixels for short. The Conrac Corporation (1985) in its handbook defines raster as “computer graphics in which a display image is composed of an array of pixels arranged in rows and columns” (281). Maguire (1989) agrees, “In the raster structure, each pixel is referenced by its row and column number and information is stored about the type of feature” (81). Dent (1999) states, “Raster formats are also called bitmapped or pixel file formats. These kinds of files contain descriptions of the On/Off state of each of the picture elements of the graphic image” (347). When applied to mapping, a picture element is called a ‘cell.’ An arrangement of cells in rows and columns on a map sheet is called a grid. The grid is one of the defining characteristics of raster graphics. Peterson (2003) defines raster as a “format in which the image is represented as a grid of picture elements called pixels” (7). LeGates (2005) states that raster “represents physical reality as a matrix (grid) of cells arranged in rows and columns. Each cell contains a single pixel” (138). Wise (2002) describes raster as “an imaginary grid laid over the map. Each cell in the grid, called a

pixel, is examined to see what feature falls within it” (8). To create a raster format, a mapsheet is first scanned. The United States Geological Survey (1999) asserts, “A digital raster graphic is a scanned image of a topographic map” (1). The father of GIS (Geographic Information Systems), Tomlinson (2003) claims that “scanning results in data that is in raster format” (257). Once a map is scanned into a raster image, there are many ways to distinguish it from vector. Tomlin (1990) contends that raster graphics “tend to be like photographic images... the data provided by satellites are in raster format” (44). Davis (2001) calls raster “a satellite image structured as a grid of cells, with each cell having a single data value” (51).

Vector graphics, by contrast, use points, lines and polygons to represent objects. Ryerson (2006) emphasizes, “Vector graphics [are] made of lines and curves defined by mathematical objects.” Davis (2001) maintains that “A vector format consists of lines, just like a hand-drawn map” (51). Wise (2002) explains, “In vector, each object which is to be stored is classified as either a point, a line or an area and given a unique identifier” (9). Tomlin (1990) states, “Vector graphics tend to be like line drawings” (44). Additionally, vector graphics are based on numerical equations. Dent (1999) explains that “The vector data model is based on points (or nodes), lines (or arcs), and polygons. Vector format is also called an object-oriented file. The files use mathematical instructions to identify the vectors of the graphic shapes in the image” (112). Peterson (2003) notes that “Vector formats use x and y coordinates to encode a map” (8).

Each type of map can do different things for the map user. The literature on raster graphics is much more negative than positive. Both positive and negative comments are included in this review. Highlighting the positive features of raster, Dikau and Saurer

(1999) state, “There are some good reasons to use raster data structures in a GIS. One reason is the simplicity” (177). The United States Geological Survey (1999) asserts, “Digital raster graphic is an effective mapping tool” (2). Davis (2001) lists the advantages of raster graphics as: a simple data structure; they are easy to understand and use, even by beginners; the grid structure makes analysis easier; the user’s computer can be low tech and inexpensive; and finally, raster graphics specialize in remote sensing imagery.

Balancing both the positive and negative aspects of raster graphics, Wise (2002) notes, “Raster has the great virtue of simplicity, but it can produce very large files. The precision with which a raster layer can represent spatial data is related to the size of the pixel” (85). Dent (1999) observes:

The advantage of [raster] is that it handles color easily. The disadvantages are that it produces jagged impressions of curved lines, consumes much storage space in the computer’s memory, and is limited to the resolution technology that existed when it was created. (347)

Among the many user complaints about using raster in the literature are extensive processing time. LeGates (2005) maintains, “The larger the number of grid cells in a raster dataset, the more time it takes a computer to process the data. Rasters covering large areas can take a long time to process” (141). Another problem is the fact that once a raster image is scanned, it cannot be altered without extreme difficulty. Brewer (2005) suggests:

Raster should be used only for maps that you want to show or print as-is. This inflexibility can be an advantage when you do not want to pass on a version of your work that can be easily edited or adapted. In raster, text, lines, and colors are difficult to edit. To change a map color, every pixel in an area [must] be selected. (33)

Another snag is that raster images are often hazy and nebulous. Včkovski, Brassel, and Schek (1999) observe that “topological relations are not well defined for raster representations” (293). DeMers (1997) claims:

Rasters do not provide precise locational information. Points are represented as a single grid cell. The assumption is that somewhere inside that grid cell, a point object can be found. The more land area contained...the less we know about the absolute position of points, lines, and areas represented by this [raster] structure. (98, 99)

Another issue with raster is its inferior scalability. Scalability is defined as the ability to increase or decrease in size without altering proportion. Designworks (2003) comments, “[Rasters’] weaknesses are in their poor scalability and relatively large file sizes.” Kerman (2005) reveals that “Raster graphics are almost always relatively large files. [They] also can’t be scaled very effectively. They tend to get grainy, similar to a photograph that has been enlarged.” Davis (2001) asserts:

[Raster] does not maintain true size, shape, or location for individual features. Even where no data exists, cells must be coded. Rasters generalize a landscape and yield spatial and classification inaccuracies. A major problem with the raster structure is that the shape of features is forced into an artificial grid cell format. (65, 70, 71)

The more you enlarge a raster image, the more it seems to come apart at the seams and you start seeing the individual pixels that make up the image. This diminishes image smoothness and quality. Hall (2003) notes that “The problem with a bitmap is that when enlarged the colored dots can be very big, making the image look very blocky.”

According to Wise (2002):

The raster model gives a poorer representation because of the jagged appearance produced by the pixels. This can be improved, but only at the cost of a smaller pixel size, and hence larger files. With a pixel representation, it is more difficult to produce a range of different symbolisms. (178, 179)

These problems lead to high computer storage needs and very large data sets, even when the useful data is low. Maguire (1989) states, “[Raster] is a very inefficient data storage structure” (81). DeMers (2002) confirms, “Raster databases take up more space and require substantial computing power. Among the more typically stated deficiencies of the grid cell are its less attractive aesthetic appeal” (23). The United States Geological Survey (2001) warns:

Keeping file sizes as small as possible may seriously compromise image quality. DRG [digital raster graphic] resolution is not adequate to duplicate the visual quality of a published paper map. Printing a DRG will never produce a map that looks as good as the published lithographic print. (4)

Thus, even though raster graphics are simple and easy to understand and use, when it comes to evaluating them on file size, scalability, processing time, smoothness of resolution, and storage space, they come up short in the literature compared to vector.

The literature on vector graphics is generally positive with only a few negative comments. Dent (1999) stresses that vector’s “disadvantages include difficulty of editing and a longer processing time” (348). According to Davis (2001), the disadvantages of vector include the fact that it is somewhat difficult and complex to manage; it requires more powerful, high-tech machines; it is more expensive than raster to produce; and learning and teaching the use of vector is more challenging than raster. Nevertheless, the

positive commentaries on vector strongly outnumber the negative. The most valuable aspect of vector images is that users can zoom in or out on them without loss of quality. Peterson (2003) suggests, “If maps are produced with vector-focused software, then users can zoom into concentrations/areas of interest at chosen points” (47). Hall (2003) states, “vector graphics are made of mathematical formulas defining lines that make up the image, so they never appear blocky when enlarged.” Designworks (2003) notes, “[Vector] strengths include their ability to render large areas of color with relatively small file sizes. They can also be reduced or enlarged to any size without losing any image quality.”

Another benefit is the low storage space needed to save vector data because the only part that changes is the mathematical factor attached to each image size. A two by four inch image is the same file size as a two by four foot image. Only the scaling factor changes, so it describes the same image with less information than raster. Dikau and Saurer (1999) state, “Vector data structures are the optimal way to store data because much disk space can be saved” (177). Tomlin (1990) argues, “Cartographic data at a given level of precision can be stored much more efficiently in vector form” (44). Dent (1999) confirms this by saying, “the advantages of vector-based files are that they take up less storage space, represent curves without jagged impressions and the resolution is limited only to the output device” (348).

Kerman (2005) adds, “Vector graphics have two advantages: the file size tends to remain small (therefore, it downloads fast), and the image can be scaled to any size without degradation of the image quality.” The ability to resize an image without altering its proportions is an essential characteristic of geographic data. ClipartLab (2003) lists the

advantages of vector as: complete scalability (you can resize vector graphics without any loss in quality); usability for both web and print; it is completely editable (you can resize, skew, rotate and reshape it, or weld and trim it); and it has background transparency (it will match any background, any color and any pattern). Marsh (2005) maintains, “Vector graphics are easily modified and are not affected detrimentally by scaling (enlarging or reducing their size). Because vector elements are mathematically-defined, scaling simply requires modification of their mathematical locations.”

Resolution is the smoothness of an object or map image. The higher the resolution, the better the image, and the easier it is to conduct research and find known locations on the map. Chastain (2004) affirms:

Vectors are defined by equations, so they always render at the highest quality. Changing attributes of a vector does not affect the object itself. Because they're scalable, vectors are resolution independent. You can increase and decrease the size of vectors and [they] remain crisp and sharp, on screen and in print.

Ryerson (2006) agrees:

A vector graphic is resolution-independent—that is, it can be scaled to any size and printed on any output device at any resolution without losing its detail or clarity. As a result, vector graphics are the best choice for graphics that must retain crisp lines when scaled to various sizes.

In summary, Davis (2001) lists all of the advantages when he states that vector graphics are more map-like, have very high resolution, have high spatial accuracy, use less storage space, and have smaller and faster files because only the essential data elements are stored. Magnification does not damage the display quality of vector.

Now that the two main types of spatial geographic data are separately defined and their advantages and disadvantages are listed, raster data can be contrasted to vector data. Contrasting their definitions, Maguire (1989) says, “Raster-based GISs deal with data encoded in grid cell format...vector-based GISs deal with data encoded as vectors using co-ordinates” (174). Krygier and Wood (2005) state, “Vector data consists of points, which can be connected into lines, or areas. Raster data consists of a grid of cells, each with a particular value or values. The most common mappable raster data is satellite imagery” (60). Davis (2001) claims, “raster uses a grid cell structure, whereas vector is more like a drawn map” (61).

The literature contrasting their features favors use of vector instead of raster. In terms of file size and storage space, Kraak and Brown (2001) suggest:

[Users] will want clear, well-designed maps that will also look good when printed. The problem here is that if such maps are in raster format, then downloading could be very slow. Providing maps in a vector format may be more efficient...a vector image consumes much less memory space than raster. (131, 132, 183)

Brewer (2005) asserts, “Vector files are often much smaller than the raster files” (34).

Maguire (1989) adds:

The vector system has the advantage that it is a more efficient data storage structure than the raster system [because] only the co-ordinates which actually describe the features in a cartographic image need to be coded. In the raster scheme every pixel in the image must be coded as either full or empty. (66)

Dent (1999) explains, “Vectors are more suited than rasters for tasks when precise location is important because of the efficiency of storing the numerous attributes...as opposed to much larger individual raster images” (113).

With regard to shape and spatial accuracy, Davis (2001) notes that in “[vector], shape is better retained, much like an actual map. Vector is more spatially accurate than raster format. Vector features appear more realistic than raster features and have better spatial accuracy” (65, 79). DeMers (2002) observes, “The primary [raster] disadvantages are related to the relative lack of spatial resolution compared with their vector counterparts” (20). DeMers (1997) states:

Even the fastest computers can be slowed to a crawl if highly complex calculations are performed on very large raster databases. Vector allows us to give specific spatial locations explicitly. The vector data structure is much more representative of dimensionality as it would appear on a map. (100)

Tomlin (1990) adds, “Raster schemes are used to record layers containing tens or hundreds of thousands of locations, while the number of locations on a vector layer may reach millions or billions” (42).

As for being editable, vector surpasses raster graphics in every way. DeMers (2002) confirms:

Some people feel more comfortable working in a vector environment, particularly those comparing cartographic objects within a single theme. Raster GISs are more position oriented than their vector counterparts, which are more theme oriented. Vector systems assign specific coordinates to individual points. (21)

Marsh (2005) writes, “Raster images can be more difficult than vector graphics to modify.” Peterson (2003) contends, “Vector graphics can be manipulated, easily created on the fly, deleted, and re-used. A raster map is only an image. It may have hotspots or image-maps attached, but nothing more” (199). Tomlin (1990) argues, “Raster structures are position-oriented, while vector structures are theme-oriented. One records

characteristics that are associated with locations, while the other records locations that are associated with characteristics” (44).

Discussing image sharpness, Davis (2001) proposes, “Vector seems to be much simpler and easier than raster for data visualization. Each raster cell has only a color/tone value and nothing else; there is no connection with surrounding cells and no recognition of features...many GIS projects prefer vector data with feature definition” (65, 147, 149). Kraak and Brown (2001) state, “Vector-based images will keep their sharp character when enlarged but raster-based images will show enlarged pixels” (92). Chastain (2004) emphasizes, “Another advantage of vector images is that they’re not restricted to a rectangular shape like bitmaps.” Finally, information from the ClipartLab site (2003) states, “While bitmap graphics is printable only if its graphical resolution is 300 dpi or higher, vector graphics is always printer friendly. Working with bitmap graphics is usually a nightmare. Working with vector graphics is always a pleasure.”

What do users need in an interface when looking at maps online? There are many examples of poor websites on the Internet today. The aspiration of this study is to supply data that will improve map interfaces. To do so, poor versus acceptable interfaces must be defined. The literature shows us that a poor interface is one that does not satisfy or respect the needs of the user. Lynch and Horton (2002) explain:

If your site is successful it will have to be genuinely useful to your target audience, meeting their needs and expectations without being too hard to use. The goal is to never require readers to conform to an interface that places unnecessary obstacles in their paths. Users are not impressed with complexity that’s gratuitous. (1, 20, 23)

Shneiderman and Plaisant (2004) add:

At an individual level, user interfaces change many people's lives. Too often, users must cope with frustration, fear, and failure when they encounter excessively complex menus, incomprehensible terminology, or chaotic navigational paths. The first goal is to ascertain the users' needs. (5, 13)

Another characteristic of a poor map website is that it is a conundrum. Andrienko, et al. (2002) state, "Users feel uncomfortable when encountering unfamiliar features with unclear purpose" (328). Norman (1998) highlights the struggle that exists between making computers more like humans versus making humans more like computers when he says:

The internet and the Web give much more power, much more information, more things to lose track of, more places to get lost in. More ways to confuse and confound...designers determine the needs of the technology and then ask people to conform to those needs. The result is an ever-increasing difficulty in learning. (74, 159)

Another problem with poor interfaces is they force users to wait a long time for information. Raskin (2000) claims:

That a user should not be kept waiting unnecessarily is [a] design principle. It is also humane not to hurry a user. Users should set the pace of an interaction. Interface features must be both accessible to the naïve and efficient for the expert, and the transition from one to the other should not demand retraining. (8, 115)

Lynch and Horton (2002) confirm, "Users will not tolerate long delays. For most computing tasks the threshold of frustration is about ten seconds" (23). Kraak and Brown (2001) agree, "On a particular Internet page, most users tend not to wait too long; after

ten seconds they get impatient and after 20 seconds they are gone. Therefore, an image on a page should display within seconds” (181).

The good news is that some map user websites, especially those from the USGS, are headed in the right direction in terms of user satisfaction. They recognize and attempt to adhere to user needs. Peterson (2003) notes, “There seems to be a general trend towards user-centered design practices [when] providing map services on the Internet. Today’s Web map services must consider the actual needs and conditions of the individual user” (229). Nielsen (1993) observes, “User interfaces are a much more important part of computers than they used to be...the user interface developer needs to acquire a certain design humility and acknowledge the need to modify the original design to accommodate the user’s problems” (8, 11).

A part of providing for users’ needs is to find out who the website users really are and what they like or dislike. Garrand (2001) contends:

A key way to anticipate needs is to know as much about [users] as possible. Knowing the audience is absolutely essential. Knowing what the user considers appealing affects every element of interactive design. Interface design is crucial in deciding how content will be organized. It dictates how the viewer will interact. (6, 11)

Rosson and Carroll (2002) argue:

People are not all the same. Individuals vary in many ways, and these differences have implications for their technology needs. It is important to keep special needs in mind when designing and evaluating user interfaces, seeking to provide new opportunities and minimizing the challenges faced by these populations. (356)

Paraphrasing a statement from the Conrac Corporation (1985) manual, “A person with a Western cultural background will automatically start at the upper left of the screen, move

to the right and progress in a clockwise direction. Size, brightness, and color all contribute to an image's impact" (259). And finally, Singh and Pereira (2005) stress:

It is increasingly an enormous challenge to be able to draw [users] to a web site and build trust and loyalty. Users are more comfortable with and exhibit a more positive attitude toward web sites that are consistent with their cultures. Culturally sensitive web content enhances usability, accessibility, and web site interactivity. (17, 18)

An excellent way to improve the sensitivity of the map interface and increase usability is to make it less bewildering to the user. Nielsen (2000) maintains, "Web browsing user interfaces must improve enough [so] that it is as easy to navigate the Web as it is to leaf through the pages of a book. Simplicity always wins over complexity, especially on the Web where every five bytes saved is a millisecond less download time" (4, 22). Waters (1997) reasons, "If your site demands a lot from its visitors, you have to consider your viewer's familiarity and comfort level with technology" (19, 20).

Every website is or should be designed with a particular population in mind. For this research study, graduate students were the target audience; in particular, graduate students from the University of North Carolina School of Information and Library Science. According to Coates and Coates (1985), "the University is sort of a miniature state, a little world, whose members represent every condition of wealth and poverty, every type of local character, every phase of religious faith and political belief" (xvii). This population was chosen for the research study because of the keen interest in how students will react to the two types of geographic images. Chartered in 1789, UNC-Chapel Hill is the oldest public university in the United States of America. Menzer

(1999) writes, “In Chapel Hill, the Southern part of heaven, the University of North Carolina was recently ranked among the top 20 in the nation for beauty” (16).

One of the most notable characteristics of the school and its graduate students is their passion for winning. Menzer (1999) states, “A game with Duke makes any Carolina fan’s heart beat faster” (16). Another important characteristic is their diversity. Mitchell (1996) reveals that “Grad students come from all walks of life and continue their studies for a variety of reasons. Some returning students are older, coming back to school for the sheer pleasure of it” (8). Although we cannot categorize all graduate students for the purpose of this study, there seems to be a common thread in the literature when it comes to a general description of the typical American graduate student. Specific traits that are common to many people who attend graduate school, according to Rold (1998) are:

- high achievers,
- well-organized,
- excellent reading abilities,
- self-motivated and intelligent,
- able to solve problems using both logic and creativity,
- able to tolerate uncertainty and frustration,
- good analytical skills,
- good research skills,
- good oral communication skills,
- enjoy studying and teamwork,
- empathetic and understanding,
- and a strong interest in seeing that justice is done.

Students in the School of Information and Library Science have these characteristics and provide a representative sample of the graduate student population.

In summary, the literature reveals that the advantages of vector graphics (adaptability, resolution, and file size) outweigh the advantages of raster graphics (comprehensible and photogenic) from the expert’s perspective. In addition, the

disadvantages of raster (file size, resolution, and scalability) offset the disadvantages of vector (expensive and complex). The fact that raster graphics cannot be altered once they are saved is a benefit for the graphics designer, but a loss to the user. The fact that vector graphics are dynamic and may be manipulated is a loss to the graphics designer but a benefit for the user. As a result of this examination of the literature, it is reasonable to assume that graduate student users will prefer maps presented in vector graphics format over those presented as raster map images. The hypothesis is that a sample of those studied will report greater satisfaction in using the vector graphic format. Modern computer monitors refresh themselves 75 times per second and display 72-130 pixels per inch. (The faster the refresh rate, the less the monitor flickers). The reasonable doubt of the above hypothesis is that on a computer screen, all images are rasterized by the monitor, so this may present a challenge and have an impact on whether users prefer vector or raster graphics.

Purpose of the Study

This study is an analysis of 18 students and their reactions to map images. Questions to be answered by the study are: What type of geographic data is more appealing to UNC SILS graduate students? Is there a significant difference between raster and vector map images? How do the two image types compare to each other in terms of user satisfaction? The purpose of the study is to provide a comprehensive understanding of why users prefer one type of map image to another. The study is needed because there are distinct advantages and disadvantages to both types of images.

This work is significant because it will benefit both the makers and viewers of map graphics. Although there has been controversy in discussion on the advantages and disadvantages of the vector versus raster images, this is the first empirical study to examine these two types of map images within the context of websites. Thus, it fills a distinct information gap and makes a useful contribution of new knowledge. The goal of all research should be to make systems better. The practical problem addressed by this research concerns the type of continuous geographic data offered on some map websites. If it can be determined what provides greater user satisfaction, better service can be provided. If graphics viewers are provided with better graphics, they can accomplish their goals faster and more efficiently. In the not-too-distant future, hikers and mountain climbers will doubtless carry sophisticated computer equipment that will allow them to navigate around the globe via map websites.

In terms of specific significance, SILS students will benefit from this study because they can learn about graphics efficiency and use this knowledge when they graduate. Some may be in a position to design websites that contain contour maps. Academic institutions will benefit from this study because professors from geography and city and regional planning can become more aware of the needs of their students. The USGS will benefit from this study because it is a major supplier of maps. USGS currently provides interactive interfaces which allow users to view topographic maps that are based primarily on digital raster graphics (USGS 2006). Results from this study may prompt this government agency to reexamine the need to invest in vector graphic images. The United States of America will benefit from this study because it will be able to assist other countries in the imaging industry. This line of research (i.e., a better understanding of map image preferences) might lead to the development of sophisticated imaging software which will enhance map readability on websites.

Methodology

An experiment is usually defined as one or more tasks or tests that are given to an individual for measuring a tool or the individual's knowledge. The purpose of this study is to determine which type of continuous geographic data users prefer—vector or raster. To achieve this end, analytical techniques, including a survey and an ordinal scale, were used in this study. 18 students were selected as subjects from a pool of volunteers. According to usability experts, four to six subjects are sufficient to answer questions about preferences and efficiency in webpage design (Nielsen 2006).

At 18 different viewing times, 18 separate graduate students sat down in front of a laptop screen and viewed maps (a mix of raster and vector) sampled from the Google Maps website. Google Maps was selected as the research venue because it is scalable and users can zoom in and out. Each student was given a series of locations to find using Google Maps. The first set of locations used the “Map” or vector function of Google Maps. The second set of locations used the “Satellite” or Raster function of Google Maps. At the end of the searches, each student answered a questionnaire about the experience.

The goal of the test was to determine whether and why users prefer vector images or raster images. The location of the test was the SILS IT lab, room 117 Manning Hall. The length of time for the test was one hour per student. The computer environment was an empty computer lab, at the end of the day, to ensure that classes were not in session. The experiment administrator and evaluator was the researcher.

Participants were graduate students, selected from students who expressed a willingness to participate in a study of maps from websites described on a flyer placed in their mail folders (See Appendix C). Students selected were listed in the UNC Directory as graduate students on the day of the study. Students were offered a chance to enter into a raffle to win a pair of movie tickets valued at \$14.00. The study design was submitted to UNC's Institutional Review Board and received approval in July 2006. The terminology of the study is defined as follows:

1. The *Websites* used in this study are defined as Google Maps websites within the www.google.com domain, with all the content therein. These were the source of the digital contour maps used in this study.
2. *Greater satisfaction* is achieved when one of the types of images randomly sampled from Google Maps and viewed by students has received at least five more satisfaction points from students (using an ordinal scale) than the other type of image.
3. *Self-reported* describes the results of an ordinal scale questionnaire that each of the users will fill out after viewing images randomly selected from Google Maps.
4. *Users* are defined as 18 UNC School of Information and Library Science graduate students selected from a pool of volunteers who were willing to participate in a study of maps from Google Maps described on a flyer placed in their mail folders, and who were listed in the UNC Directory as graduate students on the day of the study.
5. *Satisfaction* is defined as a positive, numerical, whole number value measured with an ordinal scale questionnaire filled out by the 18 students after viewing maps from Google Maps.

There were no other user aids, and no follow-up sessions. The data consists of the output of the survey, which was self-reported after the viewing, at the completion of the experiment. The criterion for evaluation was subjective. The users rated each image in their own words, using three adjectives per image. The test budget was \$14 dollars to

cover the inducement, and there was no cost to students for participating in the study.

This study followed some of the phases (not necessarily in order) of the research process:

For the Operationalize phase, the website selected was Google Maps, a website used on a daily basis. The questionnaire was designed and then pilot-tested on people who are not affiliated with SILS. The Population and sampling were performed by placing flyers in the SILS student mail folders in Manning Hall. The Observation phase was conducted by performing data collection from August to September 2006. Next, Data Processing and Data Analysis phases were completed.

The ordinal scale for data measurement was selected instead of ratio, interval or nominal, because it is easier to code into the computer and it ranks data in magnitudes, from best to worst. This type of scale uses positive whole numbers (except in the case of missing data, depicted as “-1”). To ensure reliability and validity and to guard against bias, each student was given the same exact amount of time to complete the experiment. To guarantee that questions were clear and specific, they were tested on people who are not affiliated with SILS. Users were instructed to judge which image they believed was subjectively better. Volunteers were used in selecting the students for the experiment. The unit of analysis was the subjective opinion of UNC SILS students.

The study has some limitations. Eighteen students selected from a pool of volunteers were tested in this experiment. For this reason, their opinions cannot be generalized to the entire student population, despite the fact that six individuals are generally considered a valid number for usability experiments. One website was used for the study; it contains multiple maps from multiple sources. The primary investigator

collected and analyzed the data and conducted the experiment and all interviews. Only the primary investigator came into contact with study participants.

Possible user risks or discomforts from participating in this study included but were not limited to: eyestrain, boredom, and epileptic seizures caused by flipping through images. In order to minimize these risks, the computer lab was well-ventilated and air conditioned on the day of the study. To protect user privacy, answers to the survey questions were secured in a locked container. Only the primary investigator had access to individually identifiable data. Names and PID numbers were not used. Codes were assigned, and the linkage file was secured in a locked container as well. Participants will not be identified in any report or publication about this study. A crosshatch shredder was used to destroy all evidence at the end of the study. As a reward for participating in the study, participants were entered into a drawing and the winner received a pair of movie tickets. Concerning the differences between raster and vector map images, it is hypothesized that vector images will provide greater self reported user satisfaction than raster images.

Results

The results of this study reflect those of previous evaluations of continuous geographic data. Similar studies in this area include those by: Koussoulakou and Kraak (1992), who investigated animated versus static maps and found that animated maps resulted in faster user response times; MacEachren, et al. (1998), who investigated map animation, focusing and classification and found that map animation facilitates visual thinking, pattern noticing, and hypothesis generation; and Harrower, MacEachren and Griffin (2000), who investigated map animation, temporal focusing and temporal brushing and found that “The level of the visualization system must be well matched to the knowledge users have” (279).

The 18 responses to the questionnaire were recorded and entered into a spreadsheet.

SUBJECT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Viewing	2	2	4	2	4	4	3	3	4	2	4	3	3	4	3	2	3	3
Resizing	0	2	0	1	4	4	3	3	3	2	3	0	3	1	1	3	3	4
Zooming	3	3	1	2	4	4	3	3	4	3	3	4	4	3	2	3	4	4
Enlarging	2	2	0	1	4	4	3	3	3	3	3	4	3	2	1	0	2	4

Table 1: Subject responses to questions 1-4.

The survey contained four diagnostic questions. Students were asked to rate their own prior experiences with certain map image tasks, using a scale of 0 to 4, with zero being the lowest ranking. In terms of prior experience with *resizing* map images, six of the students considered their experience to be minimal or below average, two remained neutral, and ten considered themselves above average or experts.

In terms of prior experience with *enlarging* map images, four students considered their experience to be minimal or below average, four remained neutral, and ten considered themselves above average or experts. In terms of prior experience with *zooming* map images, one student considered the experience to be below average, two remained neutral, and fifteen considered themselves above average or experts.

In terms of prior experience with *viewing* map images, five students remained neutral, seven considered themselves above average, and six considered themselves experts. Overall, most students rated themselves above average or higher in each category. For *zooming* and *viewing* map images, there were about the same number of above average ratings as there were expert ratings.

Each of the next 10 questions in the survey prompted students to list three adjectives of their own choice. If each student had selected three different adjectives, the total number possible of different adjectives would be 540. However, eight words were missing because some respondents listed less than three adjectives per question, and 27 of the recorded words were later discarded because they were not appropriate for the distinction between raster and vector map images in terms of their ease of use, speed, visual appeal, comfort level.

adequate	general	hi-fi	locational	temporal
broad	good	local	nice	too broad

Table 2: Discarded adjectives.

For each response, the remaining adjectives were examined. First, a spreadsheet was created with every question shown along the top and the adjectives arranged in sequence. Next, another spreadsheet was created using only the adjective-response questions, 5-14. These questions were divided in half between *raster* and *vector*, and the

vector responses were analyzed first. Most of the adjectives used by respondents addressed three main characteristics: ease of use, visual appeal, and level of detail. A fourth characteristic, performance speed, formed a very small subset that contained only eight adjective responses. The adjectives were then coded and sorted in terms of the three main categories and the single sub-category. The irrelevant words were discarded, and duplicates and synonymous responses were tagged and merged into the 10 most common responses. A running total was kept to ensure that each of the words was counted.

In terms of describing the vector image, the ten most common words related to *ease of use* and their frequencies are shown in Table 3.

Adjective	City	Street	School	Mountain	Lake	Total
confusing	2	0	5	0	7	14
helpful	3	3	5	0	2	13
informative	1	2	3	3	1	10
orienting	0	3	2	2	3	10
readable	2	1	1	1	1	6
representative	1	0	0	2	1	4
simple	1	2	2	1	1	7
understandable	1	4	3	0	0	8
unhelpful	0	0	3	2	9	14
useful	2	1	2	1	0	6

Table 3: Vector, *ease of use*.

As seen in Table 3, the city image in vector was described as useful, readable, and helpful. It was also described as confusing by two students. The street vector image was described as helpful, informing, orienting and understandable. The school image in vector was described as helpful the same number of times as it was described as confusing. The mountain vector image was described as informative, orienting, and representative. It was also described as unhelpful by two students. Finally, the lake image in vector was described as confusing and unhelpful by the majority of the students. In terms of ease of use, the most common adjectives used to describe vector were *confusing* and *unhelpful*.

In terms of describing the raster image, the ten most common words related to *ease of use* and their frequencies are shown in Table 4.

Adjective	City	Street	School	Mountain	Lake	Total
confusing	7	1	3	5	8	24
helpful	1	0	1	0	0	2
informative	2	0	0	0	1	3
orienting	0	1	1	0	0	2
readable	0	0	0	0	2	2
representative	1	0	1	0	1	3
simple	0	0	0	0	2	2
understandable	0	0	0	1	1	2
unhelpful	5	4	6	3	7	25
useful	0	0	1	0	1	2

Table 4: Raster, ease of use.

As seen in Table 4, the city image in raster was described as confusing and unhelpful by two-thirds of the respondents. The street raster image was described as unhelpful by four students. The school, mountain and lake images in raster were described as confusing and unhelpful by the majority of the students. In terms of ease of use, the most common adjectives used to describe raster were *confusing* and *unhelpful*.

In terms of describing the vector image, the ten most common words related to *visual appeal* and their frequencies are shown in Table 5.

Adjective	City	Street	School	Mountain	Lake	Total
cartoon-like	2	0	2	0	0	4
colorful	5	1	1	1	3	11
colorless	1	1	1	2	1	6
hidden	0	1	0	2	0	3
interesting	1	0	1	2	1	5
large	1	1	0	2	3	7
pleasant	2	1	0	4	0	7
small	2	1	1	0	1	5
sparse	1	0	0	6	0	7
uncentered	2	1	2	1	1	7

Table 5: Vector, visual appeal.

As seen in Table 5, the city image in vector was described as colorful, cartoon-like, and pleasant. It was also described as small and uncentered. The street vector image was described as pleasant. It was also described as hidden and uncentered. The school

image in vector was described as cartoon-like but also uncentered. The mountain vector image was described as pleasant but also sparse. The lake image in vector was described as large and colorful for the most part. In terms of visual appeal, the most common adjective used to describe vector was *colorful*.

In terms of describing the raster image, the ten most common words related to *visual appeal* and their frequencies are shown in Table 6.

Adjective	City	Street	School	Mountain	Lake	Total
cartoon-like	0	1	1	1	4	7
colorful	6	5	3	6	2	22
colorless	1	3	1	0	0	5
hidden	2	0	3	0	0	5
interesting	4	5	4	10	8	31
large	1	3	2	3	2	11
pleasant	5	2	3	0	6	16
small	3	3	1	0	0	7
sparse	0	0	0	0	2	2
uncentered	0	0	1	3	0	4

Table 6: Raster, visual appeal.

As seen in Table 6, the city image in raster was described as colorful, interesting, and pleasant for the most part. The street raster image was described as colorful and interesting for the most part. The school image in raster was described as colorful, interesting and pleasant. It was also described as hidden. The mountain raster image was described as colorful and interesting for the most part. The lake image in raster was described as pleasant and interesting for the most part. In terms of visual appeal, the most common adjectives used to describe raster were *colorful* and *interesting*.

In terms of describing the vector image, the ten most common words related to *level of detail* and their frequencies are shown in Table 7.

Adjective	City	Street	School	Mountain	Lake	Total
clear	6	7	3	3	2	21
cluttered	0	1	0	3	2	6
detailed	4	4	3	1	1	13
focused	1	0	0	0	0	1
high-level	2	2	3	3	0	10
precise	3	4	2	2	0	11
specific	1	7	1	1	1	11
unclear	0	1	0	0	3	4
undetailed	1	0	2	1	0	4
unspecific	0	0	0	1	2	3
vague	1	0	0	2	1	7

Table 7: Vector, level of detail.

As seen in Table 7, the city image in vector was described as clear and detailed for the most part. The street vector image was described as clear, detailed and specific for the most part. The school image in vector was described as clear, detailed and high-level for the most part. The mountain vector image was described as high-level and precise. It was also described as vague. The lake image in vector was described as unclear and unspecific for the most part. In terms of level of detail, the most common adjectives used to describe vector were *clear* and *detailed*.

In terms of describing the raster image, the ten most common words related to *level of detail* and their frequencies are shown in Table 8.

Adjective	City	Street	School	Mountain	Lake	Total
clear	1	1	1	3	1	7
cluttered	1	2	1	0	0	4
detailed	3	5	3	3	0	14
focused	1	1	1	1	0	4
high-level	0	0	1	1	1	3
precise	2	4	3	1	1	11
specific	3	2	0	0	0	5
unclear	4	1	4	6	1	16
undetailed	0	1	1	0	0	2
unspecific	0	2	0	1	0	3
vague	1	4	0	2	0	7

Table 8: Raster, level of detail.

As seen in Table 8, the city image in raster was described as unclear for the most part. The street raster image was described as detailed and precise but also vague. The

school and mountain images in raster were described as unclear for the most part. The lake image in raster was described as high-level and precise for the most part. In terms of level of detail, the most common adjective used to describe raster was *unclear*.

In terms of describing the vector image, the three most common words related to *performance speed* and their frequencies are shown in Table 9.

Adjective	City	Street	School	Mountain	Lake	Total
adjustable	1	0	0	0	0	1
immediate	0	0	1	0	0	1
moveable	0	0	0	0	1	1

Table 9: Vector, performance speed.

As seen in Table 9, the city image in vector was described as adjustable, the school vector image was described as immediate, and the lake image in vector was described as moveable. In terms of describing the raster image, the three most common words related to *performance speed* and their frequencies are shown in Table 10.

Adjective	City	Street	School	Mountain	Lake	Total
adjustable	0	1	1	1	0	3
immediate	0	0	0	1	1	2
moveable	0	0	0	0	2	2

Table 10: Raster, performance speed.

As seen in Table 10, the street, school and mountain images in raster were described as adjustable, both the mountain and lake raster images were described as immediate, and the lake image in raster was described as moveable by two students. In terms of performance speed, the most common adjective used to describe raster was *adjustable*.

For the next five questions, the subjects were asked to state their preferences for either vector or raster when searching for specific types of images. The V's in Table 11 indicate that vector was chosen, and the R's symbolize raster.

SUBJECT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
City	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
Street	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
School	V	R	V	V	V	V	V	V	V	V	V	R	V	V	V	V	V	V
Mountain	R	V	R	R	V	R	R	V	R	V	R	R	V	R	R	V	R	R
Lake	R	V	R	R	V	V	R	V	R	V	R	R	R	R	V	V	R	R

Table 11: Subject responses to questions 15-19.

When locating a *city* or a *street*, the respondents unanimously preferred vector images. As for locating a *school* building, 16 of the respondents preferred to use vector format, and two preferred raster. When viewing a *mountain*, two-thirds of the respondents preferred to use raster images, and one-third preferred vector. As for viewing a *lake*, 11 of the respondents preferred to use raster images, and seven preferred vector.

For the final eight questions, the subjects were asked to rate their experience on a scale of 0 to 4 (zero being the lowest) with the raster and vector images seen during the study, in terms of four factors: *ease of use*, *comfort level*, *performance speed*, and *visual appeal*. Table 12 shows the ratings for Ease of Use.

SUBJECT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Vector	3	3	4	4	3	4	3	4	4	3	3	4	4	4	3	4	3	4
Raster	3	2	1	2	1	3	2	4	3	1	3	3	4	3	1	4	3	3

Table 12: Subject responses to questions 20 and 21.

As seen in Table 12, one-third of students rated vector the same as raster for ease of use, while two-thirds of the students rated vector higher than raster. In addition, vector did not receive any rating lower than “3.” In terms of the highest rating, “4,” vector

received more than three times as many high ratings as raster. Table 13 shows the ratings for Comfort Level.

SUBJECT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Vector	3	3	4	4	3	4	3	4	4	4	3	4	4	3	4	4	4	4
Raster	3	1	1	2	1	4	3	4	4	3	3	3	2	3	2	4	4	3

Table 13: Subject responses to questions 22 and 23.

As seen in Table 13, half of the students rated vector the same as raster for comfort level, while the other half of the students rated vector higher than raster. In addition, vector did not receive any rating lower than “3.” In terms of the highest rating, “4,” vector received more than twice the number of high ratings as raster. Table 14 shows the ratings for Performance Speed.

SUBJECT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Vector	3	4	3	4	4	4	4	3	4	3	2	4	4	2	3	4	3	4
Raster	2	4	1	3	4	4	3	3	3	3	2	2	4	4	3	3	2	4

Table 14: Subject responses to questions 24 and 25.

As seen in Table 14, half of the students rated vector the same as raster for performance speed, eight of the students rated vector higher than raster, and one student rated raster higher than vector. In this area, vector did not receive any rating lower than “2.” In terms of the highest rating, “4,” vector received four more high ratings than raster. Table 15 shows the ratings for Visual Appeal.

SUBJECT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Vector	2	2	1	3	3	4	4	3	3	1	2	2	4	2	4	4	2	4
Raster	4	4	4	3	2	4	2	3	4	3	3	4	2	4	3	3	3	2

Table 15: Subject responses to questions 26 and 27.

As seen in Table 15, half of the students rated raster higher than vector for visual appeal, three of the students rated vector the same as raster, and one-third of the students

rated vector higher than raster. In this area, raster did not receive any rating lower than “2.” In terms of the highest rating, “4,” both raster and vector shared about the same number of high ratings.

A closer look at the answers to questions 20-27, separating the vector from the raster responses, revealed the following information.

VECTOR	0 rating	1 rating	2 rating	3 rating	4 rating
Ease of use				8	10
Comfort level				6	12
Performance speed			2	6	10
Visual appeal		2	6	4	6

Table 16: Subject responses to vector questions only.

In terms of the vector image’s overall ease of use, eight of the respondents rated it above average and 10 gave it the highest rating. In terms of the vector image’s overall comfort level, one-third of the respondents rated it above average and two-thirds gave it the highest rating. In terms of the vector image’s overall performance speed, two of the respondents remained neutral, one-third rated it above average and 10 gave it the highest rating. In terms of the vector image’s overall visual appeal, two of the respondents rated it below average, one-third remained neutral, four rated it above average and one-third gave it the highest rating. While the vector scores accumulate in the 3-4 rating level, raster scores are spread evenly across the rating spectrum.

RASTER	0 rating	1 rating	2 rating	3 rating	4 rating
Ease of use		4	3	8	3
Comfort level		3	3	7	5
Performance speed		1	4	7	6
Visual appeal			4	7	7

Table 17: Subject responses to raster questions only.

In terms of the raster image's overall ease of use, four of the respondents rated it below average, three remained neutral, and eleven rated it above average or higher. In terms of the raster image's overall comfort level, three of the respondents rated it below average, three remained neutral, and twelve rated it above average or higher. In terms of the raster image's overall performance speed, one of the respondents rated it below average, four remained neutral, and thirteen rated it above average or higher. In terms of the raster image's overall visual appeal, four remained neutral, seven rated it above average, and seven gave it the highest rating.

Two distinct patterns emerged throughout the study. If a student preferred the mountain image in vector, then the lake was also preferred in vector, with three exceptions. Looking closer at the three exceptions, two out of three exceptions prefer to see a lake image in vector but a mountain in raster, and all three exceptions preferred vector in four of the five scenarios of map images (city, street, school, mountain, and lake). If a student preferred the mountain image in raster, then the lake was also preferred in raster, with three exceptions. Looking closer at the three exceptions, one out of three exceptions prefers to see a lake image in raster but a mountain in vector, and none of the three exceptions selected raster more than once during the five scenarios of map images (city, street, school, mountain, and lake). Finally, some overall trends that were discovered in the study results include:

- 17 of the 18 students preferred the vector format in three or more of the five map image situations presented;
- Most students preferred raster in the *visual appeal* rating category;
- Students who rated their prior experience level as expert for three or more tasks tended to prefer vector format across the board except in *performance speed*, where they rated vector the same as raster;

- The self-reported novices tended to rate vector the same as raster for *ease of use* and *comfort level*;
- The self-reported average computer users tended to rate vector the same as raster for *performance speed*;
- The two students who preferred to see the school building in raster also preferred raster overall for *visual appeal*;
- The seven students who rated raster and vector as equal for *performance speed*, *visual appeal* and *comfort level* all preferred vector over raster for the city, street and school building map images;
- The one student who preferred raster over vector for *performance speed*, also preferred raster over vector for *visual appeal*.

Discussion

In most situations, vector images provide greater satisfaction to users over raster images. The results of this study show that searching for map locations causes a distinct difference in preference between vector and raster format. When users look for a topographical feature versus a named destination (a city), there can be a mismatch of desires and results. It was no surprise that users prefer vector images when viewing city and street map locations and prefer raster images when viewing a mountainous or natural landscape. Part of the intent of this study was to highlight the differences in characteristics of vector and raster map formats. In order to measure the aspect of scalability, ease of use and comfort level questions were asked; to measure resolution, the visual appeal question was asked; and to measure storage space, the performance speed question was asked.

It was somewhat surprising to discover that users prefer to see a school building in vector and a lake in raster format. Sometimes, when looking for cities and roads, the vector option on Google Maps provides specious accuracy, and displays an arrow that is not centered on the true location. This error is what most likely produced the “uncentered” and “vague” adjective responses written by the students. Many of the students stated that although they enjoyed using raster format for entertainment purposes, when it came down to pinpointing an important location to which they had to arrive on time, vector was the only travel option.

It was hypothesized that vector images would provide greater self-reported user satisfaction than raster images, and for the most part, this actually occurred. Perhaps it

was a result of a tester bias among SILS graduate students towards images of dense vegetation on maps. Because they reside in the heavily forested suburb of Chapel Hill, students may subconsciously shy away from maps that look like home; on the other hand, some could be strongly attracted to those kinds of map images. This would explain the high prevalence of the adjective responses “dense” and “sparse.”

Nevertheless, there were limitations in this study’s methodology. Not every aspect of map imagery was studied, including every imaginable type of location that could have been searched via Google Maps. Errors could have been made collecting and recording data. Regardless of the limitations, the results of this study are similar to the results of others studies found in the literature, and this study provides an impetus for further research. It would be interesting to investigate the effects of the Hybrid feature of Google Maps, which combines vector and raster into a single map overlay. A more focused study would be required to determine how hybrid map images compare to vector and raster, in terms of user satisfaction and accuracy. Other avenues of dedicated research could include the study of vectorized raster images or the study of rasterized vector images.

The data from this study suggests that SILS graduate students prefer to use vector images when searching for city, street, and school building locations with Google Maps. The implications for future map design show the need for providing more maps in vector format. It would be advantageous to explore ways of improving vector maps and increasing the number of accessible vector map formats on USGS and Google Maps websites.

Conclusion

The principal purpose of this study was to discover why users prefer one type of continuous geographic data to another. By interviewing UNC SILS students and analyzing their survey responses based upon the images they saw, a “snapshot” of trends and user preferences was taken. The conclusion is that vector map images provide greater user satisfaction than raster map images. Evidence was provided as to why the two images are desirable or undesirable. The primary differences with inexperienced users might suggest the need for more training and orientation for first time map users. Hopefully more research will be conducted in the future that pertains to user response to raster and vector imagery.

With the advent of digital imagery, an increasing number of websites are offering views of contour maps. These maps come in all shapes and sizes, and offer users a wide array of options to choose from. Two of these options come in the form of raster and vector imagery. Map librarians, in concert with the USGS (United States Geological Survey), currently offer both of these types to users. This study was a satisfaction-oriented, HCI (human-computer interaction) and usability experiment which subjectively evaluated the user's subjective opinions about a map interface. This study examined the behaviors of users who viewed continuous geographic data on USGS websites.

The research question was: when viewing continuous geographic data on Google Maps, will raster images or vector images produce greater self-reported user satisfaction for UNC SILS graduate students? This research study has shown that vector images provide greater self-reported user satisfaction because of their smoothness and the fact that they can be resized without distortion. However, for topographic features such as mountains and lakes, students prefer raster format. The null hypothesis was that there is

no difference in the self-reported user satisfaction with either the vector or the raster images. After retrieving this data by using in-depth interviews, the theory developed is that vector images are much more satisfying to UNC SILS students than raster map images. Knowledge of this theory gets at the “why” of map image satisfaction and will make it easier to satisfy map user needs. USGS websites, which people use a lot, offer maps that are primarily in raster format. After examining this study, USGS map makers may wish to provide more maps in vector format.

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Appendix A

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Appendix B

Survey/Interview Questions

1. On a scale of 0-4, 0 being the lowest, rate your experience with viewing map images.
2. On a scale of 0-4, 0 being the lowest, rate your experience with resizing map images.
3. On a scale of 0-4, 0 being the lowest, rate your experience with zooming map images.
4. On a scale of 0-4, 0 being the lowest, rate your experience with enlarging map images.
5. CITY: Click on the “Map” tab of Google Maps. Type in Laurel, Maryland. Using three adjectives, rate the image in your own words.
6. CITY: Click on the “Satellite” tab of Google Maps. Type in Laurel, Maryland. Using three adjectives, rate the image in your own words.
7. STREET: Click on the “Map” tab of Google Maps. Type in 8473 Imperial Drive, Laurel, Maryland. Using three adjectives, rate the image in your own words.
8. STREET: Click on the “Satellite” tab of Google Maps. Type in 8473 Imperial Drive, Laurel, Maryland. Using three adjectives, rate the image in your own words.
9. SCHOOL: Click on the “Map” tab of Google Maps. Type in Laurel High School, 8000 Cherry Lane, Laurel, Maryland. Using three adjectives, rate the image in your own words.
10. SCHOOL: Click on the “Satellite” tab of Google Maps. Type in Laurel High School, 8000 Cherry Lane, Laurel, Maryland. Using three adjectives, rate the image in your own words.

Survey/Interview Questions (continued)

11. MOUNTAIN: Click on the “Map” tab of Google Maps. Type in Mount Rushmore.

Using three adjectives, rate the image in your own words.

12. MOUNTAIN: Click on the “Satellite” tab of Google Maps. Type in Mount

Rushmore. Using three adjectives, rate the image in your own words.

13. LAKE: Click on the “Map” tab of Google Maps. Type in Lake Erie. Using three

adjectives, rate the image in your own words.

14. LAKE: Click on the “Satellite” tab of Google Maps. Type in Lake Erie. Using three

adjectives, rate the image in your own words.

15. If you had to find a city, would you rather use “Map” or “Satellite”?

16. If you had to find a street, would you rather use “Map” or “Satellite”?

17. If you had to find a school, would you rather use “Map” or “Satellite”?

18. If you had to find a mountain, would you rather use “Map” or “Satellite”?

19. If you had to find a lake, would you rather use “Map” or “Satellite”?

20. On a scale of 0-4, rate your experience in terms of ease of use for “Map.”

21. On a scale of 0-4, rate your experience in terms of ease of use for “Satellite.”

22. On a scale of 0-4, rate your experience in terms of comfort level for “Map.”

23. On a scale of 0-4, rate your experience in terms of comfort level for “Satellite.”

24. On a scale of 0-4, rate your experience in terms of performance speed for “Map.”

25. On a scale of 0-4, rate your experience in terms of performance speed for “Satellite.”

26. On a scale of 0-4, rate your experience in terms of visual appeal for “Map.”

27. On a scale of 0-4, rate your experience in terms of visual appeal for “Satellite.”

Appendix C

Recruiting Flyer

My name is Baasil Wilder and I am conducting research studying the influence of images on user satisfaction when viewing geographic data on the Internet.

The study will take approximately one hour per participant; as compensation you will be entered into a drawing to win a pair of movie tickets. In this study you will search map images on a computer screen and later be asked some questions. Your name will not be connected with your answers in any way.

If you are comfortable with computers, familiar with the Internet, and are interested in participating, please contact me at: bwilder@email.unc.edu.

This study will be conducted in Manning Hall, in the SILS Library computer lab on the UNC campus. For questions about the study, please contact Baasil Wilder at bwilder@email.unc.edu or Dr. Evelyn Daniel at daniel@ils.unc.edu.

All research on human volunteers is reviewed by a committee that works to protect your rights and welfare. If you have any questions or concerns about your rights as a research subject you may contact, anonymously if you wish, the Institutional Review Board at 919-966-3113 or by email to IRB_subjects@unc.edu. Reference IRB Study #06-0362.

Thank you for your time.

Appendix D

Note: the asterisks indicate user preferences.

Figure 1—Screenshot of the CITY raster image



Figure 2—Screenshot of the CITY vector image*

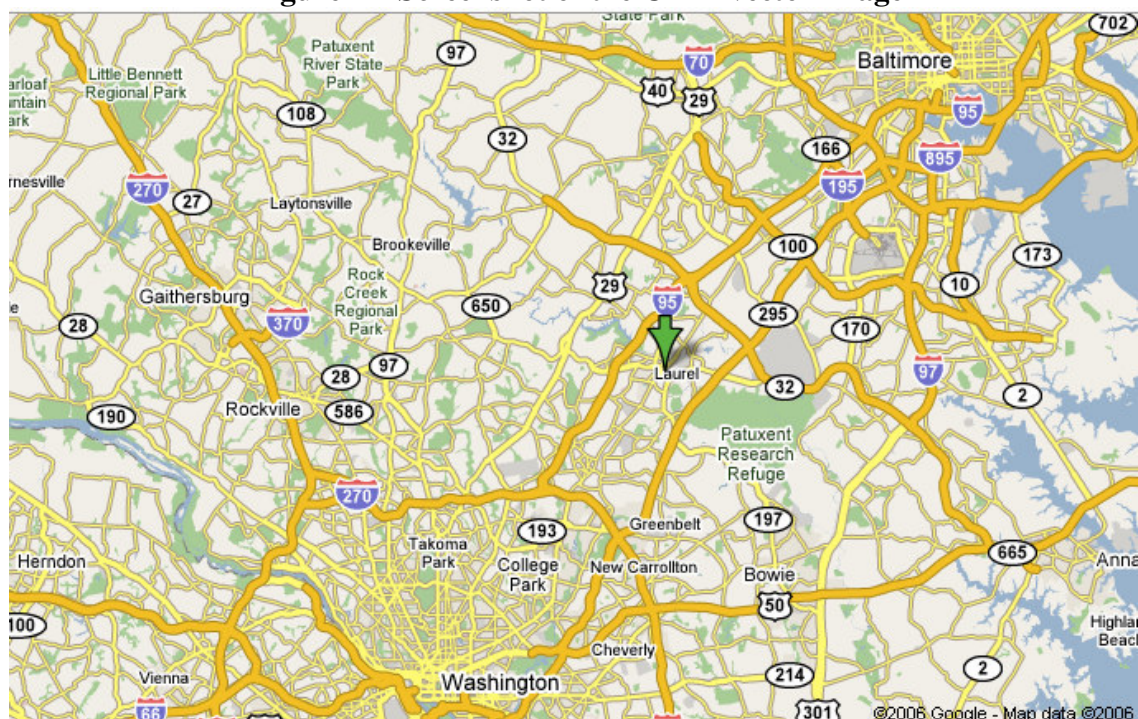


Figure 3—Screenshot of the STREET raster image

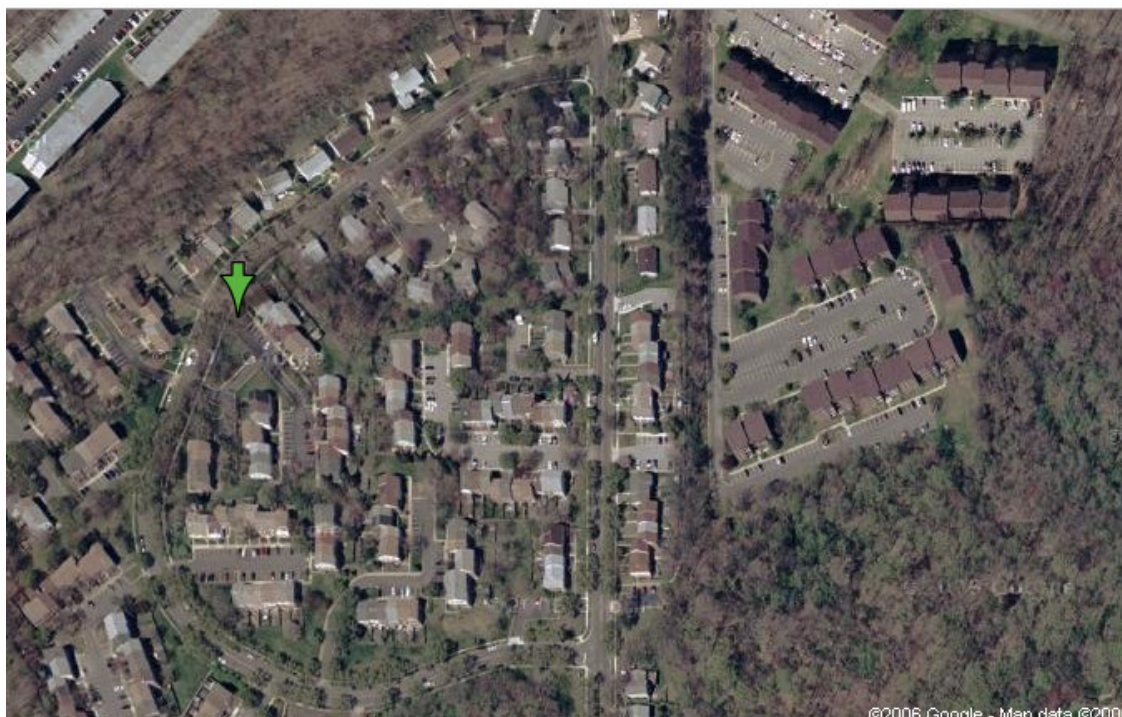


Figure 4—Screenshot of the STREET vector image*

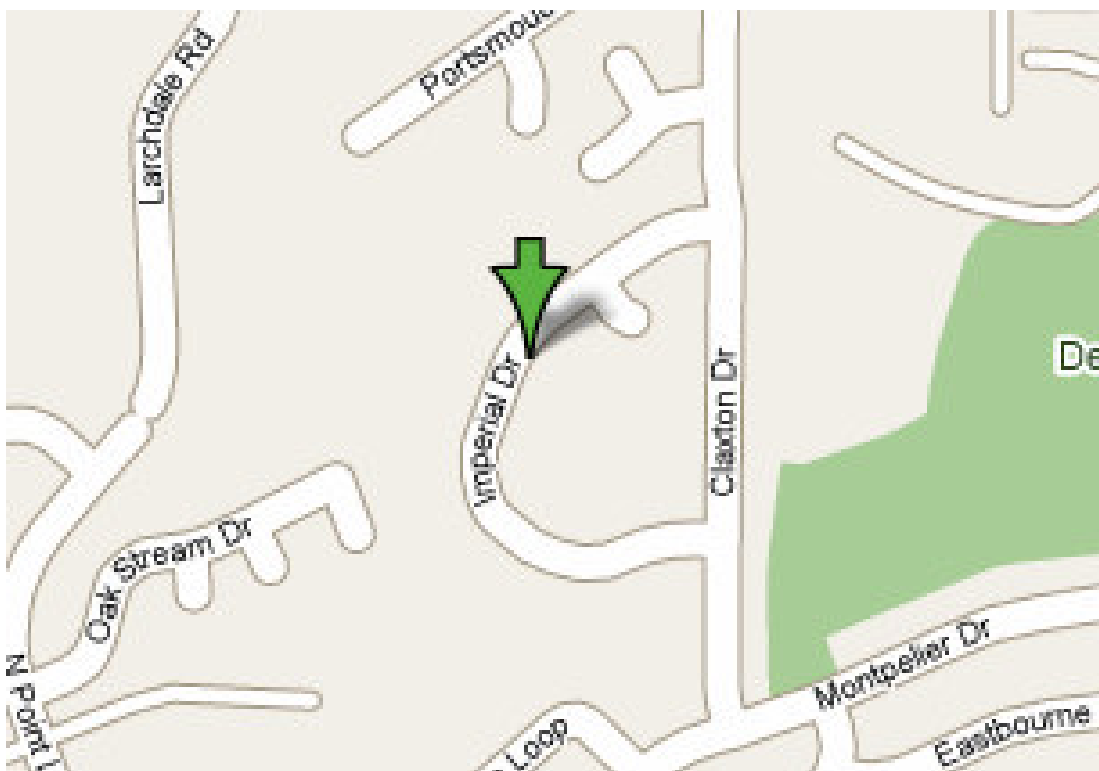


Figure 5—Screenshot of the SCHOOL raster image

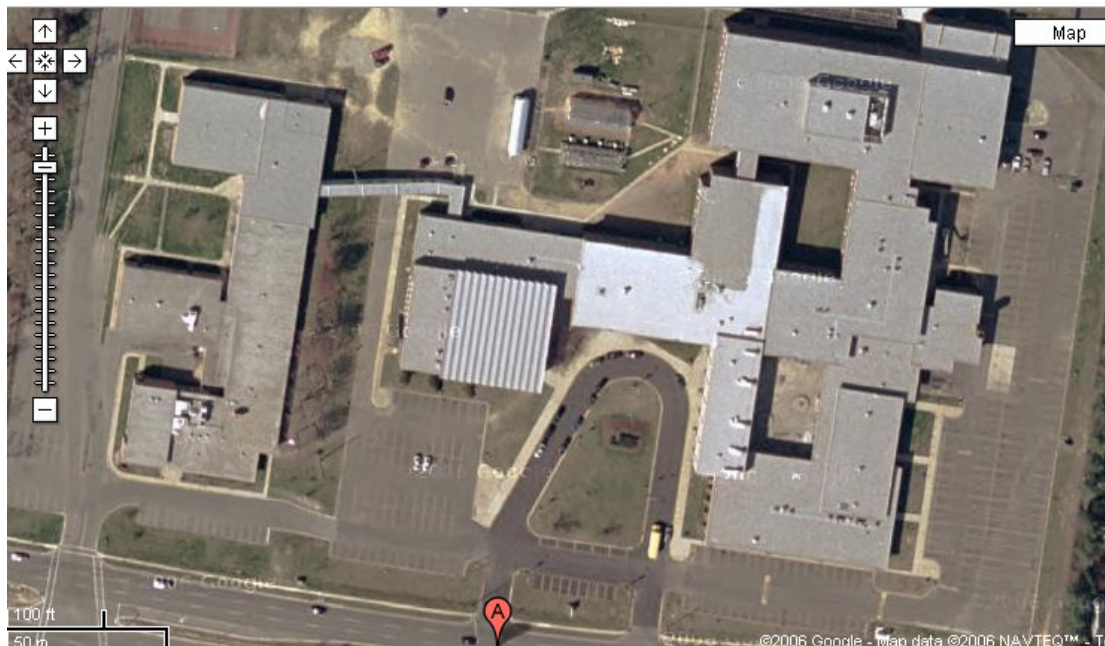


Figure 6—Screenshot of the SCHOOL vector image*

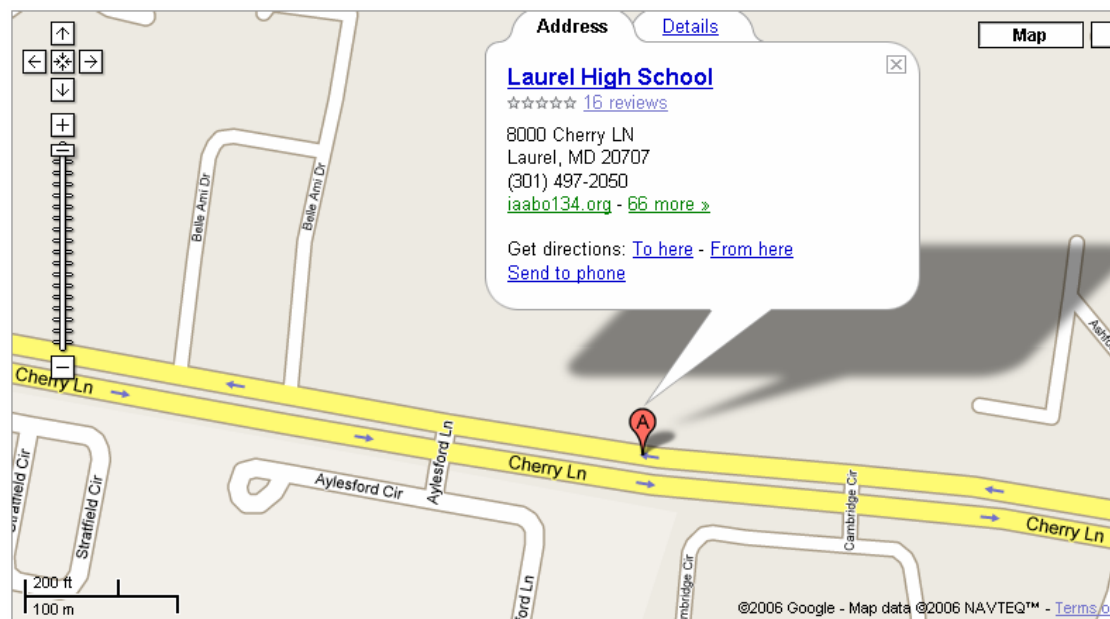


Figure 7—Screenshot of the MOUNTAIN raster image*



Figure 8—Screenshot of the MOUNTAIN vector image



Figure 9—Screenshot of the LAKE raster image*

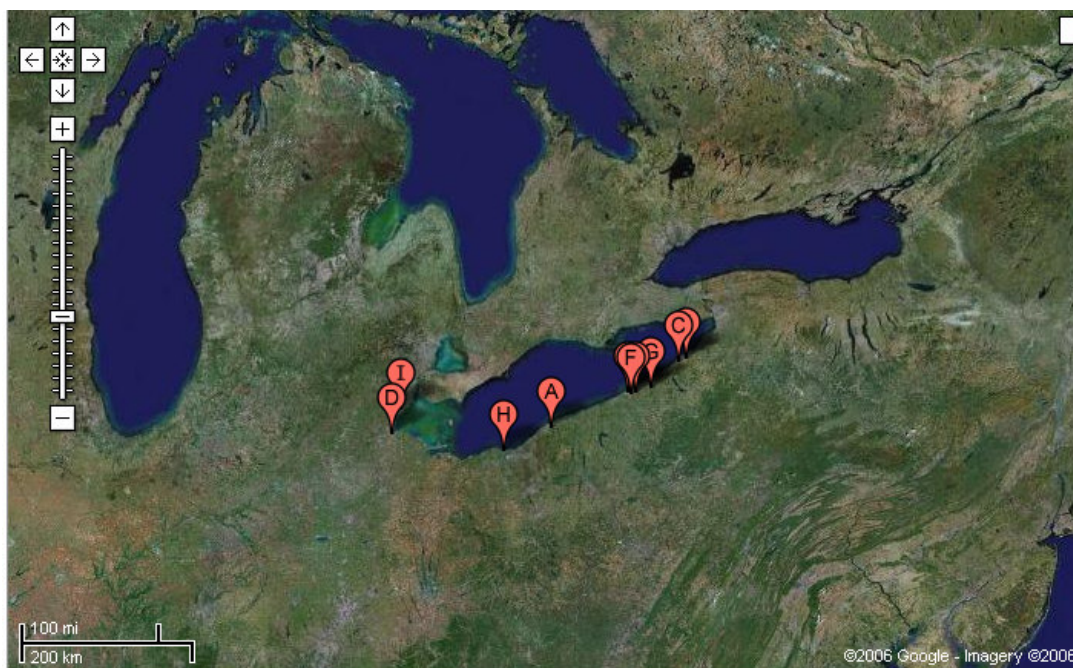


Figure 10—Screenshot of the LAKE vector image

