# Design of a sub-€1000 stereo vision enabled co-located multi-modal display

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**Figure 1:** *Consumer product assembled co-located display running FS-Wisdom dental simulation.*

## Abstract

With a stereo vision enabled co-located haptic feeback display, the user of a virtual environment can touch and feel objects where they are seen. In this paper a low-cost display is assembled from consumer market products, lowering the financial barrier required to engage in virtual environments. In particular the issue of polarised light being cancelled out in a mirrored view of a popular flat screen display is solved with a half-wave retarder film.

**Keywords:** Haptics, Co-location

## 1 Background

Working with haptic feedback and stereo vision has formerly been an endeavour limited to the professionals. Haptic feedback devices were in the €10000 price range and graphics cards capable of stereo output in the €1000 price range. Up until recently the only desktop screens capable of the required refresh rate needed to avoid flicker (above 100 Hz) were bulky CRT-screens. Since most computer displays manufactured today are LCD's, good quality CRT-screens are even more expensive and have limited availability.

### 1.1 Consumer market technology

The consumer gaming market has long since been driving the development of graphics cards and fast-response LCD's and is now moving in to new areas to immerse the gamers. Two consequences of this is the development of consumer-priced haptic feedback devices and 3D-capable flat panel screens.

With a price around €200, the Novint Falcon is the first general purpose three degrees of freedom haptic feedback device targeting the general end consumer gamer. In spring 2009, Nvidia released a consumer-priced stereo vision kit called 3D Vision consisting of active shutter glasses and a usb-based IR emitter that links the glasses to the computer. Sold together with a Samsung 2233RZ 120 Hz flat screen display, it is now available for less than €500. The combination of Falcon, 3D Vision and 2233RZ suggested that a sub-€1000 co-located display could be created.

## 2 Importance of co-location

In haptic feedback enabled virtual environments, co-location is the ability to merge the 3D vision and haptic feedback in a way so that the user feels the object where it is viewed. Previous work has indicated that co-location significantly improves interaction performance for tasks requiring accuracy and rapid motion [Swapp et al. 2006]. A common way of achieving co-location is utilizing a tilted monitor and a mirror as in figure 3.

## 3 Projecting image on top of hand

The brain has three major ways of determining depth which are accommodation (the amount of focus), convergence (the angle between the eyes line of sight) and stereopsis (the difference between the left and right images). Only convergence and stereopsis can be emulated in a flat display setup, since the eyes still need to focus on the screens surface. While a flat screen could be placed directly over the haptic feedback device, it forces an unnatural focus which can cause eye strain. The preferred method is thus to align the virtual focal plane with the main area of interest in the scene. This forces us to use a mirror (figure 3) to achieve co-location since the surface of the screen needs to be at the same viewing distance as the haptic device.

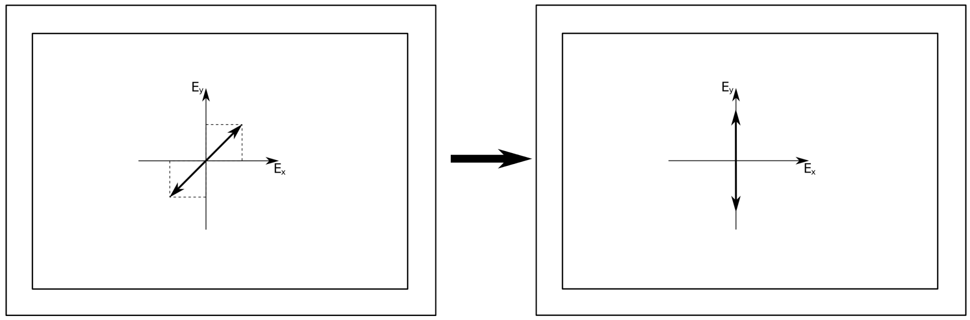


**Figure 2:** *The original polarisation direction is rotated by the added half-wave retarder film.*

### 3.1 Polarisation issues

The light emitted from the Samsung 2233RZ is polarised at an angle of $\pi/4$ and the shutter-glasses uses this property to alternately block the image for each eye. Reflecting polarised light rays at an angle of $\pi/4$ causes the polarisation plane to rotate by $\pi/2$ due to phase shift between the electrical field vectors. This makes the polarisation planes of the glasses and the image perpendicular to each other and thus completely blocking the light. We therefore need to rotate the direction of polarisation from the screen prior to reflection so that it is parallel to the reflective surface. This will ensure that the phase shift will have no impact on the polarisation since the resulting vector will be aligned with one of the electrical field vectors and thus causing the perpendicular component to have zero value. [Manneberg 1996]

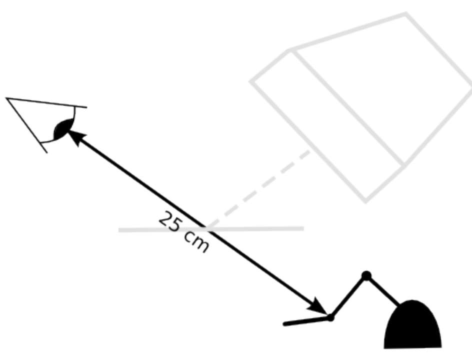


**Figure 3:** *The viewing distance to the screen and haptic feedback device is equal.*

### 3.2 Solution with retarder film

To rotate the polarisation direction, a half-wave retarder film can be placed over the screens surface which reflects the polarisation plane in the optical axis [Lipson et al. 1995]. Aligning the optical axis of the retarder film at $\pi/8$ in relation to the polarisation axis of the screen causes the polarisation to be rotated by $\pi/4$ (see figure 2). This causes the polarisation plane to be perpendicular to the mirror resulting in no rotation of the polarisation at reflection (see figure 4). By inserting a half-wave retarder film we allow the polarised light to pass through the glasses again. The retarder film (two sheets of quarter-wave retarder film) of the size needed to cover a 22 inch screen costs under €20.

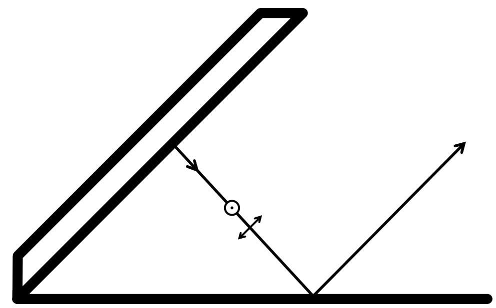

**Figure 4:** *The polarisation direction must be either perpendicular or parallel to the reflective surface, to avoid rotation.*

## 4 Software

Nvidia 3D Vision was initially designed to run DirectX based games with Nvidia consumer level graphics card. Recent drivers from Nvidia also supports OpenGL Quad-buffered stereo on their Quadro range of graphics cards which enables compatibility with software originally developed for more expensive 3D solutions. This makes the co-located display presented in this paper compatible with open source visualisation framework such as Forssim (see figure 1) and H3D in Microsoft Windows XP without modifications. To this date no free operating systems are supported.

## 5 Results

We assembled a sub-€1000 stereo vision enabled co-located multimodal display with a conventional monitor arm, a mirror, two sheets of quarter-wave retarder film, duct tape, Samsung 2233RZ, Novint Falcon and Nvidia 3D Vision. The display was successfully tested running a dental simulation software.

## References

LIPSON, S. G., LIPSON, H., AND TANNHAUSER, D. S. 1995. *Optical Physics*. Cambridge University Press.

MANNEBERG, G., 1996. Kursmateriel om optik, laser och optronik. Online: available 2009-11-18.

SWAPP, D., PAWAR, V., AND LOSCOS, C. 2006. Interaction with co-located haptic feedback in virtual reality. *Virtual Reality 10*, 1, 24–30.