Woods, A.J., Rourke, T., Yuen, K.-L. (2006) "The Compatibility of Consumer Displays with Time-Sequential Stereoscopic 3D Visualisation" (Plenary Paper), in Proceedings of the K-IDS Three-Dimensional Display Workshop 2006, pg 7-10, Seoul National University, Seoul, South Korea, 21 August 2006.

The Compatibility of Consumer Displays with Time-Sequential Stereoscopic 3D Visualisation

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Abstract

This paper summarises two recent studies that investigated the suitability of LCD monitors and DLP projectors for use with the time-sequential stereoscopic 3D display method. Fifteen DLP projectors were found that would work with 85Hz time-sequential stereoscopic display, however none of the LCD monitors tested could be used with the conventional time-sequential stereoscopic display method.

1. Introduction

For several years the dominant method for high-quality stereoscopic viewing at personal workstations has been Liquid Crystal Shutter (LCS) 3D glasses on a CRT monitor. A similar process was also used with (3 gun) CRT[1] projectors. However, the CRT is a dying breed and is steadily being replaced by LCD[1] desktop monitors, and in the projection arena, LCD and DLP[1] projectors.

While it used to be reasonable to assume that LCS 3D glasses would work with almost any user's desktop monitor (because it was likely a CRT), the multitude of new (non-CRT) display technologies in the market today means that it is now not easy to know if a particular user's desktop monitor will work with time-sequential stereoscopic display [1].

This is also happening at a time when there is increased interest and activity in stereoscopic imaging and viewing. Users are therefore often interested to know whether their existing display devices can be used for stereoscopic display purposes.

Although the anaglyph 3D method can be used with most new display devices, its quality is usually fairly poor. In contrast, the time-sequential stereoscopic display technique can produce a higher quality stereoscopic image but it is not compatible with all consumer displays. The time-sequential technique (aka: field-sequential, frame-sequential, alternate field, and sometimes active stereo) works by displaying an alternating sequence of left and right perspective images on the display whilst the user is wearing a pair of LCS 3D glasses. The LCS 3D glasses are driven in synchronisation with the displayed images such that the left eye sees only the left perspective images and similarly for the right eye.

2. LCD Monitors

Historically, LCD monitors have not been usable for time-sequential stereoscopic 3D visualisation due to their slow pixel response rate. With LCD pixel response rates for some monitors now just a few milliseconds it is reasonable to ask whether it is now possible to achieve time-sequential stereoscopic 3D viewing on LCDs.

We tested 15 different LCD monitors to establish their level of compatibility with time-sequential stereoscopic display. Five main properties of LCDs and/or LCS 3D glasses were identified that determine the stereoscopic image quality of time-sequential stereoscopic 3D viewing on LCD monitors [2]:

- LCD and LCS Native Polarisation
- LCD Refresh Rate
- LCD Pixel Response Rate
- LCD Image Update Method
- LCS Duty Cycle

With regard to the above list, if the native polarisation axes of the LCS glasses and the LCD display are orthogonal, the image in that eye will be dark, but this can be easily fixed by using quarter wave or half wave retarders on the glasses.

The refresh rate will determine whether the time-sequential image will be seen with flicker – the higher the frequency the better – 100Hz is usually considered to be the lowest refresh rate required for totally

[1] CRT = Cathode Ray Tube, LCD = Liquid Crystal Display, DLP = Digital Light Processing.

flicker-free operation. The highest refresh rate on the LCD monitors that we tested was 85Hz.

If the LCD pixel response rate is greater than the time period of one frame, the pixel will not be able to stabilise in one state before the next time-sequential frame is drawn. With some LCD monitors now providing a pixel response rate of just a few milliseconds, there is sufficient time for each pixel to stabilise within the time period of one frame, but there is another property of (some/most) LCD monitors that prevents them being used for conventional time-sequential stereoscopic display.

In all of the LCDs that we tested, a new image is written to the LCD one line at a time from the top of the screen to the bottom [3]. The time duration to update the whole screen was close to the time period of one frame. This scan-like image update method is illustrated in Figure 1. The vertical axis shows the vertical position on the LCD panel. The horizontal axis shows time. The thin diagonal line represents the addressing of each row of the LCD.

It is evident from Figure 1 that there is no one time

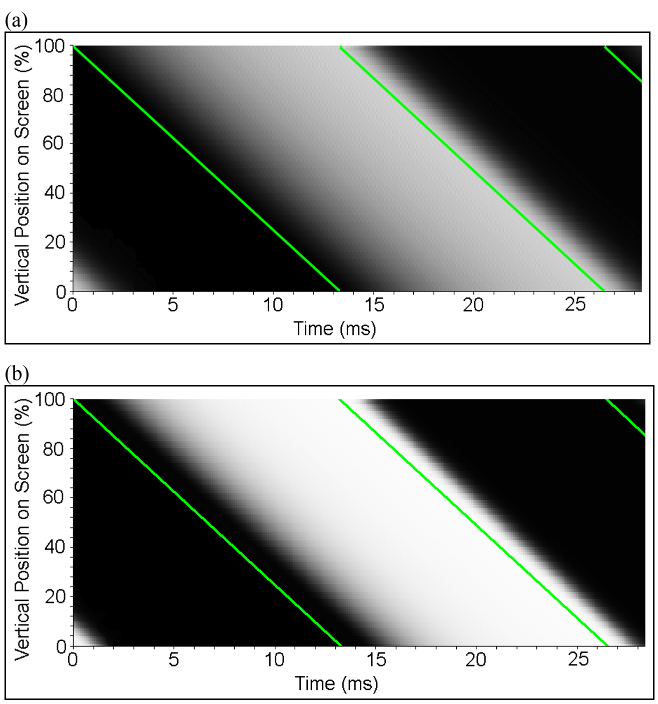

Figure 1: Time domain response of two LCD panels alternating between black and white at 75Hz for (a) a slow pixel response rate panel (21.7ms)[2] and (b) a fast pixel response rate panel (5.7ms)[2].

[2] Black-to-White (BTW) plus White-to-Black (WTB) transition time as measured between 10% and 90% thresholds.

when a single image is shown exclusively on the whole LCD panel. This means that there is no time when the shutters in LCS glasses could open and reveal exclusively a single perspective image.

In conventional time-sequential systems, LCS glasses are usually driven at ~50% duty cycle (the left shutter is open half of the time and closed the other half of the time, and vice versa for the right shutter). As can be seen from Figure 1, if a pair of LCS glasses operating at 50% duty cycle are used to view a time-sequential image on one of these LCDs, there would be a significant amount of crosstalk between the two perspective views.

We found that by switching the LCS glasses with a very short duty cycle, letterboxing the image (black strips at the top and bottom of the screen), and using a short pixel response rate LCD monitor, we were able to achieve a stereoscopic image on part of the screen, however the image was very dim and is therefore not a practical long-term solution [4][5].

3. DLP Projectors

The capability for some DLP projectors to be used with time-sequential stereoscopic display has been known for some time [6]. This is due to the extremely fast pixel response time (~2μs) of the DMD (Digital Micro-mirror Device) chip [7], the fact that the whole of the screen updates at once, and the capability of some DLP projectors to correctly display an alternating sequence of discrete left and right images.

Several DLP projectors are already available in the marketplace that are advertised as being "stereo-ready" and capable of 120Hz time-sequential stereoscopic display – available from suppliers such as Barco (Galaxy series), Christie Digital (Mirage series), and Infocus / Lightspeed Design Group (DepthQ).

A lesser known fact is that some consumer grade single-chip DLP projectors are also compatible with time-sequential stereoscopic display – although at lower refresh rates.

We tested 44 consumer grade single-chip DLP projectors to determine their level of compatibility with time-sequential stereoscopic display. Each projector was tested to establish: (1) whether the colour wheel synchronised with the incoming video signal, (2) whether there was crosstalk between alternate fields or frames, (3) the maximum frequency at which the projector would work in stereo, (4) the time delay between the incoming video signal and the displayed images, (5) whether the projector converted interlaced video sources to progressive format in a 3D compatible way, and (6) the colour wheel speed at various video input frequencies.

Fifteen projectors were found to work well at up to 85Hz stereo in VGA mode. 23 projectors would work at 60Hz stereo in VGA mode. 35 projectors were found to be compatible with progressive component video (480P and 576P) at refresh rates of 60Hz and 50Hz [8][9]. In controlled circumstances there will only be a slight amount of flicker visible with 85Hz stereo. Ordinarily, however, 60Hz and 50Hz stereo produce significant flicker[3].

The projectors that were found to be compatible with 85Hz VGA time-sequential stereoscopic display are listed in Table 1. The table also lists the time offset (from the trailing edge of the vertical sync signal to the start of image display), and the native resolution of the projector.

Table 1: Consumer DLP projectors found to be compatible with 85Hz VGA time-sequential stereoscopic display.

Projector Make/Model	Time Offset (ms)	Resolution
Acer PD322	0.96	1024x768
Acer PD523	0.96	1024x768
Acer PH110	0.31	854x480
BenQ MP610	0.58	800x600
BenQ PB6240	0.55	1024x768
Boxlight Raven	not measured	800x600
Casio XJ-360	0.35	1024x768
NEC LT35	0.42	1024x768
Optoma EP719	not measured	1024x768
Optoma EP739	not measured	1024x768
Plus U4-237	not measured	1024x768
Plus U5	0.94	1024x768
Sharp XR-10X	0.30	1024x768
Toshiba TDP-S8	0.53	800x600
Yamaha DPX-530	0.42	1024x576

The time offset is important because if the time-offset is significant, and the switching of the LCS glasses is not adjusted accordingly, a significant amount of image crosstalk could occur. The largest time offset measured at 85Hz was 0.96ms, which corresponds to 8% of the time period for one frame – this could result in a noticeable amount of crosstalk if not corrected. A custom LCS glasses driver was developed as part of this project to allow the switching of the LCS glasses to be time-offset by an adjustable amount.

More details about compatible and incompatible consumer projectors will be available in [8] and [9]. The 120Hz stereo-ready projectors do not appear in Table 1 and can be found by visiting the websites of the companies listed previously.

One other aspect of interest about the operation of most of the 85Hz capable projectors listed above is that the colour wheel speed drops down from 2x at 60Hz to 1.5x at 85Hz. "2x colour wheel speed" means that the colour wheel performs two colour

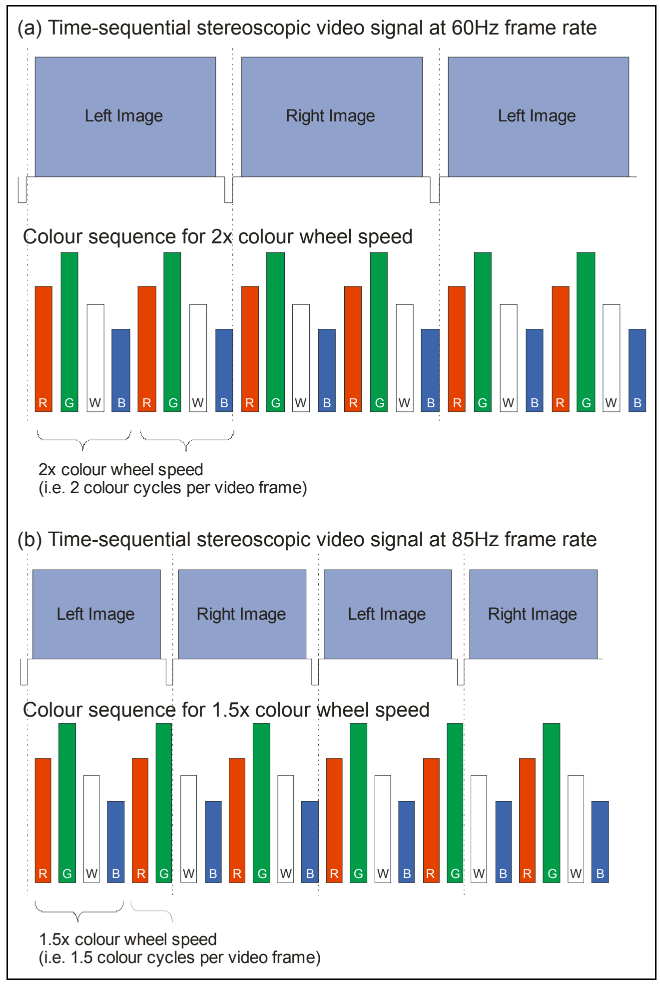

Figure 2: Illustration of (a) 2x and (b) 1.5x colour wheel speed at frame rates of 60Hz and 85Hz respectively (for an example 85Hz stereo capable single-chip DLP projector).

[3] Perceived flicker can be reduced by reducing image brightness and room brightness.

cycles per frame. "1.5x colour wheel speed" means that the colour wheel performs one and a half colour cycles per frame. It can be seen in Figure 2 that for 85Hz the left eye will see two red segments and two green segments whereas the right eye will only see one of each. The opposite occurs for the white and blue segments. Images for each eye will therefore have a slightly different colour bias. The effect is noticeable but slight, and may be ameliorated by the auto-white-balance capability of the human eyes.

4. Discussion and Conclusion

This study has revealed that most current generation LCD monitors cannot be used with the time-sequential stereoscopic display technique – this is due to the image-update method. There is continuous development in this area hence there is the possibility that newly released LCD monitors might be 3D compatible in some way - one example is LCD TVs which use a blinking or scanned backlight [3]. LCD panels can be used for other stereoscopic viewing methods and these are summarised in reference [1].

A second study reported in this paper has revealed a relatively large number of consumer single-chip DLP projectors that can be used for time-sequential stereoscopic display – some at image refresh rates as high as 85Hz. Although 60Hz and 85Hz stereo are generally not suitable for situations requiring totally flicker-free stereoscopic viewing, the knowledge that low-cost consumer DLP projectors can be used for time-sequential stereoscopic viewing will open up the range of applications and users of stereoscopic visualisation. Such users and applications can graduate to higher-end flicker-free "stereo-ready" projection systems when requirements dictate.

A wide range of other stereoscopic and autostereoscopic displays are now available in the market or are near to market. With stereoscopic imaging now being used in an increasing number of applications, this is great news for users.

5. Acknowledgements

The work on consumer DLP projectors was supported in part by iVEC (the hub of advanced computing in Western Australia), Jumbo Vision International, and ISA Technologies. We also thank the multitude of companies and individuals who lent LCD monitors and DLP projectors for testing.

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