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Compatibility of Display Products with Stereoscopic Display Methods

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ABSTRACT

Stereoscopic Imaging is coming of age – new high-resolution stereoscopic displays and related stereoscopic equipment are readily available, and a wide range of application areas is making use of stereoscopic imaging technologies. Unfortunately, new display products are not always compatible with existing stereoscopic display methods. This paper discusses the compatibility of current display products with various stereoscopic display methods.

INTRODUCTION

Many stereoscopic specific display products are now readily available in the marketplace. Vendors include Sharp, StereoGraphics, Opticality (formerly X3D), SeeReal, Dimension Technologies Inc. (DTI), VREX, Christie Digital, Barco, and many others. A wide range of supporting stereoscopic compatible hardware and software is also readily available for creating, transmitting, storing, and serving the stereoscopic images (and video) for display on these stereoscopic display products. But more importantly, a wide range of application areas ranging from science to entertainment are increasingly making use of these stereoscopic imaging technologies. For example, stereoscopic 3D DVDs are widely commercially available, thousands of commercially available PC games can be played in stereoscopic 3D by the use of a stereoscopic driver from nVidia, and the 2004 NASA Mars rovers (Spirit and Opportunity) are each fitted with four stereoscopic cameras.

The Cathode Ray Tube (CRT) has been the dominant display technology for many years, however a number of new display technologies have begun to dominate the new display market in recent years (e.g. Liquid Crystal Displays (LCD), Plasma, DLP[†], and many others). These new display products use different display principles and hence their compatibility with various stereoscopic display methods varies from good to bad.

STEREOSCOPIC DISPLAY METHODS

There are many methods available to display stereoscopic images – all of these methods rely on some underlying technique to present each of a person's eyes with a different perspective image. The "underlying technique" is usually based on a method of coding and decoding the multiple stereoscopic views in the same light field – these can be colour, polarisation, time, and/or spatial separation. Summarised below are the main stereoscopic display methods which are currently used in commercial displays:

TIME-SEQUENTIAL (FIELD-SEQUENTIAL)

In this method, left and right perspective images are shown alternately (sequentially) on the same display surface. The observer wears a pair of liquid crystal shutter (LCS) 3D glasses whose lenses switch on and off in synchronisation with the left and right perspective images shown on the display such that the left eye only sees the left perspective images and the right eye only sees the right perspective images.

This method is more commonly known as 'field-sequential' or 'frame-sequential' because it is a sequence of fields or frames. It is described here generically as 'time-sequential' because it is a time-sequential sequence of left and right perspective images (which can either be frames or fields).

Time-sequential stereoscopic image quality is dependent upon the persistence and refresh rate of the display and also the quality of the particular LCS 3D glasses used[1]. Shorter persistence pixels and faster refresh rates produce better time-sequential stereoscopic image quality. Important 3D image quality factors in time-sequential 3D are ghosting and flicker.

LENTICULAR, PARALLAX BARRIER AND PARALLAX ILLUMINATION

These three stereoscopic display methods are similar in that they require a display whose pixels are spatially-fixed - they rely on the use of an optical element which must accurately align with the pixels of the display. The optical element works to create viewing zones where particular groups of pixels (corresponding to a particular view) are only visible from a particular direction. If an observer's eyes are in two different zones, a stereoscopic image can be observed without the need for 3D glasses.

In the case of Lenticular, the optical element consists of a series of vertical lenslets (lenticules) fitted over the face of the display.

[†] Digital Light Processing. Developed by Texas Instruments. Also known as the Digital Micro-mirror Device (DMD).

In the case of Parallax Barrier, the optical element consists of a series of opaque vertical strips which are placed over the face of the display.

In the case of Parallax Illumination, a backlight made up of vertical strips of light is fitted behind the display.

In two view systems there is one vertical lenticule/barrier strip/light strip per two-pixel column. The fitting of the optical element requires accurate registration between the display's pixels and the optical element, hence it is not usually an end-user option. Lenticular and Parallax Barrier methods can be applied to rear projection displays but are not currently implemented commercially.

SPATIALLY MULTIPLEXED POLARISED

In this method an optical sheet is placed over the face of the display which polarises alternate pixels of the display in orthogonal polarisation states[2]. The viewer wears a pair of polarised 3D glasses to view the stereoscopic image on screen.

This method will only work with displays which have spatially-fixed pixels. The fitting of the optical element requires accurate registration between the display's pixels and the optical element, hence it is not usually an end-user option.

POLARISED PROJECTION

With polarised projection, two displayed images are optically overlayed (e.g. two video projectors projecting onto a single silvered screen) and polarisation is used to code and decode the two views. The observer wears polarised 3D glasses to see the stereoscopic image.

ANAGLYPH

This stereoscopic display method uses colour to separate the two perspective views. Usually the left perspective image is displayed in the red channel of the display and the right perspective image is displayed in the blue and green channels of the display. The observer(s) wears glasses with the left lens red and the right lens cyan. Other combinations of colour primaries are possible.

The anaglyph method is widely used because it is compatible with all full colour displays, however the quality of the perceived stereoscopic image is relatively poor as compared to other stereoscopic methods and truly full-colour stereoscopic images cannot be achieved using anaglyph.

A recent study revealed that anaglyph image quality was dependent upon the spectral colour purity of the display and the glasses[3]. The study ranked the following displays from best to worst for anaglyph image quality: 3-chip LCD projector, 1-chip DLP projector, CRT display, LCD display.

OTHER METHODS

There are many more methods of displaying stereoscopic images available (plus variations of the methods summarised above), however a full description of all possible stereoscopic display methods is beyond the scope of this paper. For further information, the interested reader is referred to the proceedings of the Stereoscopic Displays and Applications conference[4].

STEREOSCOPIC COMPATIBILTY

Several factors determine whether a particular display is compatible with a particular stereoscopic display method. These factors include: native polarisation, image persistence (sometimes referred to as response time or refresh rate), colour purity, and whether the pixels are spatially-fixed.

The stereoscopic compatibility of the fundamental technology used in a range of different displays is summarised in Figure 1 and described below:

CRT

CRT display technology is fundamentally compatible with time-sequential, polarised projection, and anaglyph methods but incompatible with fixed-pixel methods[‡].

LCD

LCDs are compatible with fixed-pixel methods[‡] (although some care must be taken with native polarisation and the arrangement of the individual colour primary pixels) and polarised projection methods. The colour purity of different LCDs has been found to vary considerably from display to display hence anaglyph compatibility varies from poor to good (not withstanding the limitations of anaglyph)[3].

LCDs are usually incompatible with time-sequential 3D – their long persistence (low refresh rate) usually causes significant stereoscopic image ghosting. Refresh rates of LCDs are steadily improving hence this problem may soon be overcome.

PLASMA

Plasma display technology is fundamentally compatible with time-sequential, and fixed-pixel methods[‡]. Anaglyph compatibility is untested by this author but it is expected to be similar to CRTs. Plasma is currently only used in direct-view displays.

DLP

DLP display technology is fundamentally compatible with time-sequential and polarised projection methods. DLP technology is currently only used in projection displays and hence it is not usually considered for fixed-pixel methods[‡]. The colour purity of different DLP displays varies considerably (usually depending upon the spectral

[‡] Fixed-Pixel Methods = Lenticular, Parallax Barrier, Parallax Illumination, and Spatially Multiplexed Polarised methods.

	Time-Sequential	Lenticular	Parallax Barrier	Parallax Illumination	Spatially Multiplexed Polarised	Polarised Projection	Anaglyph
Direct View							
CRT	√	X	X	X	X	n/a	Moderate
LCD	X*	√	√	√	√	n/a	Poor to good
PLASMA	√	√	√	X	√	n/a	?
DLP	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Projection (Front and Rear)							
CRT	√	n/a	n/a	n/a	X	√	Moderate
LCD	X*	n/a*	n/a*	n/a	√	√	Poor to good
PLASMA	n/a	n/a	n/a	n/a	n/a	n/a	n/a
DLP	√	n/a*	n/a*	n/a	X	√	Poor to good

Figure 1: Summary of display method compatibility with stereoscopic display methods. (* = see text)

quality of the colour wheel) hence anaglyph compatibility varies from poor to good[3].

OTHER DISPLAY PRODUCTS

A range of other display products is also available (or becoming available) in the market, including LED (Light Emitting Diode), OLED (Organic Light Emitting Diode), FELCD (Ferro-Electric Liquid Crystal Display), LCoS (Liquid Crystal on Silicon), and many others. Their compatibility is not discussed in this paper but their own fundamental display properties will determine their compatibility with the various stereoscopic display methods.

DISCUSSION

A good number of stereoscopic specific display products are now commercially available. However, there are instances where a consumer would like to use their existing display to view stereoscopic 3D images or video. The stereoscopic display methods which can be most easily retrofitted to an existing display by an end user are anaglyph and time-sequential. Anaglyph will work with all current displays however its 3D image quality is relatively poor. Time-sequential provides much better 3D image quality, however there are several mitigating factors which may prevent that particular display from being used with time-sequential 3D (even though the fundamental display technology may be compatible with time-sequential 3D display). These mitigating factors usually relate to video processing functions performed in the particular display product - such as interlaced to progressive conversion, 50 to 100Hz conversion, frame rate conversion, and image scaling.

INTERLACED TO PROGRESSIVE CONVERSION

Interlaced to progressive conversion (sometimes called deinterlacing) is necessary for displays which are natively progressive (LCD, Plasma and DLP). Several different algorithms for interlaced to progressive conversion are currently in common usage in different display products, and unfortunately some of these algorithms are incompatible with time-sequential 3D (they disrupt the 3D content by mixing the fields). In some instances ‘interlaced to progressive’ converters also implement reverse 3:2 pulldown however this is also incompatible with time-sequential 3D video. Fortunately there is an interlaced to progressive conversion algorithm which is compatible with field-sequential 3D and a number of display products (and DVD players) use this particular algorithm.

If it is found that a particular display product uses a deinterlacer which is incompatible with field-sequential 3D, the internal deinterlacer can often be bypassed by using an external (3D friendly) deinterlacer, and inputting this signal into the particular display product.

50 TO 100Hz CONVERSION

Some displays include another form of video processing (50 to 100Hz conversion - sometimes called ‘100Hz Digital Scan’) designed to reduce the amount of visible flicker in a television image. Most display products which include 50 to 100Hz conversion use an algorithm which is incompatible with time-sequential 3D, however there is a 50 to 100Hz conversion algorithm which is compatible with time-sequential 3D which could be relatively easily included to maintain time-sequential 3D compatibility.

50 to 100Hz conversion is a very good thing for time-sequential 3D because it overcomes the flicker problem normally associated with viewing field-sequential 3D video (particularly at 50Hz)[4], however a 3D compatible algorithm needs to be used.

(DLP) FRAME RATE CONVERSION

Some models of DLP projector have a fixed internal operation frequency (usually 60Hz) – a frame rate converter is used to convert a video input signal of any other frame rate to the native frequency of the DLP engine. Unfortunately frame rate conversion usually disrupts the 3D content of a time-sequential 3D video signal. In order to achieve 3D compatibility with these devices, it is necessary to input time sequential 3D video into these display devices at a field-rate or frame-rate which matches the internal operating frequency of the DLP engine.

IMAGE SCALING

In order for display products which have a fixed pixel resolution to display video from a different source resolution, it is necessary for the input video signal to be up-scaled or down-scaled to the resolution of the display. Image scaling will likely disrupt the 3D compatibility of fixed-pixel stereoscopic display methods[‡] but should not affect time-sequential 3D.

For optimal 3D compatibility, it would be desirable if display products which included the video processing functions described above also provided a menu option which either allowed the device to be switched into a time-sequential 3D compatible mode or disabled the particular video processing function. Interestingly some HD television sets do include a menu option called “game mode” which puts the television into a display mode which is compatible with field-sequential 3D NTSC.

It is also problematic that display product documentation does not usually list whether that display is time-sequential 3D compatible. Third-party listings of products that are compatible and incompatible with time-sequential 3D video are appearing and this should be encouraged.

FIELD-SEQUENTIAL 3D NTSC/PAL

As mentioned in the introduction, a wide range of 3D DVDs is now commercially available – many of these are in field-sequential format (a defacto standard for time-sequential 3D on NTSC and PAL video[6]). Unfortunately a high percentage of new display products are incompatible with time-sequential 3D (in their default mode) and hence more care must now be taken to check or ensure field-sequential 3D will work with particular display products.

Although SD (Standard Definition) video standards such as NTSC and PAL are on the road to retirement, they will remain with us for some time as we gradually transition to HDTV and other formats. Field-sequential 3D will likely remain a useful format during this transition period.

CONCLUSION

The market for stereoscopic compatible display products is increasing and many new stereoscopic specific display products are now available in the market place. This paper has summarised the compatibility of a selection of stereoscopic display methods with a range of display product technologies.

The biggest stereoscopic compatibility problem at the current time is with the time-sequential 3D method - a high percentage of new display products being released are incompatible (in their default mode) with time-sequential 3D. In some cases this incompatibility is due to fundamental display technology limitations (e.g. LCD) but in some cases it is due to the implementation of advanced video processing features which disrupt the 3D video signal (in some cases this could be relatively easily corrected).

Display manufacturers need to be aware of the growing stereoscopic imaging market and the potential for their display products to be used in stereoscopic display applications.

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