A Simple Viewfinder for Stereoscopic Video Capture Systems

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Abstract

The emergence of low cost digital video in the consumer market now makes possible high quality stereoscopic video productions. The creation of stereoscopic content requires a comprehensive understanding of many issues related to camera alignment, scene composition, synchronization, lighting and human vision. Many of these can be simplified by providing a stereoscopic viewfinder enabling the videographer to see the 3D image as it unfolds. This paper describes the design, construction and theory of a simple, low cost stereoscopic viewfinder for converged stereoscopic camera systems.

Background

Stereoscopic imaging has fascinated and entertained the public since its inception. It's commercial development and use has been hindered by a variety of factors. Stereoscopic photography enjoyed enormous popularity during the last half of the nineteenth century. The Holmes stereoscope was as popular during the Victorian era as is television today. Stereoscopic movies enjoyed a short renaissance of popularity in the early 1950's but were hindered by the lack of movie theatres capable of displaying the stereoscopic films that were produced. Film Studios did not understand the issues involved in the production of comfortably viewable stereoscopic images. Projectionists did not understand the importance of image alignment or the requirement of using a polarization preserving screen so that viewers could see the independent images intended for right and left eyes. Some films shot in 3D (e.g. Kiss me Kate, Dial M for Murder) were subsequently released in 2D and were highly successful [1].

Stereoscopic imaging remains the domain of hobbyists and enthusiasts in much the same way that wireless communications was dominated by amateur radio operators until the introduction and wide deployment of CB radio and eventually the emergence of cellular telephones. Wireless communications is now one of the fastest growing segments of the electronics market.

Stereoscopic images continue to fascinate and intrigue. There is something magical and unreal about these images. The perception of depth stimulates parts of the brain that delight viewers. Moreover, the direct expression of depth in images has been found to be extremely useful in a variety of application domains ranging from product development, medicine, education, architecture, geology, weather analysis and oil exploration. Despite the wide range of potential applications, stereoscopic imaging remains the province of a handful of small companies providing proprietary systems that lack standardization and uniformity.

The creation of good stereoscopic video images requires an understanding of a variety of issues ranging from optics, human visual perception and film craft. It requires the precise alignment and synchronization of video cameras. If the cameras are not properly aligned the resulting images will not be viewable or will cause severe eye fatigue. The geometry and the separation of the two optical axes are manually adjusted during filming to establish and re-position the zero parallax plane within the scene being captured. A variety of factors can result in image misalignment.

In this paper we describe a simple and effective solution to the problem of image misalignment for stereoscopic video image capture. It simplifies the creation of comfortably viewable stereo images enabling untrained amateurs to create surprisingly good video images. Previously, most stereoscopic image capture systems did not provide stereoscopic viewfinders. Stereoscopic film cameras were often designed with a monoscopic viewfinder that enabled the photographer to determine the boundary of the captured image, but provided no depth information. A number of factors make it difficult to create a stereoscopic viewfinder (e.g. a top mounted viewfinder on a film camera causes one's nose to interfere). A stereoscopic viewfinder provides invaluable information enabling the videographer to capture stereoscopically viewable footage. This paper describes the design, theory and implementation of a simple, low cost stereoscopic viewfinder for stereoscopic video capture systems.

Discussion

Stereoscopic imaging requires a comprehensive understanding of a number of complex issues. The placement, alignment, optical geometry of the cameras as well as the composition of the scene are critical elements for creating comfortably viewable images. Small errors (as little as 1 degrees of vertical displacement) in any of these elements may be tolerated by the viewer but will result in eye fatigue. Major errors in controlling these elements will result in images that cannot be fused and will appear doubled to the viewer[2]. A stereoscopic viewfinder simplifies this process by enabling the videographer to "see" the 3D images as they are captured, thus simplifying the creation of stereoscopic content.

There are two basic geometries for the optical axis of the dual capture devices for stereoscopic imaging: parallel and converged optical axis (Figure 1). Converged optic systems are the simplest to control but impose limits in terms of the scene to be captured. This paper describes a stereoscopic viewfinder for converged optic systems. A different, more complex solution is required for parallel optical systems and is not discussed in this paper.

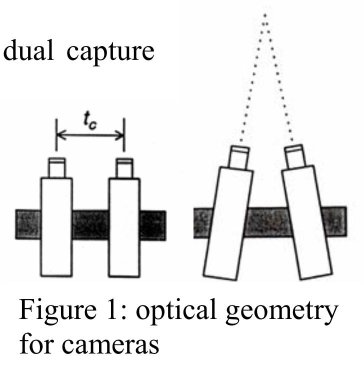

Figure 1: optical geometry for cameras

A short overview of some of the issues involved is helpful. Binocular stereopsis is based on retinal disparity. Each camera captures the scene from a slightly different position. The image from each camera is presented independently to either the right or left eye. There are four basic geometric relationships that can exist between the placement of an object (shown in Figure 2) when overlaying the image from each camera. These determine how the object is stereoscopically perceived. Objects with *positive* parallax are perceived to exist behind the plane of the display device. Objects with *zero parallax* are perceived to exist at the plane of the display device. Objects with *negative parallax* are perceived to be in front of the display device. Finally, objects with *divergent parallax* can not be fused and will appear as two separate objects by the viewer (*diplopia*). It is critically important when using converged optical configurations that no object within the scene displays divergent parallax.

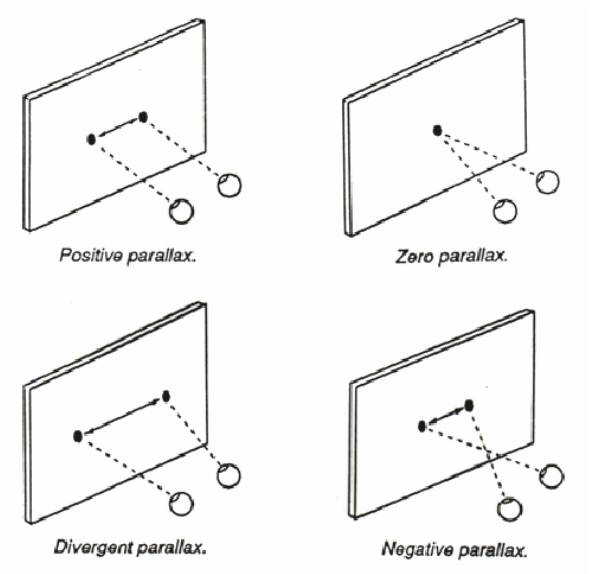

Figure 2: Four Types of Parallax

Varying the angle of convergence between the two cameras enables the videographer to set the zero parallax plane. The point where the optical axis of the two cameras intersect defines this property.

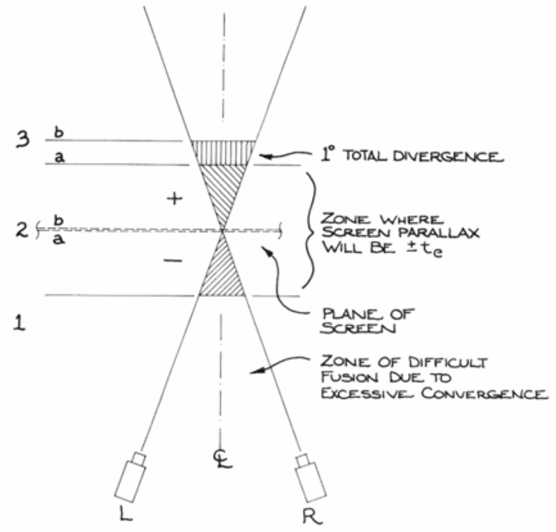

Figure 3: relationship between angle of convergence and camera separation

Although we rely on lateral displacement of identical objects within the scene to determine their perceived depth position via retinal disparity, vertical displacement of the images cannot be tolerated. A very small vertical misalignment of the cameras results in stereoscopic images that are either completely unviewable or can be fused but with extraordinary effort and considerable eye fatigue. Finally, the separation between the two cameras determines the range of depth within a scene. The smaller the separation between the cameras, the greater the range of depth that can be captured and perceived by the viewer (as is depicted in Figure 3).

Typically, two video cameras are mounted on a slide-bar that permits variable lateral displacement between the cameras. These are mechanical systems that are incapable of providing sufficient vertical alignment be maintained between the images from the two cameras. Moreover, incorporating optical zoom magnifies errors in vertical displacement. Finally, video camcorders sold into the consumer market are mass produced and there is no guarantee that the CCDs within them are precisely aligned to the plastic cases within which the internal assemblies are mounted. Thus, for a variety of reasons, it can be extremely difficult to insure accurate vertical alignment between the images from each camera. In most cases, it becomes a matter of luck rather than skill that determines the quality of the resulting images. Consequently, we use one or more multi-axis adjustable camera mounts to precisely align the camera's position.

Design:
A simple, low cost stereoscopic viewfinder can be constructed using two small LCDs. These are typically sold as display screens for automobile entertainment systems. Our system uses two 4" LCDs[*] that retail for less than 100 SFr. The viewfinder is configured as a cube with the two LCDs positioned so that one is fixed to the far wall of the cube and the other along a side wall. A beam splitter is positioned (as shown in Figure 4) so that the two images overlap when viewed from the front of the cube. We used a small piece of reflective glass commonly used for office buildings[†] because it is readily available at very low cost.

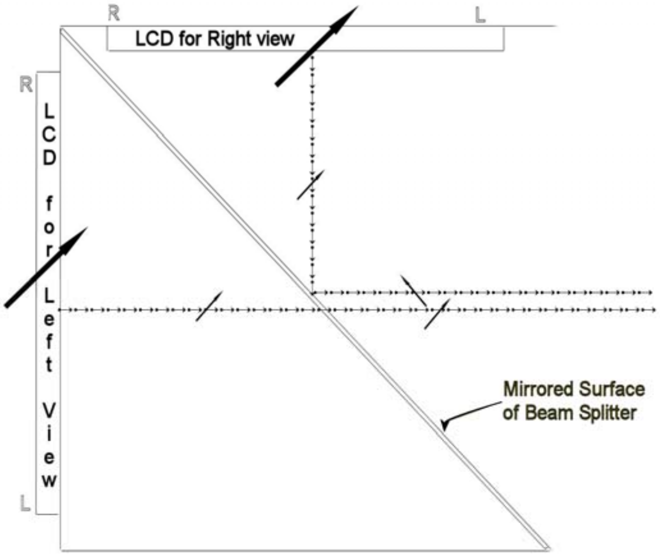

Figure 4: Top view diagram of Cube Viewfinder

The perception of high quality stereoscopic images requires each eye to see a different and unique image. Cross talk or mixing of these images can significantly reduce the 3D illusion. The viewfinder uses linearly polarized light. LCDs by virtue of their construction, emit linearly polarized light. Since we use two identical LCDs the angle of polarization is identical. Our design employs the reflection properties of a mirrored surface to transform the angle of polarization of the light from one of the LCDs (the one seen via reflection) Since we seek to minimize cross talk between the two images we insure[‡] that the initial angle of polarization from the LCDs is set to 45 degrees from vertical. We choose 45 degrees because this is the only angle that results in an orthogonal orientation is generated by reflection. Orthogonality insures the two images will have a minimum of cross talk.

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[*] dual composite input, PAL & NTSC, 12V, 13W

[†] Downey Glass ¼" Grey Eclipse Float

[‡] The angle of polarization can be adjusted using a half wave retarder. A thin sheet of household cellophane film (e.g. plastic wrap) is a surprisingly good half wave retarder that can be used to rotate the initial angle of linearly polarized light from the LCD to 45 degrees. Alternatively, one can select an LCD whose angle of polarization is 45 degrees.

Additionally, since one of the images (the right view as seen in Figure 4) is seen via reflection, the scan direction of the image must be reversed with respect to the other (left) view. This can be achieved via either the LCD panel or the video camera.

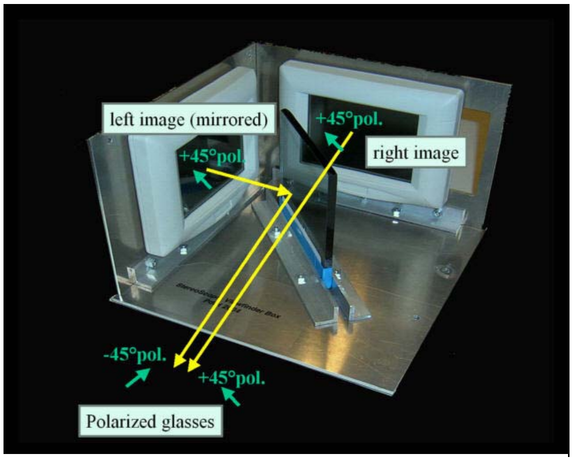

Image 5: Interior of Stereoscopic Cube Viewfinder

Finally, the orientation of the beam splitter within the cube should be arranged so that the reflective surface of the beam splitter is placed *toward* the viewer. If not, the reflected image will be seen as slightly doubled. This would be caused by reflection off both the front and back surface of the beam splitter. Unequal attenuation of light passing through and reflected off of the beam splitter is compensated by adjusting the brightness setting of the LCDs.

A functioning prototype of the resulting stereoscopic cube viewfinder is shown in images 5 and 6. The aluminum housing is designed to facilitate mechanical linear adjustment of the LCDs and to enable 5 degrees of rotation of the beam splitter. The entire assembly was constructed in Switzerland for approximately 250 SFr.

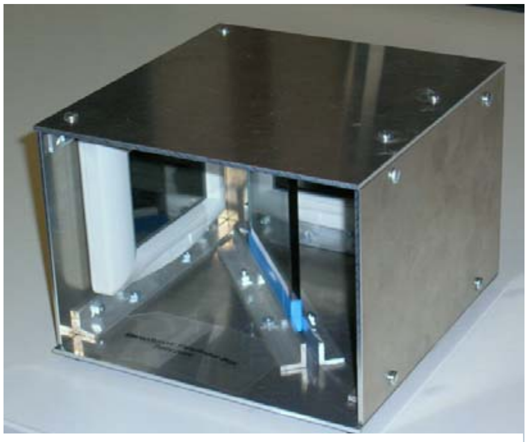

Image 6: Exterior of Stereoscopic Cube Viewfinder

Alignment and Use

An alignment procedure must be used to insure proper optical alignment of the two LCDs within the stereoscopic viewfinder. A symmetric alignment pattern is displayed simultaneously on both LCDs. The physical positions are adjusted until both images are seen to overlap. Since the beam splitter merely folds the optical path of one display image, the alignment is not dependent on the viewing angle. Once the LCDs are aligned they are “locked” in place. The alignment procedure must be performed before using the viewfinder because the optical axis of the cameras are adjusted with respect to the aligned viewfinder.

The viewfinder is connect to the video output from each camera/camcorder. The videographer adjusts the camera positions with reference to the images displayed within the viewfinder. Image alignment can be performed without glasses by merely adjusting the superimposed images until proper vertical and horizontal alignment is made. A stereoscopic image is seen when the images are viewed with appropriately oriented linearly polarized glasses. Stereoscopic viewing enables the videographer to assess and modify issues such as pinning, partial occlusion and divergent parallax[§].

Conclusion

A simple, low cost stereoscopic video viewfinder has been designed and built. It provides a simple method for insuring proper image alignment for converged stereoscopic video camera systems. The resulting system could be easily commercialized facilitating stereoscopic video production for consumers and non-professionals. It would enable untrained users to create stereoscopic video simply and easily.

Acknowledgements

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References

[1] Lipton, L., Foundations of the Stereoscopic Cinema, a Study in Depth, Van Nostrand Reinhold (1982).
[2] Wandell, B.A., Foundations of Vision, Sinauer Associates Inc (1995)

[§] The issue with respect to divergent parallax is also dependent on the size of the field of view and the viewer's inter-ocular pupillary separation.