

REPORT ITU-R BT.2088

Stereoscopic television

(2006)

1 Introduction

Stereoscopic image systems allow the illusion of depth to be presented using a flat display. They have been developed for cinema, television and other uses such as medical imaging. Stereoscopic image systems should not be confused with holography, which requires the use of lasers and is not in general compatible with existing cinema or television technology.

The technology for stereoscopic still imaging has existed almost since the invention of photography in the mid 19th century. For moving images, it has existed commercially since the 1950s.

ITU-R documents on stereoscopic television currently include one active Question and a further question in the approval process, two Reports and two Recommendations:

Question ITU-R 88/6 – Subjective assessment of stereoscopic television pictures.

Report ITU-R BT.312 – Constitution of a system of stereoscopic television (last updated 1990). This Report briefly describes techniques for reproducing stereoscopic images, lists requirements for development of practical stereoscopic television systems, lists prior CCIR documents on the subject and has a short bibliography.

Report ITU-R BT.2017 – Stereoscopic television MPEG-2 multi-view profile.

This Report describes Amendment 3 to the MPEG-2 video coding standard (ITU-T Recommendation H.262/ISO/IEC 13818-2), ratified in 1996, which allows for coding of stereoscopic images.

Recommendation ITU-R BT.1198 – Stereoscopic television based on R- and L-eye two channel signals (1995).

This provides a brief (one page) list of requirements for compatibility between monoscopic and stereoscopic signals for broadcast, and specifically mentions autostereoscopic displays in the considerations.

Recommendation ITU-R BT.1438 – Subjective assessment of stereoscopic television pictures (from Question ITU-R 88/6 Subjective assessment of stereoscopic television pictures, formerly Question ITU-R 234/11).

This covers: assessment factors, assessment methods, viewing conditions, visual screening of observers and test materials, both still and moving.

It is timely to review the subject of stereoscopic imaging for several reasons:

- Developments in broadcast image technology have brought larger, flatter screens at increasingly affordable prices. These offer an ideal platform for various implementations of stereoscopic images.
- Personal computer technology has encouraged the development of LCD shutter spectacles for computer games. These are now affordable and readily available.

- The advent of digital broadcasting has brought greater flexibility in image encoding formats. This flexibility offers the possibility of stereoscopic imaging with much improved monoscopic compatibility. By contrast, stereoscopic images encoded using analogue techniques generally showed visible artefacts such as ghosting, flicker or “puppet-theatre effect”, and had limited monoscopic compatibility.
- Developments in computer-generated imaging now allow highly detailed synthetic stereoscopic images to be generated almost as easily as monoscopic images.

2 Stereoscopic vision and parallax

Stereoscopic image systems use two images, one presented for each eye. For correct parallax, these images should be captured from positions about one inter-ocular distance apart (about 65 mm). The difference in perspective from the two positions allows depth to be perceived when the brain compares the two images presented separately to the right and left eye.

The close spacing of the image capture points places some constraints on cameras and lenses. In some cases, this restricts permissible combinations of aperture and focal length. The use of mirrors however can alleviate such problems to some extent. It is not currently possible however to post-process stereoscopic images to change their parallax. This places a responsibility on both the camera designer and the camera operator to consider parallax effects at all times.

Parallax is often varied in 3D production work for creative effects. Conventional parallax will cause the stereoscopic image to appear behind the screen. Parallax can be reversed however by swapping left and right images to make the image appear in front of the screen, with resulting image distortions. Parallax may also be exaggerated by varying the inter-lens distance to enhance or reduce the apparent depth.

Parallax is a particular problem for macro close-up images as the focal length may be comparable to, or shorter than, the inter-ocular distance. This can lead to unpleasant effects due to a short depth of field and/or lack of overlap between the left-eye image and the right-eye image and/or large angles subtended by the viewed object and the image capture points. To solve this problem, parallax may be deliberately distorted in macro work by reducing the inter-lens distance on the camera. The optical paths may also be skewed to increase image overlap. This technique is commonly used in stereo microscopy. As parallax gives not only depth information but also information about scale, a side-effect of this parallax distortion is that the image is given an unrealistic scale, appearing much larger than its actual size. While this gives some scope for creative effects, the brain is able to compensate because it knows that it is using an artificial viewing system.

3 Compatibility – general

Just as it is desirable for colour video to be compatible with monochrome video, it is desirable for stereoscopic video to be compatible with conventional monoscopic video. Most early stereoscopic video systems were not very compatible with conventional video, resulting in blurry and/or flickering images when viewed on a normal monitor. This issue is discussed in more detail for each individual stereoscopic technique.

4 Display techniques and technologies

Stereoscopic image technology has existed for well over a century, originating with the work of Wheatstone and Brewster on static imaging in the 1830s. Because the main technologies for stereoscopic moving images involved image separation by colour, stereoscopic motion picture

technology was not developed until after WWII when the use of colour film stock became widespread.

A number of systems have been used commercially for viewing stereoscopic moving images. Most of these systems, with the notable exceptions of time multiplexing and Pulfrich effect, are developed from still-image stereoscopic photography techniques. These techniques include chromatic anaglyph, polarization anaglyph, and integrated anaglyph.

4.1 Discrete image displays

4.1.1 Head-worn displays

Left-eye and right-eye images can be presented using discrete displays worn as spectacles. These were used in some early “virtual reality” video games. These displays and their images move with the head however, which can be disconcerting, and because of the small display size, the resolution is limited. The technique is not really suited to viewing by groups.

4.1.2 Side-by-side displays with prismatic spectacles

Discrete displays can also be used at a distance provided the optical paths to the eyes are suitably bent either by spectacles containing mirrors or prisms. This technique requires the viewer to minimize head movement and can be quite fatiguing.

4.2 Anaglyphic display

Anaglyphic displays superimpose two images in the same display and then separate them for viewing by optical filtering.

4.2.1 Separation by colour filter (chromatic anaglyph)

Any combination of mutually exclusive colours can be used for the chromatic anaglyph display. For full-colour rendition of the neurally-recombined image, complementary left eye/right eye colours should be used – red/cyan, green/magenta or blue/yellow. The convention is to use red and cyan, as this combination has a simple low-pass/high-pass wavelength characteristic. While green/magenta has a better match of luminance values (see Table 1), this combination requires a band-stop/band-pass characteristic which is more difficult to reproduce accurately and consistently.

TABLE 1

Luminance values and luminance ratios of complementary colours used for anaglyphic representation (using PAL/SECAM/NTSC/SDTV colorimetry)

Colour 1	Colour 2	Luminance ratio
Red	Cyan	
$Y' = 0.299$	$Y' = 0.701$	2.34
Green	Magenta	
$Y' = 0.587$	$Y' = 0.413$	1.42
Blue	Yellow	
$Y' = 0.114$	$Y' = 0.886$	7.77

The coloured filters are used at the image capture stage by two separate cameras. The two images are then mixed and presented as a single image for viewing. The two parts of the image are then separated into left-eye and right-eye images by spectacles with red/cyan lenses. The combined