Compatibility of LCD Monitors with Frame-Sequential Stereoscopic 3D Visualisation

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Abstract

Historically, LCD monitors have not been able to be used for frame-sequential stereoscopic 3D visualisation due to their slow pixel response rate. With LCD pixel response rates now in the single-digit millisecond range it is natural to ask whether it is now possible to achieve frame-sequential stereoscopic 3D viewing on LCDs.

1. Introduction

Historically, LCD monitors have not been able to be used for frame-sequential stereoscopic 3D visualisation primarily due to their slow pixel response rate.

The frame-sequential stereoscopic display method (also known as field-sequential, time-sequential, or alternate field) works by displaying an alternating sequence of left and right perspective images on a display screen. The observer wears a pair of Liquid Crystal Shutter (LCS) 3D glasses which alternately occlude the left and right eyes, such that the left eye sees only the left perspective images as they are displayed on the screen, and the right eye sees only the right perspective images as they are displayed on the screen. In order for the frame-sequential stereoscopic viewing method to work on a particular display device, the display must be capable of displaying separate and discrete alternate images without noticeable crosstalk between images (and at a sufficiently high image update frequency to avoid visible flicker). If the display is not able to completely extinguish the previous image before displaying the next image, ghosting (aka: crosstalk) [1] will be visible in the stereoscopic image and this can significantly degrade stereoscopic image quality. A slow pixel response rate will have this effect.

With some currently available LCDs having pixel response rates in the single-digit millisecond range it is natural to ask whether it is now possible to achieve frame-sequential stereoscopic viewing on LCDs.

We conducted a study to establish the important factors determining whether LCD monitors can or cannot be used for frame-sequential stereoscopic 3D visualisation.

These questions are particularly pertinent now because the production of CRTs is declining and the production of LCDs is increasing. CRTs have been the display of choice for use with the frame-sequential 3D method for many years, but there is a risk that at some point the production of CRTs could cease completely. The use of stereoscopic viewing is also increasing rapidly in a wide range of application areas – more people now want stereoscopic capability on their desktop or laptop PC.

2. Experimental Method

In this study we tested fifteen different LCD monitors from various manufacturers ranging from units that are several years old to units that have been just released in the last six months.

Equipment used for testing included: two custom built photodiode sensor pens (based on an Integrated Photomatrix Inc. IPL10530 DAL), an oscilloscope (Goldstar OS-3000), a PC equipped with an NVIDIA 6600GT (stereoscopic capable) graphics card for test image generation, and a custom built LCS 3D glasses driver box capable of adjustable phase and duty cycle.

The measurement method consisted of driving the LCD monitors with a range of video test signals via the VGA or DVI port, and monitoring the light output of the monitor with the photodiode sensor pens.

Data analysis was performed using a range of custom-written Maple programs and Excel spreadsheets.

3. Important LCD and LCS Properties

The frame-sequential stereoscopic display method has traditionally been used with CRT monitors, however LCD monitors have a very different mode of operation than CRTs. The main significant difference is that LCDs are a hold-type display whereas CRTs are an impulse-type display [2].

In this study five main properties of LCDs and/or LCS 3D glasses were identified which affect the stereoscopic image quality of frame-sequential stereoscopic 3D viewing on LCD monitors.

3.1 LCD and LCS Native Polarisation

The native polarisation of the display and the native polarisation of the LCS 3D glasses can affect whether both eyes can see a bright image. If the polarisation axis of either of the LCS glasses lenses is perpendicular to the polarisation axis of the display, that particular eye will appear dark at all times. Most of the LCD monitors that we tested had a native polarisation axis at -45º (from vertical). Some LCS glasses that we tested had the polarisation axes of the two eyes -45º and +45º, therefore one eye would see an image and the other eye would not - but there are many other orientations in common circulation.

This problem is easy to overcome by the addition of a quarter wave or half wave retarder in front of the LCS glasses lenses. A half wave polariser can be used to rotate the native polarisation of each LCS to match the polarisation axis of a chosen LCD, or a quarter wave polariser can be used to effectively jumble the polarisation by converting linear polarisation to circular or elliptical polarisation. The half wave polariser method offers a brighter image but is tuned to a particular polarisation angle and hence won't work with all LCDs.

3.2 Refresh Rate

The maximum vertical refresh rate of a monitor determines the maximum speed at which it can display a sequence of images. When used for frame-sequential stereoscopic display, the frame rate per eye is half that of the overall monitor refresh rate. If the refresh rate is too slow, flicker will be visible in the stereoscopic image. An overall refresh rate of 100-120 Hz is usually considered necessary to obtain a fully flicker-free stereoscopic image, however this also depends upon image brightness.

Most of the LCD monitors that we tested were able to accept and display video signals with refresh rates between 60Hz and 75Hz. Two would work at 60Hz only, and four would work at up to 85Hz. At 60Hz significant flicker would usually be evident. At 85Hz a small amount of flicker would be evident.

3.3 LCD Pixel Response Rate

In LCDs the pixel response rate is a measure of how fast an individual pixel can switch from one state to another.

As can be seen in Figure 1, it takes a finite time for a pixel to switch from black-to-white (BTW) and from white-to-black (WTB) (in the example of Figure 1, BTW = 4.4ms (10% to 90%)) and WTB = 1.3ms (90% to 10%)). In this study, BTW was always found to be longer than WTB. The transition time from one grey level to another (grey-to-grey (GTG)) can also be measured, however areas of high contrast between the two perspective views are usually the location of most stereoscopic ghosting [1]. Hence, the value for BTW response time seems to be more important than WTB or GTG for stereoscopic image quality.

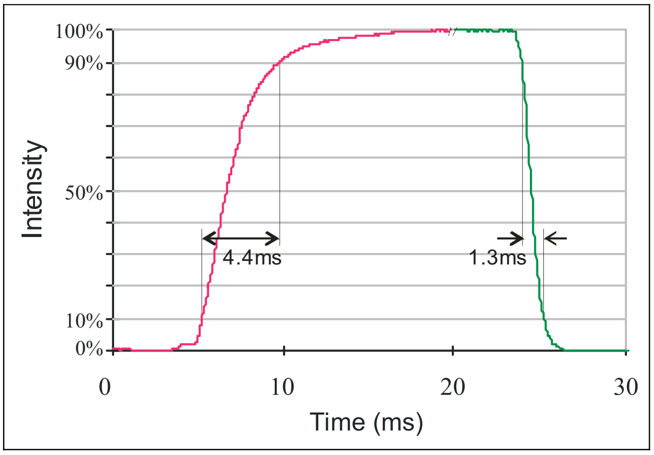


Figure 1: Example LCD pixel response (BTW and WTB)

For frame-sequential 3D viewing, the LCS shutter should not be opened until the switching of the pixel (from one state to another) has stabilised sufficiently. If the BTW pixel response time is too slow (i.e. greater than the period of one field or frame. e.g. >17ms for 60Hz field rate) the image would never stabilise before the next image was displayed and hence it could not be used for frame-sequential 3D because too much ghosting would be present.

3.4 Image Update Method

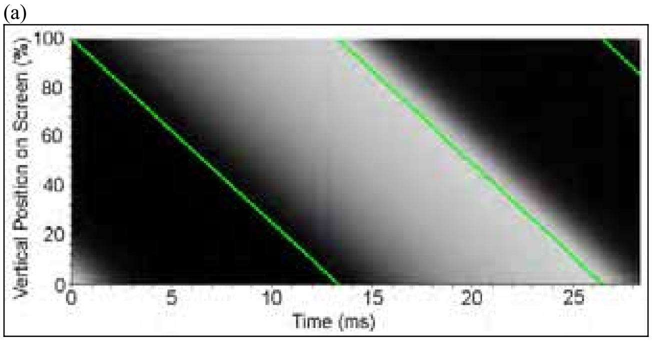
The method by which the display updates from one image to the next also needs to be considered.

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 (1 / frame rate) (e.g. the time period for 1 frame at 75Hz is 13.3ms).

This transition from one image to the next is similar in some respects to the way that an image is scanned on a CRT (except that an LCD is a hold-type display and not an impulse-type display like a CRT). This transition from one image to the next is also similar to the vertical wipe transition effect in video editing. Convolved on this scan-like image update is also the LCD pixel response.

The scan-like image update method is illustrated in Figure 2. 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. The top plot (a) shows the result for a LCD monitor with a slow pixel response rate (BTW+WTB=21.7ms) and the lower plot (b) shows the result for a LCD monitor with a fast pixel response rate (BTW+WTB=5.6ms). It can be seen in the figure that the BTW transition is slower than the WTB transition.

(a)



(b)

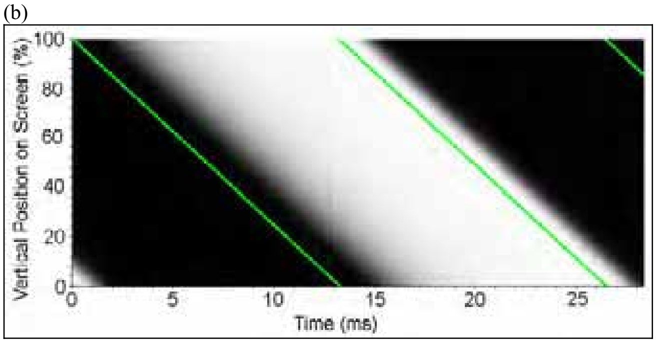


Figure 2: Time domain response of two LCD panels alternating between black and white at 75Hz for (a) a slow pixel response rate panel (21.7ms) and (b) a fast pixel response rate panel (5.7ms).

It is evident from Figure 2 that there is no one time when a single image is shown exclusively on the whole LCD panel – this is particularly so for LCD monitors with a long pixel response rate but is also true for LCD monitors with a short pixel response rate. This means that there is not a time when the shutters in LCS glasses could open and see only a single perspective image (exclusively).

3.5 LCS Duty Cycle

Most driving electronics for LCS 3D glasses drive the glasses with a 50% duty cycle. The left shutter is open 50% of the time (when left perspective images are displayed on the screen) and opaque the other 50% of the time. The right shutter is driven in a similar fashion but out of phase with the left shutter. This scheme works fine with CRT monitors (impulse-type display) but not with conventional LCD monitors (hold-type display) because of the finite LCD pixel response time and image update method discussed above.

The option of using a reduced LCS duty cycle is discussed below.

4. Discussion

Slow pixel response rate has historically been considered to be the main reason that LCD monitors cannot be used for frame-sequential stereoscopic 3D viewing. Although pixel response rate is important, the section above has revealed that the image update method of the panel is also an important consideration. Even if the pixel response rate is improved, the scan-like image update method of most conventional LCDs will still cause problems for the frame-sequential 3D method.

Two methods are proposed to allow stereoscopic images to be displayed on LCD monitors using the frame-sequential method.

Firstly, we have been able to achieve a reasonable quality stereoscopic image on a fast pixel response rate LCD monitor by switching the LCS glasses with a very short duty cycle and by adding black bands to the top and bottom of the screen image (i.e. letter-boxing the screen image). This is illustrated in

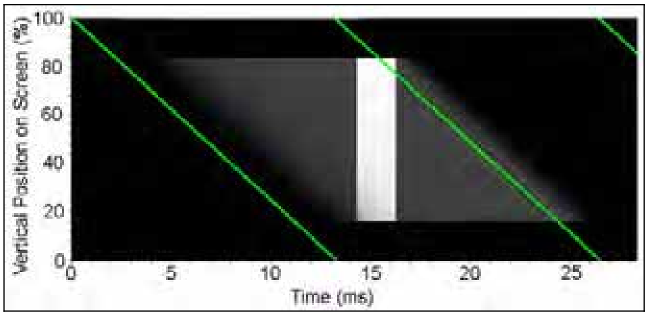


Figure 3: The use of a reduced duty cycle LCS 3D glasses† and letterboxing to achieve frame-sequential stereo on a fast pixel response rate LCD.

Figure 3. It should however be noted that the image will be fairly dim due to the reduced duty cycle and the letterboxing of the image may be problematic in some instances. There can also still be a slight amount of ghosting at the bottom of the stereoscopic image.

Secondly, if the addressing of the LCD panel could be sped up, perhaps completing a full panel update in 50% of the time period of one frame (rather than the full period of one frame), there would exist a period in time when a single image could be seen exclusively on the screen. This is illustrated in Figure 4. One way to achieve this might be to allow the LCD monitor to accept higher frequency video signals (e.g. twice the desired stereo frequency) and change only the image in the video signal once every second frame. Unfortunately this is not a solution for existing LCD monitors and will be limited by the maximum addressing speed of the LCD panel.

Fifteen different LCD monitors were tested during this study and although all of the monitors tested had very similar display properties, it is not suggested that all LCD monitors are the same. There are already some new LCD TVs which operate differently than the LCD monitors described above, namely LCD TVs which use a blinking backlight [3] or a scanning backlight [4]. These technologies which have been developed to improve motion image reproduction in normal television viewing.

† Please note that the switching of the LCS also has a response rate [1] but this has not been illustrated correctly in this figure.

(a)

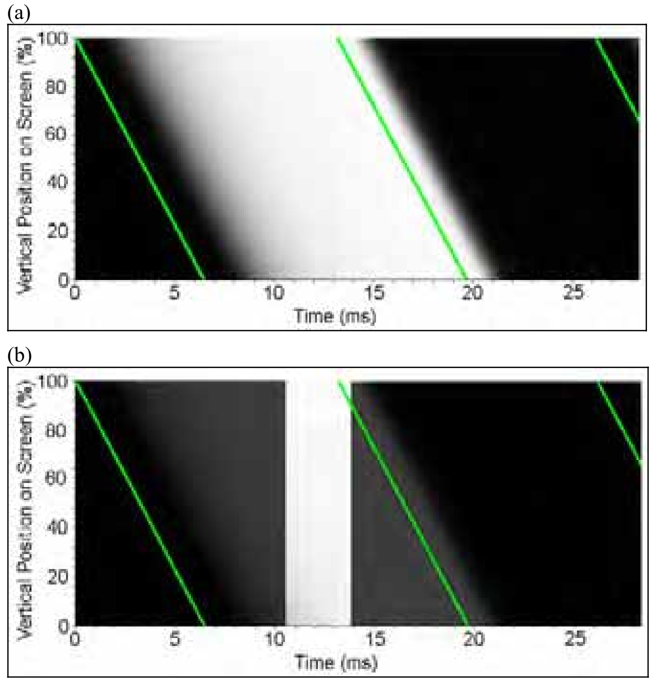


Figure 4: (a) Time domain response of a fictitious LCD monitor with a fast addressing rate and fast pixel response rate and (b) the same being used with reduced duty cycle LCS 3D glasses†.

5. Conclusion

This study has identified five main properties of LCDs and LCS 3D glasses which affect the quality of stereoscopic images displayed using the frame-sequential stereoscopic display method on LCD monitors.

Despite the fact that the pixel response rate of new LCD monitors is falling, the scan-like image update method used by many/most conventional LCD monitors still prevents them being used with conventional LCS 3D glasses to achieve a full-screen stereoscopic image using the frame-sequential stereoscopic display method.

This paper has suggested two possible methods of achieving frame-sequential stereo on fast response LCD monitors. However both methods are not ideal.

LCD technology is developing fast and new drive methods may mean that new generation LCDs could be compatible with the frame-sequential stereoscopic display method by using a modified LCS drive technique.

LCD panels can be used for other stereoscopic viewing methods and these are summarised in reference [5].

6. Acknowledgements

We wish to thank the companies and individuals who lent LCD monitors for testing.

7. References

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