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Can Aliens See in 3D?
Exploring the Prospect of Three-Channel Stereoscopic 3D.

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Abstract

This paper is a hypothetical investigation – with tongue firmly in cheek - prompted by the discovery of a plastic collectible Toy Story Alien toy depicted wearing anaglyph glasses. The Toy Story Alien has three eyes and was first introduced in the 1995 Pixar movie Toy Story. Would it be possible for three-eyed aliens to see in 3D using red-cyan anaglyph glasses? Probably not, for reasons described in the presentation, but a possible solution is provided. There are real-world examples of anaglyph glasses being fitted to Praying Mantis and Cuttle Fish to investigate 3D vision, so why not aliens? The presentation also discusses options for other types of three-lens 3D glasses such as passive polarised and active 3D glasses. Are there any useful insights from this investigation? It's an interesting thought experiment, so we'll let you decide!

Introduction

This presentation was prompted by the discovery of a collectible plastic toy in a toy store in Japan. That toy was a Toy Story Alien, from the 1995 Pixar movie Toy Story [1], wearing a pair of three lens anaglyph 3D glasses – see Figure 1. This in turn triggered an interesting thought experiment. Could the three-eyed Aliens see in 3D whilst wearing the shown 3D glasses?

Figure 1. *The Toy Story Alien figure wearing a pair of three-lens anaglyph 3D glasses.*

This paper is obviously a bit of a joke. The Toy Story Aliens are a completely fictitious character from the first feature-length computer animated film "Toy Story" that was originally released in 1995. [1] A still-frame from the scene where the Toy Story Aliens first appear, in a Pizza Planet Claw Machine, is shown in Figure 2. Being fictitious, the Toy Story Aliens don't have a real visual system behind those animated eyes. Who knows whether extra-terrestrials actually exist – the universe is a very big place and the search for extra-terrestrial intelligence (SETI) continues without a result so far. [2] If alien life is actually ever discovered we don't know whether they will actually have three eyes, or any eyes. Are you smiling yet?

Figure 2. *The Toy Story Aliens as they first appeared in the 1995 Pixar movie "Toy Story" in the Pizza Planet Claw Machine. © Disney Pixar. [1]*

Nevertheless, this bit of humour actually triggers an interesting thought experiment: could a three-eyed alien (or any other three-eyed being) wearing a pair of three-lens 3D glasses actually see in 3D to resolve an image with depth.

As an aside, although the original Toy Story movie was released in 1995, a new stereoscopic 3D version of the film was re-released in 3D theatres worldwide in 2009 by Pixar. Additionally in 2011 the 3D version of the movie was released on Blu-ray 3D disc. The re-mastering of the new 3D version of Toy Story was overseen by stereoscopic supervisor Bob Whitehill from Pixar Animation Studios.

Background

3D glasses-based stereoscopic 3D displays a separation technique to send a different image to each of a human's two eyes. That separation technique can be polarisation (with passive polarised 3D glasses), wavelength/colour (with anaglyph 3D glasses), or time (with active 3D glasses).

The anaglyph 3D technique uses different colours of the visual spectrum to separate the left and right views. The most common colours are red and cyan (red for the left eye, and cyan for the right

eye), but other colour combinations are also possible, including red and blue, green and magenta, or blue and yellow.

Two-channel anaglyph 3D is well understood and I have co-authored four papers on the performance of a wide variety of types of anaglyph 3D glasses and displays. [3][4][5][6] The four papers cited have particularly focused on calculating and simulating the crosstalk performance of anaglyph 3D glasses.

Crosstalk is a 3D image quality metric which can be defined as the "incomplete isolation of the left and right image channels" [7][8]

By analysing the spectral characteristics of the lens filters used in the glasses, and the spectral performance of the emissive display it is possible to estimate the amount of crosstalk that would be present in this situation.

The process of simulating crosstalk in anaglyph 3D images with emissive displays (such as LCDs - Liquid Crystal Displays) is illustrated by the block diagram shown in Figure 3. With reference to Figure 3, in the case of red-cyan 3D, stage (1) is to consider the spectral output of the red and cyan channels of the display. In stage (2) we need to consider the spectrum of the red and cyan filters of the anaglyph 3D glasses. In stage (3) we used a program to multiply the spectrums of stage (1) and (2) to calculate the intensity of the intended image to each eye and also the amount of crosstalk shown in stage (4). Stage (5) provides an illustration of the intensity of the visible image and also the amount of crosstalk.

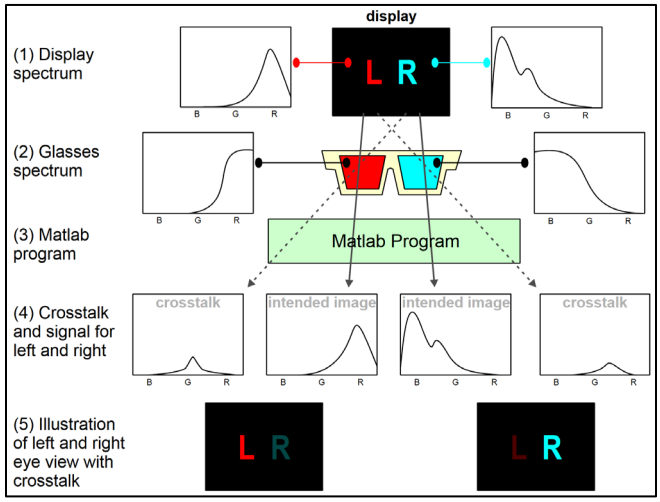

Figure 3. *The process of simulating crosstalk in anaglyph 3D images with emissive displays as described in Woods et al 2010. [5]*

The anaglyph 3D technique can also be used with printed 3D images and in that case we need to consider the spectral characteristics of the printing inks and the paper, and the spectral output of the light source used to illuminate the print. More details of that approach is detailed in reference [3].

Crosstalk is generally considered to need to be less than 1% for a stereoscopic display to be comfortable to view. [9]

The spectral response of a selection of cyan and red filters are illustrated in Figure 4.

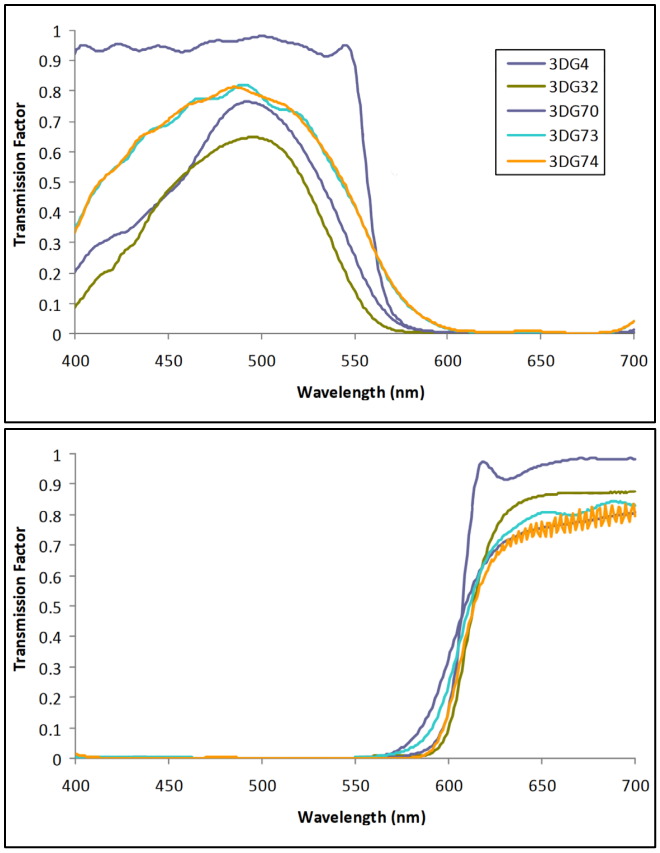

Figure 4 (top and bottom). *The spectral response of cyan filter (top) and the red filter (bottom) of several pairs of anaglyph 3D glasses. [5]*

The three lens anaglyph 3D glasses shown in Figure 1 has red and blue filter colours rather than red and cyan. Red and blue is an acceptable type of anaglyph 3D however it is not usually very popular because it reduces image brightness and uses less colour of the visual spectrum.

Discussion

Three-Channel Anaglyph 3D?

Let's look back at the anaglyph 3D glasses being worn by the Toy Story Alien in Figure 1. The three lenses are Red, Blue and Red - Red over the left eye, Blue over the centre eye, and Red again over the right eye. Unfortunately, this means that the Alien's left and right eyes receive the same perspective view, whilst the centre eye receives a unique perspective view – as shown in Figure 5. Ignoring for a moment at the Toy Story Aliens aren't real, the three eyes of the Toy Story Alien would normally receive three different perspective views due to their spatial separation, whereas with Red-Blue-Red glasses this would result in the left and right eyes of the Alien not receiving unique perspective views – so this type of anaglyph 3D glasses would not work.

Figure 5. *The Toy Story Alien with its red-blue-red 3D glasses, and*

Of course, the reason that the designers of this figurine have used red-blue-red lenses for this figurine is that they are recognisable as 3D glasses. The general public are familiar with red-blue and red-cyan glasses being associated with 3D glasses so it was natural to use those colours for the three lenses of the Alien's anaglyph 3D glasses, but repeating one of the colours for the third lens. However, that means three-channel 3D would not work with that sequence of colours.

Fortunately there is another sequence of colours that could be used to provide three separate channels of vision for the three lens anaglyph 3D glasses. For this to work, three separate ranges of colour would need to be used that (mostly) don't overlap. Conceivably that can be achieved using a Red, Green and Blue filters for each of the three channels of the three-lens 3D glasses – as illustrated in Figure 6.

Figure 6. *The Toy Story Alien wearing a pair of anaglyph 3D glasses with Red, Green and Blue filters.*

The spectrum of a selection of Red, Green and Blue filters are shown in Figure 7. These curves illustrate that the three types of filters mostly cover different parts of the visual spectrum with, relatively, only a small amount of overlap. The small amount of overlap of the curves for the three colour bands means that there will only be relatively small amount of stereoscopic crosstalk.

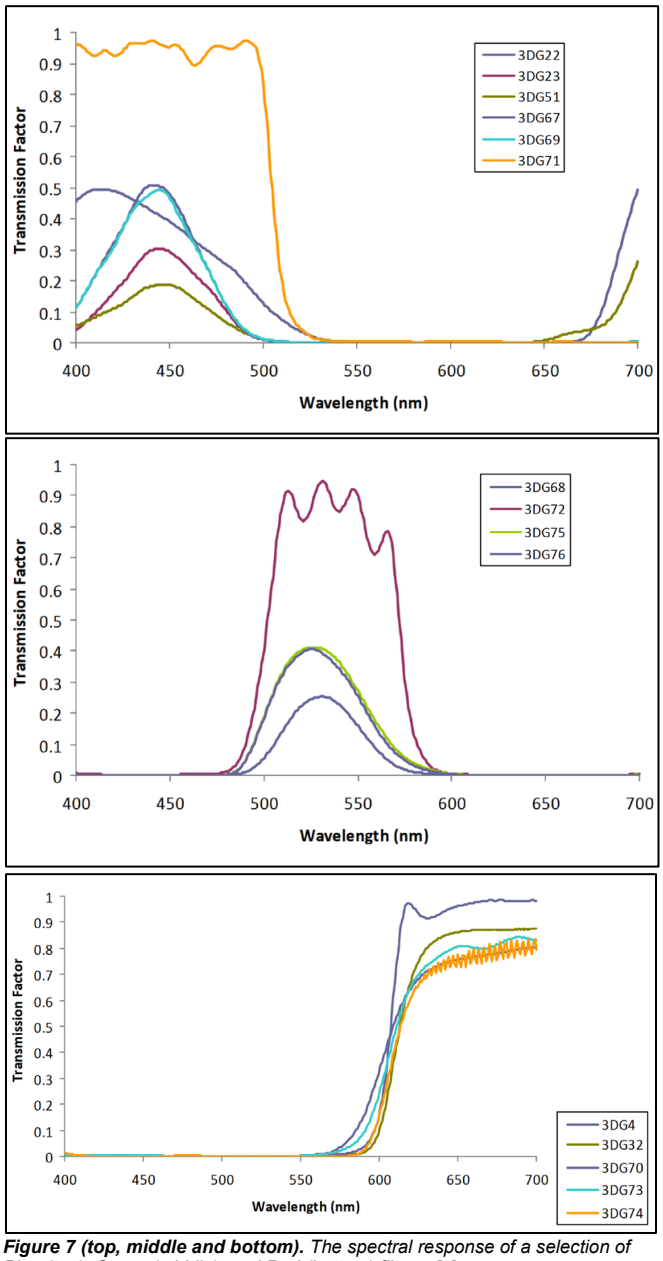

Figure 7 (top, middle and bottom). *The spectral response of a selection of Blue (top), Green (middle), and Red (bottom) filters. [5]*

The curves of Figure 7 are shown overlaid in Figure 8 which more directly illustrates the amount of spectral overlap, and the coloured blocks indicate the three visual channels available.

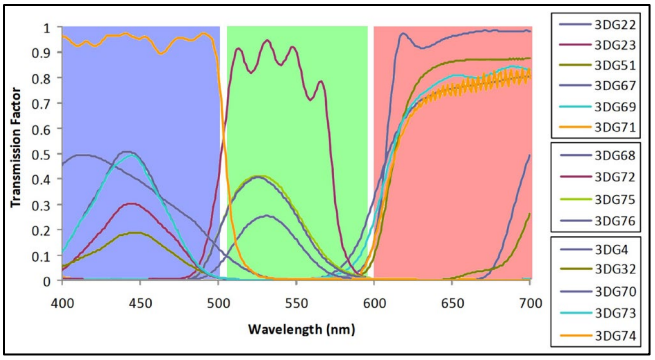

Figure 8. *The spectral response of a selection of red, green and blue filters – overlaid to illustrate potential for crosstalk. [5]*

The spectral curves do overlap somewhat so there will be some level of crosstalk. Whether the amount of crosstalk present in this configuration falls below the 1% figure discussed earlier would need to be calculated, using a variation of the approach outlined in Figure 3.

So we have established that it is possible to achieve three-channel 3D with anaglyph 3D glasses however the Aliens would need to use a different set of colours – Blue, Green and Red – but what about other 3D methods?

Three-Channel Polarised 3D?

Polarised 3D glasses are a very successful way of displaying 3D images (on 3D TVs, in 3D cinemas, and some other 3D displays) but can they be applied to three-channel 3D?

There are two types of polarized 3D glasses – linear and circular.

Linear polarisation only has two states – horizontal-vertical (as used by IMAX), or +/-45° (as used in 1950s 3D movies). A third linear polarisation orientation, which does not create crosstalk with the other linear polarisation orientations, is unfortunately not possible.

Circular polarisation also only has two states – clockwise and anti-clockwise (as used in RealD 3D systems).

Hence three-channel polarised 3D (as illustrated in Figure 11) would not be possible.

Figure 11. *An illustration of the Toy Story Alien wearing polarised 3D glasses.*

Three-Channel Active 3D?

Active 3D glasses, usually using liquid crystal shutters, are another very successful way of displaying 3D images (on 3D TVs, in some 3D cinemas, and on some other 3D displays). Active 3D glasses normally work by switching each of the lenses on and off to match a sequence of left and right images displayed on a screen.

Active 3D glasses and 3D projectors have already been developed that can operate with a six image sequence – to provide three viewers with three independent 3D views. [10][11]

Hence it is possible for a pair of three-channel active 3D glasses to be made to switch on and off to match a sequence of three images displayed in sequence – as illustrated in Figure 12.

Figure 12. *The Toy Story Alien wearing a mocked-up pair of three lens active 3D glasses – based on a design by Volfoni.*

Other Multi-Channel 3D Systems

In addition to the six-channel active 3D projection system by Digital Projection mentioned above, there is at least one other 3D display system which allows more than just two channels for stereoscopic purposes.

The Hologram Table developed and marketed by Axiom Holographics (formerly Euclidion), allows four-channels of independent content viewed for stereoscopic display purposes. [12] With this system, two users can have independently driven stereoscopic views. The Hologram Table achieves the four independent views by using 3D glasses which combine two 3D methods – active 3D, and interference filter 3D.

Unusual Use Cases of 3D Glasses

There are additional examples of anaglyph 3D glasses being used in unusual applications. Anaglyph 3D glasses have been used with Preying Mantis [13][14] (Figure 13) and Cuttle Fish [15] (Figure 14) to study the stereoscopic vision of these living beings. In the case of the Preying Mantis 3D glasses, the colours of green and blue lenses were chosen to better match the optical sensitivity range of the Preying Mantis eyes.

Figure 13. *A Preying Mantis wearing anaglyph 3D glasses for a research study led by Jenny Read from Newcastle University (UK). Source: Newcastle University. [16]*

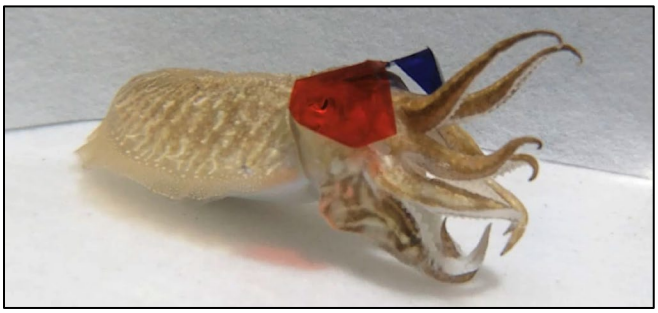

Figure 14. *A Cuttle Fish wearing anaglyph 3D glasses for a research study led by Trevor Wardill at University of Minnesota (USA). Source: Wardill Lab [17]*

Do Any Earth-Based Animals Have a Third Eye?

"In most cases, the idea of a third eye is symbolic" (for example Figure 13) "but it does raise the question… are there any animals that actually possess a third eye?" [18]

Figure 13. *The concept of a third eye is usually symbolic. Source: https://www.djis.org/images/app/discourses/jeevan%20ka%20lakshya%20ishwar%20bhakti.webp*

"Short Answer: Yes, but it is more commonly called a parietal eye, and is only found in certain species of lizards, sharks, bony fish, salamanders and frogs. It typically doesn't see, but is instead photoreceptive in nature." [18]

Figure 14. *The parietal eye (very small grey oval between the regular eyes) of a juvenile bullfrog (Lithobates catesbeianus). Source: Wikipedia [19]*

Compound Eye

Another option to consider is the compound eye.

"A compound eye is a visual organ found in arthropods such as insects and crustaceans. It may consist of thousands of ommatidia, which are tiny independent photoreception units that consist of a cornea, lens, and photoreceptor cells which distinguish brightness and color" [20] - see Figure 15.

But as far as I can tell, compound eyes always come in pairs, not in threes.

Figure 15. *The Compound eye of a Dragonfly. Source: Wikipedia [20]*

Spider Eyes

"About 99% of spiders have eight eyes. Some have six, four, or two." "Spiders have two types of eyes. The large pair of primary eyes forms images. The secondary eyes help the spider track movement and gauge distance." [21] See Figure 16.

Figure 16. *Face of an adult male Phidippus audax male jumping spider. Source: Wikipedia [22]*

Polarised vision

It is worth noting that some animals and insects have eyes that are sensitive to polarised light. [23] It appears that the polarisation sensitivity is generally used for navigation purposes, and nothing to do with watching 3D movies. One factor for vision scientists to consider when they are researching the stereoscopic vision of animals and insects would be whether the polarization sensitivity of the subjects eyes might interfere with the polarisation of the 3D glasses used for the study.

So, in conclusion of this section, as far as I can tell, there are no animals or insects on earth with 3 fully functional eyes hence the Toy Story Aliens are unique (although fictitious).

Terminology

Do we need to develop and use new terminology for three-channel 3D vision? Some of the terms that we regularly use in relation to 3D vision are "Stereoscopy", "Stereoscopic" and "Binocular".

The terms "Stereoscopy" and "Stereoscopic" are derived from the Greek word στερεός (stereos) meaning 'firm, solid', and σκοπέω (skopeō) meaning 'to look, to see.' [24] As such, these terms are not limited to two-channel 3D vision, hence these terms are still applicable to three-channel 3D vision.

The term "Binocular" is derived from the Latin word binoculus, which means "having two eyes." [25] Hence for three eyes we should use the term "Trinocular" (as in Trinocular Vision).

Alien Vision

There is a lot we don't know about Alien stereoscopic vision – not the least because the Toy Story Aliens don't exist in reality. But if they did exist, we would need to know a lot more about how the alien visual system works to be able to understand whether three-channel 3D glasses would work.

To fully understand the viability of the Aliens using anaglyph 3D glasses, we should really know the spectral sensitivity of the alien eyes. Are they sensitive to the same visible light range that our human eyes are sensitive to. Praying mantis eyes have a different spectral response than human eyes which is the reason that green-blue glasses were used for the praying mantis study rather than red-blue or red-cyan. [14]

For active 3D glasses, we would need to know what the critical fusion frequency of alien eyes are so we know how fast the shutters in the glasses should operate so the alien can see flicker-free 3D images.

It would also be useful to know whether the alien visual system uses vision from all three eyes to calculate depth, or whether their brain is able to process images from just two eyes to see depth.

Do the three eyes track (verge and converge) together?

Additionally, is the slight vertical offset of the centre eye significant?

There are lots of questions – of course not helped by the fact that these Toy Story Aliens don't actually exist in reality. Nevertheless, to explore the topic in more detail, so we leave no stone unturned, there are some leads and reference material we can explore.

The first lead is the Toy Story movies – Toy Story (1995), Toy Story 2 (1999), Toy Story 3 (2010), and Toy Story 4 (2019). What can the depiction of the Toy Story Aliens in these movies tell us about their vision? Unfortunately, the movies don't actually reveal much about the nature of their 3D vision, so there's limited amount we can directly ascertain from that information source. It was however fun to watch the movies again – especially since all four films are available on Blu-ray 3D disc format. [26]

A second lead is the voice actor, Jeff Pidgeon, who has voiced the Toy Story Aliens across all four Toy Story movies. I was fortunate to have a quick chat with Jeff at the Pixar Animation Studios campus in Emeryville, California in January 2024. Jeff explained that this comes down to "lore" and with a knowing look, we left it at that.

Figure 17. *Jeff Pidgeon (right) from Pixar is the voice actor for the Toy Story Aliens in Toy Story 1, 2, 3 and 4. On the left is Eric Kurland from LA 3-D Space and SD&A committee member. Photographed at the Pixar campus in January 2024 by Andrew Woods.*

Capturing Three-channel 3D content

So far we have shown that three-channel 3D glasses are possible, but to use those glasses, three-channel 3D content would also be needed. Fortunately there are already three-lens smart

phones (see Figure 18) which could potentially be used to capture trinocular 3D content. For a moment we will ignore the fact that the three lenses in most three-lens smartphones will have different focal lengths for each lens– but perhaps that's OK for Alien vision.

***Figure 18**. The Samsung Galaxy S24 has three camera lenses mounted in a row.*

Conclusion

In conclusion, we hope you've had a laugh from this topic. At the end of the day, I think we can all agree that (if they actually existed) the Toy Story Aliens most likely could see in 3D, and they could probably watch (special three-channel) 3D movies, but only if we gave them special three-channel anaglyph 3D glasses, or special three-channel active 3D glasses, but unfortuntely three-channel polarised 3D glasses are not possible. If none of this works, perhaps they could just wear an eye-patch!

***Figure 19**. If all else fails, the Toy Story Alien could always just wear an eye-patch.*

In closing, let's ask a final question: is there a real-world use for three-channel 3D glasses? Probably not. But it was fun exploring the topic. ☺

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Author Biography

Andrew Woods is an Associate Professor at Curtin University where he manages the HIVE visualisation facility and is a Research Engineer at the Centre for Marine Science & Technology. He specialises in visualisation, stereoscopic 3D imaging, 3D reconstruction, 3D cameras and displays, video electronics, underwater vehicles (ROVs), and engineering software development, with applications in offshore oil and gas, and maritime archaeology. He has BEng and MEng degrees in electronic engineering and his PhD was on the topic of crosstalk in stereoscopic displays. He is a senior member of IS&T. He was the technology lead on the Sydney-Kormoran Project which surveyed the wrecks of HMAS Sydney (II) and HSK Kormoran in 2015, and imaging lead for the survey of the wreck of HMAS AE1 in 2018. In 2017 he was recognised as one of Australia's Most Innovative Engineers by Engineers Australia. He has been co-chair of the Stereoscopic Displays and Applications conference since 2000. Some people have also said he has an unusual sense of humour.