Stereoscopic Vision with Reduced Definition in One Eye

Practical experiments with stereo pairs show that an adequate stereoscopic image can be formed by the human brain even when one of the images is considerably defocussed or pixelated. In a digital data transmission, the reduced-definition image can have a bandwidth (pixels x palette size) as low as 1/48th that of the full-definition image. ***David Gibson*** *suggests that this could have useful implications in the transmission of stereoscopic images over reduced bandwidth channels.*

I am short-sighted, requiring optical correction to my vision of about –5 dioptres. However, as I have aged, I have also developed far-sight, requiring a correction of +2 dpt. For outdoor sport in the rain, I have worn daily-disposable contact lenses that corrected only my short-sightedness, which meant that I found it very difficult to read maps or operate a camera.

My optician suggested that I try a combination of contact lenses, correcting for short-sight in my dominant eye and for far-sight in my other eye (i.e. left eye: –5 dpt; right eye: –3 dpt). Although it took a bit of 'training', this appears to work well. My brain clearly filters the information and allows me to see objects both far away and close at hand without difficulty. It seems an amazing solution to the problem.

My curiosity was raised, however, because my stereoscopic vision is unhindered by the lack of information supplied by one eye. One can imagine the brain deciding to 'ignore' information from one eye, but clearly that is not precisely what it is doing, because it still manages to produce a good stereoscopic image.

This reminded me of the optics behind conventional analogue colour television. An analogue TV system does not transmit 'red', 'green' and 'blue' channels, but a 'luminance' (monochrome) channel (known as 'Y') and two 'chrominance' channels that contain Blue minus Y and Red minus Y information. This allows the RGB data to be re-constructed but, importantly, it allows 625-line colour television broadcasting to remain compatible with the earlier monochrome-only receivers – the additional colour information being transmitted on a sub-carrier that the monochrome receivers simply ignore [1]. The salient point, which I am leading up to, is that the chroma channels are transmitted at a lower bandwidth; that is, the image is rather blurred compared with the luma channel. Clearly, the human eye does not 'mind' receiving this low-bandwidth information, and manages to reconstruct a complete image, regardless. Is that what is happening with stereoscopic vision with a reduced definition in one eye?

If that is the case, it suggests that the bandwidth of a stereoscopic transmission can be reduced without compromising the resolution of a flat, non-stereoscopic picture. This may be of use on bandwidth-limited channels such as Mars landers or remote operations in deep coal mines.

Demonstration of the effect

The effect of having a limited definition in one eye can easily be demonstrated using a set of stereo pairs, displayed on your computer monitor. An online version of this article [2] shows a number of such photos, summarised as follows.

- A blur applied to left or right eye
- Overlaid blurred and original images
- Left eye pixelation of ×8 times
- Left eye pixelation of ×4 times
- ×4 pixelation with 8-bit palette
- ×4 pixelation with 4-bit palette

Viewing the images

The images are stereo pairs but – unconventionally – the image intended for the right eye is on the left. This makes it easier to view the images without a special viewer. With your eye at a normal viewing distance, cross them, so that you see three images and then, with a bit of effort, it is possible to get the central image to snap into 3D. You will see a 'smaller' version of the image floating in space in front of the computer screen. It can take a bit of practice, but it is far easier than trying to view a conventional stereo pair without a viewer, because making the eyes cross is easier than making them diverge – which they would need to, as the images are further apart than the separation between the eyes. A word of warning though – I have been told that if you view stereo pairs professionally, for a living, viewing them with your eyes crossed will lead to a bad habit that will affect your work!

Blurred images

Having mastered the technique, you can now perform a few experiments. You should find that – surprisingly – it makes little difference to the stereoscopic image if one image is quite severely blurred. This is a demonstration of what I see when wearing my adjusted contact lenses.

Overlaid Images

At this point, you may be thinking that, whatever the eye and brain are up to, it is aided by having the two images in separate channels. So what happens if we overlay the original and the blurred images into a single picture? Surprisingly, it does not look very different to the original.

Pixelation

If the images are digital, rather than analogue, then a low bandwidth would be achieved by pixelation rather than blurring. The examples (online) show that reducing the linear resolution by 8 times, so that the reduced-definition image occupies 1/64th of the bandwidth, still results in an adequate 3D image. A less severe x4 pixelation coupled with a reduction in the colour palette from 24 to 8 bits decreases the bandwidth of the reduced-definition image by an overall 48 times, but with some banding in the sky.

With a 4-bit palette (and a 1/96 bandwidth), the banding is worse, but we still get a 3D picture. There is no advantage to using monochrome over colour – it would simply mean specifying 16 greys instead of 16 colours, but it is interesting to note that with a monochrome palette, the image remains substantially the same – true, there is less 'colour' in it, but it is still stereoscopic.

This article is a shorter version of the online text, which includes examples of stereo pairs [2].

References

1. **en.wikipedia.org/wiki/Chrominance** (Retrieved 4 May 2015)
2. Gibson, David (2015), Stereoscopic Vision with Reduced Definition in One Eye. Available at **site2.caves.org.uk/3d** (Retrieved 4 May 2015)

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