Map design for the Internet

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Bernhard Jenny, Helen Jenny, Stefan Räber
Institute of Cartography, ETH Zurich

Abstract

To successfully transmit spatial information, maps must be well designed. There exists a canon of design guidelines for paper maps, but a concise compilation of guidelines for the design of web maps is currently not available. This chapter contributes to this need by providing recommendations and guidelines specific to the design of web maps. Topics include the choice of a viewing technology; the influence of limited screen resolution and anti-aliasing; minimum dimensions and distances for map features; the generalization of information density and geometry; problems of screen typography; color rendition; and the design of user-friendly navigation tools. Some of these guidelines are based on the authors' mapping experiences, while others were deducted from the observation of Internet user behavior or compiled from selected sources.

1   The relevance of digital map design

Map authors can choose today among a range of GIS or graphics software products to create maps for the Internet. These out-of-the-box maps are quickly made and published, but many fall short of effectively conveying the intended information. One of the main reasons for this shortcoming is that "instant maps" are not well designed. Four major reasons can be singled out why map authors should spend the extra time to rethink the graphical design of out-of-the box maps:

1. A map should be legible at a glance. A graphically well-designed map allows the reader to easily grasp the map content and quickly find the required information. This is especially important for web maps that tend to get a shorter period of attention from the user than paper maps.

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[1] *Reference:*

Jenny, B., Jenny, H. and Räber, S. (2008). Map Design for the Internet. In: M. P. Peterson (editor), International Perspectives on Maps and the Internet, Berlin Heidelberg New York: Springer, p. 31-48.

2. Map information must be unambiguous. Information contained in a map that does not follow basic cartographic design principles is hard to read and can be misinterpreted.

3. Map information must be easy to remember. The map reader recalls information better when it is presented in a graphically pleasing way and with the use of different media (e.g. images, sound, text, animation).

4. The map reader must trust the map. The map reader has more confidence in the validity of the presented information when the map has a clear and efficient design (Harrower et al. 1997).

The opinions, on what good map design actually is, differ. Still, over-time, a canon of design guidelines for paper maps has been developed that can be found in most text books on cartographic design. Luckily, most of these guidelines, with which the reader is assumed to be familiar, can also be applied to web mapping. Yet, some aspects of web map design need additional attention because the special demands of Internet user behavior and Internet technologies need to be accounted for.

The authors of this article are collaborators of the Institute of Cartography of ETH Zurich. Map design is part of our daily work and is strongly influenced by internationally renowned products of Swiss cartography, such as the topographic maps of swisstopo or the printed edition of the Atlas of Switzerland. Our Institute is producing various virtual cartographic products, such as the award-winning digital version of the Atlas of Switzerland. Based on these experiences, the following chapters will collect and suggest some guidelines geared especially at web map design.

As for paper map guidelines, source and validity of the suggested principles for web map design differ: some were confirmed by user surveys, others have merely been accepted by the majority of web cartographers, are self-evident or based on culturally influenced conventions and many have never been scientifically verified. In general, the quality of web map design can be measured with difficulty only. While the map information content retained by a subject can be quantified and methods from computer science to evaluate graphical user interfaces (Raskin, 2000) can be applied to interactive web maps, the graphical attractiveness of a map, its clarity and efficiency are very difficult to objectively assess. Consequently, the design guidelines suggested in the following paragraphs do not claim absolute correctness or universal applicability, but should be considered as a starter-kit for good web map design based on the experience, thoughtful combination and graphical intuition of the authors.

2   Guidelines for web map design

2.1   Choosing an appropriate viewing technology

Consumers of web map graphics and Internet users in general expose some additional behavior that authors of printed maps do not need to be concerned with: Internet users are often reluctant to install additional software components (e.g. plug-ins) on their computers that are sometimes necessary to view certain maps. Chances are high that users may decide to abort the operation and search for the information elsewhere because they are either too impatient, have security concerns or lack the necessary knowledge to perform the installation. When choosing a web map design technology, the cartographer therefore needs to consider its accessibility as well as the graphical design and interface functionalities that the technology offers.

In general, it is advisable to design for the most widespread technologies to reach a maximum of Internet users. For Intranet applications, where the map author knows exactly what software programs are installed on the users' computers, it might be excusable to design for a certain platform or web browser that allows for better design conditions or complies with the company's security guidelines.

To publish maps on the Internet, it is therefore essential to keep informed on the acceptance and distribution of web-browsers and plug-ins (Table 1) and to evaluate the graphical appearance and interactive behavior of the map with these browsers. Appearance and behavior of a digital map may vary for different browsers or plug-ins because of different rendering algorithms, rendering and scripting capabilities, font availability and a varying degree of adherence to official web standards.

Internet Explorer	Firefox	Safari	Other / unknown
~80%	~15%	~3%	~2%

Table 1. The most popular browsers in January 2007. Approximate estimation based on http://www.thecounter.com and http://www.upsdell.com/BrowserNews/. Note that identifying and counting browsers is difficult and error prone.

Choosing an appropriate viewing technology usually means to either decide in favor of the most common technical standards that still offer the required level of interactivity – or to adjust the desired level of interactivity to the available viewing technique.

A common dilemma is the use of Scalable Vector Graphics (SVG), an open-source format preferred by many web cartographers for interactive and animated maps. The SVG plug-in still needs to be installed with many web browsers, since only an estimated 30% of all computers have SVG viewing capabilities, while the competing Flash technology has a market penetration of 98% according to Adobe.

SVG is in many ways superior to Flash, but its use is hindered by its limited diffusion. Hence, a cartographer might decide against a technology that offers better design options if user-friendly accessibility of the map is more important.

2.2   Considering transmission speed

The ordinary web surfer is accustomed to web pages loading within seconds and as a consequence expects the same behavior from maps. He or she is not willing to wait during a long time for a map to load, unless the user himself has deliberately triggered the download of large datasets or many maps.

How long the user needs to be patient to view a map depends on the bandwidth of the Internet connection. While high speed Internet is becoming standard in many countries, a lot of users are still connected by modems over standard telephone lines at 56 kbps. Depending on the estimated hardware equipment of the target audience, the map designer should only embed images, movies and other datasets in the map of an appropriate size. A common recommendation for web authors is to aim at a size of around 50 kilobytes per single web page, which allows the page to download within a few second over a modem connection.

It is, however, often impossible to comply with this recommendation. The author is then forced to find a compromise between an acceptable rendering quality and the limited bandwidth. For images, this necessitates the use of compression techniques with their corresponding graphical problems, such as compression artifacts for JPEG and reduced number of colors in GIF files. For dynamic and interactive maps and atlases, a common solution is to limit the amount of downloaded data to what is required for the currently visible map. Additional data is transmitted when the user changes the map content or the visible area. Variations of progressively growing status bars are another device that is often used when operations take more than a few seconds. Such devices indicate the user that there is an operation running in the background, and will (hopefully) make the user wait more patiently.

2.3   Keeping special user needs in mind

Accessibility of maps for users with special needs can be facilitated with web mapping technologies. Web accessibility means that people with disabilities can perceive, understand, navigate, and interact with the web (or a web map). Web accessibility also benefits others, including older people with changing abilities due to aging. It encompasses all disabilities that affect access to the web, including visual, auditory, physical, speech, cognitive, and neurological disabilities. An accessible web provides equal opportunity to people with disabilities and helps them to more actively participate in society. In some cases, web accessibility is required by laws and policies (see the Web Accessibility Initiative WAI at http://www.w3.org/WAI/).

Hence, cartographers should design their maps with accessibility in mind – be it traditional paper maps or digital web maps. Web technology can support accessible map design: the user should be able to enlarge maps with very detailed information; vector-based symbols should change dynamically at the user's request; the user should be able to increase the size of text; and color schemes should be exchangeable according to the needs of the visually impaired. All of these aids should be activated with as little user interaction as possible, preferably with a single button click.

2.4   Designing for varying screens sizes and resolutions

One aspect that makes web maps difficult to design is the fact that the map author usually cannot control the hardware and software that is used to display the map. Readers of web maps use screens of variable sizes and with differing resolution. The smallest graphical unit of a modern computer display, a pixel, is still relatively large, despite regular improvements by monitor manufacturers. The large pixel size and the limited screen size hinders the design of web maps in many ways, as will be shown in this section.

2.4.1   Screen size

An important constraint for web map design is the limited screen size. An estimated 14% of the computers connected to the Internet use screens that are only 800×600 pixels large. Another 78% use monitors with a size of 1024×768 pixels or larger (Table 2). After subtracting the space required for the browser window and other elements of the web page, only limited space remains for the map. If the map is the essential content of a page, it should be allowed to occupy an appropriate amount of space.

800×600	1024×768	1152×864	1280×1024	Unknown
14%	54%	3%	21%	5%

Table 2. Common screen sizes in December 2006 (Source: http://www.thecounter.com).

The map should be designed to adjust its size dynamically to the size and proportion of the available space. The simplest solution is to display the same map at a larger scale – better options are to enlarge the map and add additional map data (which requires scalable map data), or to enlarge the mapped area (i.e. extend the area covered by the map).

2.4.2   Screen size and resolution

The resolution of a screen is its resolving power: the number of pixels per surface unit commonly expressed in dots or pixels per inch (dpi). The resolution

determines the degree of detail visible on screen. An average pixel has a diameter of around 0.26 mm resulting in a density of 96 pixels per inch (dpi), which is more than 10 times lower than the resolution achieved on printed paper. Table 3 lists typical screen sizes and the corresponding pixel size and resolution for modern liquid crystal displays (LCD).

Display Size	Number of pixels	Visible area	Pixel size	Resolution dpi
17"	1280×1024	338×270 mm	0.264 mm	96
19"	1280×1024	376×301 mm	0.294 mm	86
20"	1400×1050	408×306 mm	0.292 mm	87
20"	1600×1200	408×306 mm	0.255 mm	100

Table 3. Size and resolution of commonly used liquid crystal displays (LCD).

A consequence of the variable screen resolution for the map designer is the impossibility to predict the final scale at which a screen map will be displayed. The actual size of a map depends on the resolution of the monitor, which may vary by 20% (Table 3) or even more. Indicating the scale in numbers (e.g. 1:25 000) should therefore be avoided and scale bars or regular grids should be used instead.

With the current resolution of around 96 dpi, a pixel is larger than the smallest surface the human eye can discern. Figure 1 shows that for a paper map at a reading distance of 30 cm, the smallest object that can still be clearly identified by the eye measures 0.09 mm. It is partially based on these considerations that cartography textbooks recommend for paper maps a minimum line width of 0.1 mm for thin black lines on a bright background. Computer monitors are viewed from an estimated distance of around 60 cm. The doubled viewing distance duplicates the size of the smallest identifiable object. The resulting 0.17 mm are however clearly smaller than the size of a pixel at a screen resolution of 96 dpi, which is 0.26 mm. The human eye is therefore capable of identifying individual pixels on a computer screen under average viewing conditions, if color contrast between pixels is high enough. This means that the higher the contrast between two neighboring pixels is, the more jagged or saw-toothed lines appear.

Apart from using scale bars to indicate map scale, map designers should be familiar with a technique called anti-aliasing. Anti-aliasing helps reducing the saw-toothed appearance of map objects and is discussed in the following chapter.
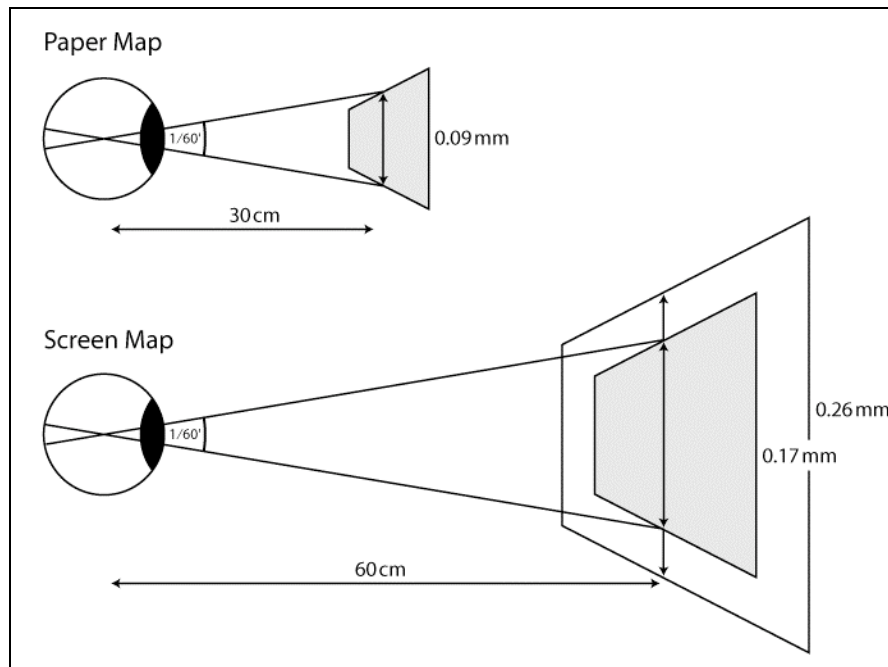
Fig. 1.   Performance of the human eye. Top: A printed map at a distance of 30 cm. Bottom: A screen pixel at 60 cm is considerably larger than the smallest area discernable by the human eye.

2.5   Increasing legibility of map elements: anti-aliasing

Anti-aliasing is a technique used to add greater realism to digital imagery by smoothing jagged edges of map elements. The goal of anti-aliasing is to improve graphical appearance and to increase readability. Along borders with visually high contrast, intermediate colors are assigned to the pixels. This creates a blurry image when viewed from a close distance, but the overall readability of the image is increased if the image does not contain too many details (Figure 2). Anti-aliasing is applied when converting vector objects to a raster image for display on the screen. Relatively complex time-consuming algorithms are required for this process – a factor that can become important when maps are rendered in real-time by a web mapping service, resulting in increased hardware requirements. The anti-aliasing algorithm can differ among graphics programs and browser plug-ins and should be evaluated by the map author beforehand.

Fig. 2.   Web map without (left) and with anti-aliasing (right). Source: MapQuest in the years 2000 and 2006.

Figure 3 shows Bézier curves with increasing width rendered with the Macromedia Flash Player 5 and the Adobe SVG Viewer 3. The SVG Viewer renders thin lines that are narrower than one pixel more accurately than the Flash Player. Figure 4 illustrates the effect on a web map: type and vector lines are rendered differently.
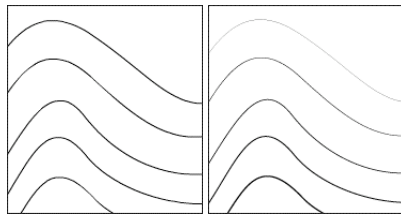

Fig. 3.   Flash Player (left) renders thin lines in black, the Adobe SVG Viewer 3 in gray.
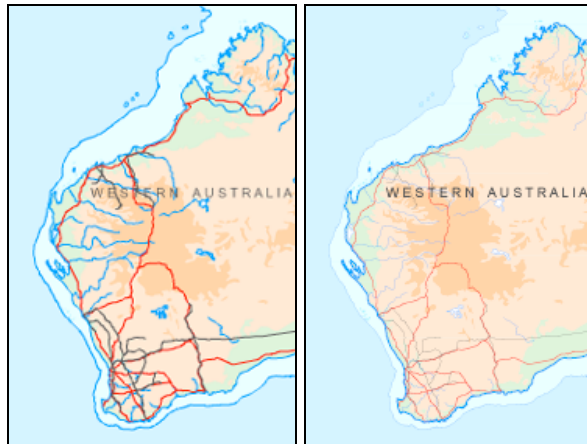

Fig. 4.   Same vector data rendered differently. Left: Macromedia Flash Player 6. Right: Adobe SVG Viewer 3.

2.6   Making signatures and symbols readable: dimensions and distances

For optimum readability, the symbolization of graphical objects for screen maps needs to be adapted to the low screen resolution and to the use of anti-aliasing. Both require line widths, minimum sizes for point symbols and minimum distances between graphical elements to be larger than on paper maps. Reference values for sizes and distances will be suggested in the following paragraph.

A series of test objects (Figure 5, left) is used to identify the minimum distance between two surfaces. In order to unequivocally differentiate two black surfaces on white background, the surfaces must be separated by at least one pixel when rendered by the Adobe Flash Player 9, a distance of 1.5 pixels ($\approx$ 0.4 mm) or more is recommended. This is about twice the distance generally recommended for paper maps, which is between 0.15 to 0.2 mm for black surfaces on white background.

A similar test can be done with lines to find the minimum distance for linear elements – the minimum recommendable distance between two lines is 1.5 pixels. If the distance is only 1 pixel wide, the two lines are not clearly separated when rendered with the Adobe Flash Player 9 (Figure 5 right).
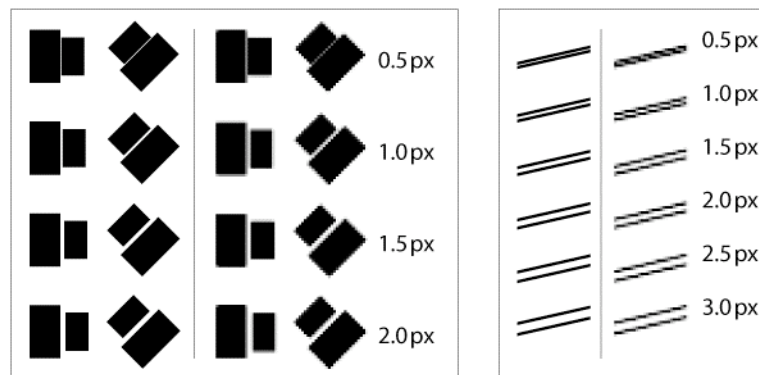

Fig. 5.   Variable distances between surfaces and lines at full resolution (left) and screen resolution (right), rendered with Adobe Flash Player 9.

The minimum size of point signatures is considerably larger for screen maps than for printed maps. As can be seen in Figure 6, dot symbols using various basic shapes are clearly distinguishable with a rather small diameter on paper; a diameter of approximately 0.8 mm ($\approx$ 3 pixels) is sufficient. Screen maps require a minimum diameter of 6 pixels – even larger symbols are recommended, especially for more detailed and complex symbols.
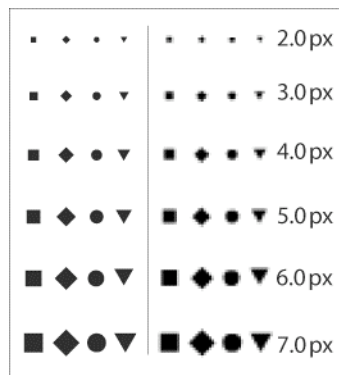
Fig. 6.   Minimum dimensions of point signatures at full resolution (left) and screen resolution (right), rendered with Adobe Flash Player 9.

The numbers suggested in this section are only general guidelines. Graphic rendering engines other than Adobe Flash Player 9 may use different algorithms for antialiased rendering, which may require other distances and dimensions. As a rule of thumb, minimum distances and dimensions of point symbols must at least be doubled compared to paper maps. This results from the doubled distance between the observer's eye and the computer screen, as well as from the low screen resolution and the necessary anti-aliasing. It is therefore essential to always visually verify the final map at screen resolution before publishing.

2.7   Simplifying to emphasize the relevant: Generalization

2.7.1   Information density and symbolization

The information density of a screen map must be reduced compared to a printed map for good readability. Again this is due to the increased eye distance, the low screen resolution and the use of anti-aliasing. Anti-aliasing improves the graphical appearance of objects and renders them more readable, but also requires some extra space along the edges of objects to smoothly render a gradient between two colors. Hence, the number of map features per area must be reduced to produce a screen map with optimum readability. When simply scanning a paper map and displaying it on the screen, the size would have to be increased 2.5 to 3 times. Such a scanned web map would however be difficult to read, since it lacks the necessary adjustments for on-screen display. Scanning and enlarging paper maps is therefore not recommended for optimum results. A paper map can be used as a starting point for the creation of a screen map, but its information density must be reduced and its graphic design simplified.

Intricate pictograms for point features or subtly dashed lines are difficult to read on screen. Symbols must generally be more differentiated, especially for thematic map symbols, to keep features pertaining to different classes easily distinguishable. For

example, the width of lines symbolizing various classes must clearly differ among classes. Since the minimum line width is about 1 pixel (depending on the software renderer), the following line classes must be much wider than on paper maps. Thematic classes may possibly have to be restructured and reduced in number. E.g., the number of road classes in topographic maps may need to be reduced for screen display.

2.7.2   Shape simplification

To guarantee a good readability of screen maps, the geometry of map features must be much more generalized than for paper maps. Particularly the point density of lines must be reduced. A thin line with a high point density may appear perfectly clear in print, but thick and unaesthetic on screen. This is due to the increased line width necessary for rendering thin lines and the low screen resolution (Figure 7). As a side note, it is the authors' opinion that dashed lines should be used carefully on screen maps, since they often result in visual clutter.

Fig. 7.   Reduced point density in lines improves readability on screen.

2.8   Designing text: screen typography

The selection of an appropriate type for a web map is a difficult task; a balance between often contradicting criterions has to be found. As for paper maps, text labels must be easily legible and type should be optically pleasing. There exist a few criteria that can help guide the cartographer in the choice of suitable type families for screen maps. Indeed, for screen maps only a limited number of common type families are suitable that are also available on all widespread operating systems.

Readability is again hampered by the low screen resolution, which blurs type. A much-discussed topic is the use of anti-aliasing for screen type (Figure 8). Typographers agree that it enhances the graphical appearance considerably for type sizes of 18 points and above. For smaller sizes its impact on the legibility should be

tested. The result mainly depends on the chosen typeface as well as on the software that converts the vector geometry into raster images (the browser, a plug-in or a vector graphics software package). In the authors' opinion, text should generally be rendered with anti-aliasing, because it is graphically more pleasing.
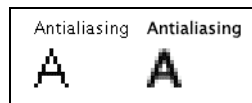

Fig. 8.   The effect of anti-aliasing on type rendering.

The latest versions of the Windows and Macintosh operating systems enhance anti-aliased type rendering using subpixel rendering. This technique (called ClearType on Windows) increases the apparent resolution of a liquid crystal display (LCD) by taking advantage of the fact that each pixel on a color LCD is composed of individual red, green, and blue subpixels. Black type on a white background is not rendered with different shades of gray as with normal anti-aliasing, but with additional red, green and blue subpixels. This results in type with considerably greater detail. It is, however, only available on LCD monitors and not well suited for CRT displays. Subpixel rendering should therefore only be used when type is rendered on the viewer's computer based on the geometric outlines of the font, but should not be used by the designer to rasterize and embed type in a raster image.

2.8.1   Type in web maps

Type size is very important for good readability: type in web maps should be set at a minimum size of 12 points. As an exception, smaller sizes can be used with particularly well readable typefaces that have been designed for screen display. If type must be set in sizes smaller than 11 or 10 points, subpixel rendering or special bitmap fonts for rendering without anti-aliasing should be used.

Sans serif type can be read more easily on screen than serif type, especially at small sizes between 10 and 16 points. Figure 9 shows a classical specimen of a serif type family used for printed topographic maps that is inappropriate for on-screen display in comparison with a more suitable sans serif typeface. Serif typefaces should only be used for titles in larger size using type families specifically designed for screen display (e.g. Georgia or ITC Stone Serif).

Fig. 9.   Italic serif (top) and regular sans serif (bottom) at screen resolution.

Regular and bold typefaces are more easily readable on screen than thin and condensed ones (Figure 10). An increased tracking (letter spacing) can make type more easily readable, especially for italic type. Type with a tall x-height and a wide punch width should be preferred (Figure 11). Characters with simple and open

shapes are more easily legible. For example, Helvetica's closed forms are hard to read on screen compared to the more open Cisalpin (Figure 12). A good face for maps should have robust forms that can stand out in a complex graphic, but without eye-catching shapes.

A good face should take only little space to minimize spatial conflicts with other map elements. Verdana, for example, is well readable on screen, but needs a lot of space when compared to other fonts (see top row in Figure 13, which also lists other recommendable type families).

10 Point Size	13 Point size
Serifs	Sans-serifs
Light	Regular
Italic	Italic with increased spacing
Condensed	Regular

Fig. 10.   Typefaces that are hardly (left) and easily legible (right) at screen resolution.

Good screen type Tall x-height
Wide punch width   Wide letter spacing

Fig. 11.   Good screen type has a tall x-height and a wide punch width.

acegs

acegs

Fig. 12.   Closed shapes of Helvetica (top) and open shapes of Cisalpin (bottom).

Font for webmaps	Verdana
Font for webmaps	Lucida Grande
Font for webmaps	Frutiger
Font for webmaps	Stone Sans ITC
Font for webmaps	Cisalpin
Font for webmaps	Myriad
Font for webmaps	Univers Condensed

Fig. 13.   Recommended typefaces for screen display (image at screen resolution).

2.8.2   Type availability and hinting

Besides the typographic criteria described above, there are also a few technical aspects to take into account when selecting a typeface for a web map. The most important consideration is whether the font is already installed on the user's computer to render the map. This must be the case when the web browser renders type. Alternatively, the Flash and PDF file formats allow for embedding font definitions in the file, which are used when rendering the file content. This permits authors to distribute their type definitions. The simplest, but also most rigid solution is to rasterize the map and to deliver a raster file.

Typefaces for web maps should provide hinting capabilities for optimum display on screen. Font hinting is the process of adjusting the glyphs to make them line up with the grid of the screen pixels. Especially at small sizes, hinting is critical for producing legible type. High quality manual hinting is unfortunately a very laborious task, which is the reason why seldom-used typefaces do not include hinting.

2.9   Dealing with inconsistent color display

Color rendition varies among computers for reasons related to hardware and software. The quality of monitor hardware has increased tremendously during the last few years. The majority of Internet users are using computer screens capable of displaying millions of colors (Table 4) and monitors with only 256 colors are practically extinct (note however, that these numbers may be biased by the customer distribution of the publishing company). This means that only in very particular circumstances web cartographers will have to limit themselves to 256 colors and web designers do no need to worry anymore about the restrictive so-called web-safe color palette (Lehn and Stern, 2000).

256 Color	Thousands of Colors	Millions of Colors	Unknown
0%	11%	86%	3%

Table 4. Most common monitor color depths in September 2006 (Source: http://www.thecounter.com).

While all monitors can display thousands or millions of colors nowadays, there are still differences in hardware quality among monitors of different manufacturers and different types (CRT or LCD). The age of the monitors, different adjustments (brightness, contrast, color temperature, etc.) and ambient light keep color rendering inconsistent.

There are also two software related reasons for inconsistent color display. First, operating systems use different gamma curves, which map RGB color values to

voltages for the monitor and mainly influence image brightness. Colors on a MS Windows operating system appear darker and more intensive (gamma value of approximately 2.2) than on Mac OS (gamma value of 1.8). The other software-related reason is that different web browsers and plug-ins may interpret color values differently, although the World Wide Web Consortium (W3C) recommends using the sRGB color space for the Internet (Stokes et. al., 1996). Color differences are also due to the inhomogeneous interpretation of color depending on the image format. For example, a color value defined in a PNG raster file might be rendered differently from a numerically identical color in a HTML or CSS file (Sivonen, 2003).

It is not possible to foresee or even control any of these factors. To at least partially solve the problem, the cartographer should design color for the most common user, who uses MS Internet Explorer (Table 1) with a gamma value of 2.2. When designing web maps, it is therefore advisable to set the monitor to a gamma value of 2.2 and to use the sRGB color space.

Inconsistent and imprecise color rendering can make two close colors appear clearly distinctive on one screen, but hardly discernable on another. It is therefore recommendable to use larger color contrasts for screen maps than for paper maps. This is particularly the case for thematic mapping, when color is used to differentiate among classes. It might also be necessary to reduce the number of classes to minimize the potential of confusing classes.

Cartographers can also contribute to web accessibility: visitors with color vision impairments should be able to read the map or switch to another color scheme. Tools like Color Oracle (http://colororacle.cartography.ch) help making sure that color schemes are also readable by the color vision impaired.

2.10   Keeping the user interface friendly: placement of interactive elements

The average user is not willing to learn unknown and complex tools and graphical interfaces to interact with a map. Complex or unusual interface elements may undergo unnoticed or be too complex or too uncommon to learn at first sight. Most users can generally not afford spending precious time with the learning of new tools – all the map readers want is spatial information and this within the shortest possible time. It is therefore important to provide interface elements that are well known from other applications or web maps, for example, underlined hyperlinks, buttons, sliders or other standardized interface elements.

Interface elements that are directly placed in the map are an excellent alternative to GIS-like user interfaces that usually place them outside of the map. When integrated into the map, the map reader is more likely to quickly discover the tools, since the map is already in his focus of attention. Figure 14 shows a map that contains a magnifier glass that links with a more detailed map, and also contains

three-dimensional buttons that highlight the road leading to a site of interest. Figure 15 uses simple rectangles to link with more detailed maps.

For the two maps in Figure 14 and 15 the assumption, that interactive features are more easily discovered by the user when placed inside the map, was verified by non-representative usability tests with a few users. We suggest that the map author should always test an interactive map on at least a few subjects to verify the effectiveness of the chosen design.
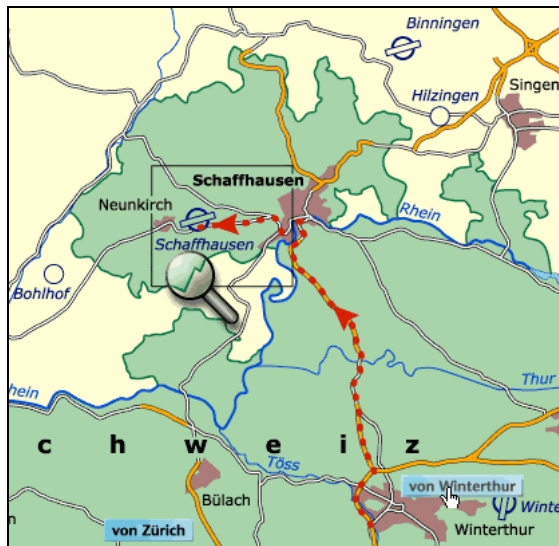

Fig. 14.   Magnifier glass and buttons placed inside the map (author: T. Brühlmeier).

Fig. 15.   Rectangles in the map link to more detailed information (University of Zurich campus, source: www.plaene.unizh.ch).

3   Conclusion

The graphical design of a web map must be coarser and simpler than the design of a paper map so that it conveys the desired information under the less than ideal conditions of low screen resolution, increased viewing distance and shorter reading time. The design will have to be very simple, using few colors, and containing only the truly relevant information (Brown, 1993).

The Internet offers cartographers the potential to reach a large public with their maps. It is therefore most important not to exclude anybody from viewing the map, including users with special needs. We have to note, however, that many users are reluctant to install additional software, are not willing to wait for a map to load, don't want to learn unknown tools to interact with a map, or have variable and out-dated hardware and software. This forces cartographers to find a compromise between what is desirable to optimally convey the mapped information, and what options are available from a technical point of view.

We hope that the suggested guidelines will help map authors to successfully design graphically appealing web maps, and that others will be motivated to develop additional design guidelines for aspects not treated here, such as the design of more

complex user interfaces for interactive maps or the design of cartographic animation.

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