Anti-aliasing and dithering in the ‘Freiburg Visual Acuity Test’

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Abstract—Anti-aliasing is a technique for improving spatial resolution at the cost of luminance resolution. Dithering is a technique for improving luminance resolution at the cost of spatial resolution. These techniques are applied to the testing of visual function in the 'Freiburg Visual Acuity Test': by employing anti-aliasing, spatial resolution was improved. Thus, even the shape of small Landolt-Cs with oblique gaps is adequate, and visual acuities from 5/80 (0.06) up to 5/1.4 (3.6) can be tested at a distance of 5 m. By employing dithering, subthreshold contrast stimuli can be generated on a conventional display having standard 8-bit video resolution. Rapid acquisition of a semi-objective and reliable acuity estimate makes the 'Freiburg Visual Acuity Test' useful for subject screening in vision research, as well as for routine assessments in the ophthalmic practice.

ANTI-ALIASING AND DITHERING

A powerful method to increase spatial resolution at the cost of intensity resolution is provided by ‘anti-aliasing’ (Fig. 1, see also Bach et al., 1997). If high spatial resolution is not required, luminance, or colour resolution, or both, can be improved at the cost of spatial resolution by ‘dithering’ (Fig. 2, see also Bach et al., 1997). Dithering can be seen as the opposite operation to anti-aliasing. These techniques are applied here in visual-acuity testing.

TESTING VISUAL ACUITY

A rapid and examiner-independent test of visual acuity is desirable, both for clinical studies and basic research. How to present optotypes on a computer screen, interactively driven by the subject, has often been described (see Bach, 1996, for a literature overview). Previous studies have suffered from the inherently low resolution of standard visual display units. We have overcome this limitation by anti-aliasing. The

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Figure 1. ‘Anti-aliasing ’ as used in the Freiburg Visual Acuity Test. Top row: ideal shape, centre row: shape rendered on a coarse pixel raster without anti-aliasing, bottom row: rendered with anti-aliasing. With anti-aliasing, the shape is more accurately rendered, and, after low-pass filtering through the eye’s optics, the retinal image corresponds to one having 1/4 the pixel size. The effect is difficult to present in print, and is better appreciated by blurring the figure.

improved resolution allows the use of the oblique positions of the Landolt-C in addition to the four straight ones. Thus eight different orientations are possible, which reduces measurement time as the guessing rate is lower compared with four different orientations.

What pixel size is required to display optotypes with sufficient resolution? Let us assume an observer distance of 5 m, which is typical for measuring visual acuity. The pixel size of current monitors is slightly below 0.4 mm. If the gap in the Landolt-C has the width of one pixel, at 5-m this would correspond to a visual acuity of 3.6, which seems sufficiently high. However, a Landolt-C with a one-pixel gap size has an inadequately defined shape, particularly for oblique gap orientations, and at least two pixels are necessary. This reduces the maximum acuity that can be presented on a typical monitor to 1.8, which is below the value reachable by young normal subjects under forced-choice conditions; Rassow et al. (1990) found a median acuity of 1.99. Furthermore, physically realisable optotypes are limited to integer gap widths (in pixels), which leads to coarse sampling in the high-acuity range. Anti-aliasing, which solves this problem, is especially simple to implement on Apple Macintosh computers: internally, the computer program renders the optotypes with fourfold magnification on a virtual black-and-white pixel map. For display, this pixel map is shrunk by a factor of four, while the operating system automatically applies anti-aliasing using the built-in ‘CopyBits’ routine to a pixel map with 16 or 256 grey levels. Thus, the