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ClearType sub-pixel text rendering: Preference, legibility and reading performance

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Abstract

ClearType is an onscreen text rendering technology in which the red, green, and blue sub-pixels are separately addressed to increase text legibility. However, it results in colored borders on characters that can be bothersome. This paper describes five experiments measuring subject preference, text legibility, reading performance, and discomfort symptoms for five implementation levels of ClearType rendered text. The results show that, while ClearType rendering does not improve text legibility, reading speed or comfort compared to perceptually-tuned grayscale rendering, subjects prefer text with moderate ClearType rendering to text with grayscale or higher-level ClearType contrast. Reasons for subject preference and for lack of performance improvement are discussed.

Keywords: Sub-pixel rendering; Font; Legibility; Readability; Reading; Resolution; ClearType

1. Introduction

Computers and digital devices dominate the office, amusement and entertainment businesses. Even though text can be easily viewed on electronic displays, people often prefer to print documents and read the hard copy. One possible reason for the preference of printed pages to onscreen text is the compromised image quality of electronic displays, which have limited addressable pixels compared to very high number of addressable points for printed images. For example, to present a 10-pt font character on a typical computer screen of 96 dpi (actually should be *pixels per inch, or ppi*), only 13.33 ($=10/72 \times 96$) pixels are available in the vertical dimension to represent all vertical designing features of the same font type family including capital letters, letters with ascenders and descenders, and space for side bearings. While most current computer displays have resolutions of 72–130 ppi, a typical laser printer offers resolution of 300–1200 dpi (dots per inch). The limited pixel matrix on computer displays poses serious challenges in designing screen fonts. Viewed with magnification, the same-sized character appears smooth and sharp on paper but blocky and jagged (or "aliased") on the computer screen. The image quality becomes worse with smaller font sizes and lower resolution displays with resulting loss of fine details and reduced legibility, and appears jagged with larger font sizes [1] (see Fig. 1: aliased text).

1.1. Grayscale rendering

Grayscale is a commonly used anti-aliasing technique used to smooth the edges of aliased text. It works by assigning gradient shades of gray to the pixels of a character according to the percentage that the pixel is involved in the idealized image. For black text on white background, rather than a choice of "on or off", each pixel is usually stored as a byte with value between 0 and 255 to indicate the level of gray. It has been shown that a thin impercepti-

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Aliased	Grayscale	ClearType
This is text in 6-pt TNR.	This is text in 6-pt TNR.	This is text in 6-pt TNR.
This is text in 8-pt TNR.	This is text in 8-pt TNR.	This is text in 8-pt TNR.
This is text in 10-pt TNR.	This is text in 10-pt TNR.	This is text in 10-pt TNR.
This is text in 12-pt TNR.	This is text in 12-pt TNR.	This is text in 12-pt TNR.
This is text in 14-pt TNR.	This is text in 14-pt TNR.	This is text in 14-pt TNR.

Fig. 1. The effect of font rendering technique by font sizes. The sentences were created in MS Word, displayed in Times New Roman at different font sizes. A screen shot was taken (by PrintScreen) each time the font smoothing setting was changed in ClearType Tuner. The derived image was copied and pasted onto MS Paint to save as a bmp file.

ble gray strip interposed between a black/white border causes a perceived displacement of the border [2]. This result provides the basis by which gray pixels can help to create smoother edges to the perceived image. Studies have shown that, compared to aliased text, grayscale enhances reading performance in character identification [3] and decreases visual discomfort [3]. Grayscale also has been shown to decrease search time at letter search tasks and subjects report preference for grayscale text to aliased (b/w) text [4]. Although grayscale rendering is an improvement over aliased text, it is not good enough for comfortable reading on screen for extended hours, as most office workers do today. In addition, at smaller font sizes, the text becomes extra blurry and hard to read [1,5] (see Fig. 1, grayscale text). The problem with grayscale is that the smoothing technique is at the whole-pixel scale. Constrained by the limited number of screen pixels available for a character, the text image tend to be blurred with foggy edges and hard to focus at, which is fatiguing for eyes.

1.2. Sub-pixel rendering

The latest anti-aliasing technique is *sub-pixel rendering*, used to increases screen resolution in liquid crystal displays (LCDs) by separately addressing sub-pixels [5–8]. In LCDs each pixel is comprised of three primary sub-pixels (red, green and blue) arrayed as vertical bars in a fixed order of RGB or BGR. Normally the relative luminance of the 3 sub-pixels is spatially summated by the visual system to determine the perceived brightness and color of the whole pixel as in Cathode Ray Tubes (CRT) displays. Different from CRT, in which a "pixel" is a projected dot generated by beaming electrons on phosphor screen with color "bleeding" onto neighboring pixels to create the effect of edge-smoothing, LCD pixels are on real pixel grid with sharp edges to define each pixel boundary, which loses the side-effect of color bleeding [9]. However, the rigid sub-pixel layout allows LCD to address each of the sub-pixels separately as an independent unit and precisely with the designated amount of colors. By carefully controlling the luminance of the red, green, and blue sub-pixels to highlight the body of the character, it increases screen resolution to 300% horizontally; hence it can be called a "color anti-aliasing" technique. A consequence of sub-pixel rendering, however, is that the characters have colored sub-pixels on their edges which can cause some unwanted color perception. The challenge in sub-pixel rendering is to maximize the increased resolution while minimizing the color artifacts, by employing the knowledge of human visual system [5–7,10–12].

There are several characteristics of human visual system affecting what we perceive from a computer display. First, our visual system is more sensitive to changes in luminance than to changes in hue or saturation; in other words, we are more capable in detecting the change of luminance (or perception of different sheds of brightness) than the change in color. Second, the perceived luminance (i.e., *brightness*) depends on surrounding luminance. Therefore the same shed of gray can look different with different background luminance while different sheds of gray can be perceived identical with different surroundings. Third, human vision is more sensitive to luminance contrast than absolute luminance. Therefore, minor tune in luminance may cause significant difference on brightness depending on its contrast to the surroundings. Fourth, human visual system tends to undershoot or overshoot around the boundary of regions of different intensities. The imbalance of human vision to luminance and color allows display technology to create an illusion of font smoothing at the pixel level by manipulating color depth of sub-pixels, and the key is in tuning the color to the right brightness but lowering the chromatic scheme to below the threshold of just noticeable difference (jnd).

1.3. ClearType technology

ClearType is an example of the sub-pixel rendering, developed by Microsoft and tested in this study. It starts with a full-color image, over-samples the horizontal dimension to at least 6 times, and then pre-filters each sub-pixel color channel with a low-pass filter to remove small details. The trick in ClearType is how it removes the color anomaly at the edge of the glyph. For instance, for a dark character on a light background, a stroke with 5 sub-pixel width (e.g., GBRGB) will have two sub-pixels (G and B) off and one sub-pixel (R) on in the first triplet, which leads to a colorful edge (in this case, redness on the left side of