ABSTRACT
Current consumer-level priced and state-of-the-art scan-rate converters enable a spatio-temporal decoupling of the received video and the displayed video. This paper presents the results of a subjective assessment indicating the preferred CRT-display format.

INTRODUCTION
Interlaced video with 525 or 625 lines and a 50 or 60 Hz picture rate has been the television broadcast standard for quite some time. Modern bright television screens, however, require a modified display format to prevent annoying large area flicker and/or interline flicker. Moreover, matrix displays require format conversion as they cannot directly cope with interlace. Finally, new image sources, such as the Internet, benefit from an increased spatial pixel density to improve the legibility of displayed textual and graphical information. As such, the optimal scanning or video format requirements may differ per application.

The techniques for high quality video format conversion have recently reached a price / performance ratio that enables application in the consumer domain [1, 2, 3]. As a result, we can choose the displayed number of scanning lines, the interlace factor and the picture rate at will. Given this new freedom, the question arises how to optimally choose a display format for the current applications. Increasing the number of scanning lines increases the vertical resolution. Modifying the interlaced scanning to the progressive format reduces or eliminates any of the possible interlace artifacts like line flickering and line crawl that may appear. Finally, an increase in the refresh rate reduces or eliminates the large area flicker. Consequently, one might expect optimal performance by using both the highest number of scanning lines and at the highest refresh rate possible. Obviously, there is a cost increase associated with such an increase in overall quality.

In order to have a fair optimization of the television display format, i.e. comparing options with approximately the same cost¹, we may increase the number of scanning lines at the cost of a lower refresh rate, or a change in the interlace phase. Note that this recently obtained additional freedom enables a variety of pixel distributions in both space and time, for every chosen pixel rate.

THE EXPERIMENTS
The optimal balance between the various parameters can only be found by conducting a subjective assessment, as defining a reliable objective metric is still a major challenge.

In our experiments, we selected the following scanning formats for the subjective assessment (see also Figure 1):

- 50 Hz, progressive (1:1), 625 scanning lines (50p)
- 60 Hz, progressive (1:1), 525 scanning lines (60p)
- 50 Hz, interlaced (2:1), 1250 scanning lines (50i)
- 75 Hz, interlaced (2:1), 833 scanning lines (75i)
- 100 Hz, interlaced (2:1), 625 scanning lines (100i)

Note that the above formats differ in the number of scanning lines, the interlace phase and the refresh rate, but all use the same pixel frequency.

A complication, when comparing different scanning formats on a single Cathode Ray Tube (CRT), is that the spot dimensions cannot be simultaneously optimal for all formats. Clearly a fine spot is required to exploit the highest vertical resolution resulting from the scanning format with the highest number of lines. However, for the scanning formats with a lower line count, such a fine spot may lead to an annoying visibility of the line structure. To prevent the choice of the spot dimensions leading to a bias in the optimization of the scanning format, we optimized the spot size per scanning format as a balance between perceived sharpness and the visibility of line structure in a first session of the subjective test.

To realize a variable spot size without changing the display, we emulated a relatively low resolution display on a high resolution monitor. A single line was mapped to a number of scanning lines on the monitor, using a Gaussian filter to represent the spot dimensions of the emulated CRT. The viewing distance in the subjective assessment was selected in accordance with the emulated low resolution display.

¹the same pixel frequency
Figure 1: Decoupling of the input video format and the display format.

Table 1: Overall results of the subjective assessment.

<table>
<thead>
<tr>
<th></th>
<th>50p</th>
<th>60p</th>
<th>50i</th>
<th>75i</th>
<th>100i</th>
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<tbody>
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<td>50p</td>
<td>40.8</td>
<td>83.5</td>
<td>97.4</td>
<td>84.2</td>
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<tr>
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<td>59.2</td>
<td>84.2</td>
<td>96.7</td>
<td>89.5</td>
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<td>15.8</td>
<td>71.1</td>
<td>44.7</td>
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<tr>
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<td>2.6</td>
<td>3.3</td>
<td>28.9</td>
<td>21.0</td>
<td></td>
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<td>10.5</td>
<td>55.3</td>
<td>79.0</td>
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</tbody>
</table>

From the subjective evaluation, we draw the conclusion that the video format of 75i is superior to the alternative scanning formats. A remarkable observation is that the preference is most impressive in comparing the 75i format with the two progressive display formats (50p and 60p). In fact, all the interlaced formats are preferred over the progressive formats. The loss of vertical resolution of the progressive formats is apparently recognized as the most distinguishing element.

Another interesting observation is that the preference of the 75i format over the 100i format indicates that the observers clearly notice the difference in vertical resolution, and probably hardly observe any difference in large area flicker or line flicker. The difference of the 100i with the 50i format was not considered to be significant, i.e. it was found difficult to chose between a picture with significant line / large area flicker and a high vertical resolution, and a picture with a significant lower resolution and no visible interlace artifacts.

**CONCLUSIONS**

Recent progress in scan-rate conversion technology enables a decoupling of the received video format and the display format. As a result, we can choose the displayed number of scanning lines, the interlace factor and picture rate at will. Our subjective evaluation revealed that, for CRT television displays and for the tested formats, our viewers always preferred interlaced scanning over progressive scanning with the same pixel rate. From the range of picture rates that we tested, the 75i format turned out to provide the best balance between flicker and resolution. Finally, our (European) viewers preferred the 100i high-end television format over the 60p high-end format. Of all tested formats, we conclude that the interlaced format at 75 Hz, 833 lines is optimal for CRT displays with a 27 MHz luminance pixel rate.

**REFERENCES**

