PRODUCTION ISSUES WITH 3D CONTENT TARGETING CINEMA, TV, AND MOBILE DEVICES

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ABSTRACT

As 3D TV and 3D cinema are at the extremes of the screen size spectrum, issues are unavoidable when trying to use them to present the same content. Differences between screen sizes and viewing distances can be huge. As both parameters dictate how to create content, it is difficult to fulfill the requirements of TV and cinema with the same content. These issues are explained together with some ways to overcome them and to reach the best compromise.

Index Terms— 3D TV, 3D cinema, depth, parallax, screen size, comfort zone.

1. INTRODUCTION

To convey depth information in a 3D movie, we transmit two sets of pictures to the left and right eyes. But our brain is where the 3D reconstruction process takes place, and the screen size is one of the parameters used in this computational process. So, taking screen size into account when preparing 3D content is mandatory. As this was not an issue with traditional "flat" cinematography, this phenomenon is often overlooked [1].

2. PARALLAX

The 3D feeling in stereoscopic movies is given by presenting objects to left and right eyes with a slight shift in horizontal position. This shift is called parallax. In this paper, we take the left eye view as a reference and describe parallax as the shift of the right view with respect to the left reference view of the same object.

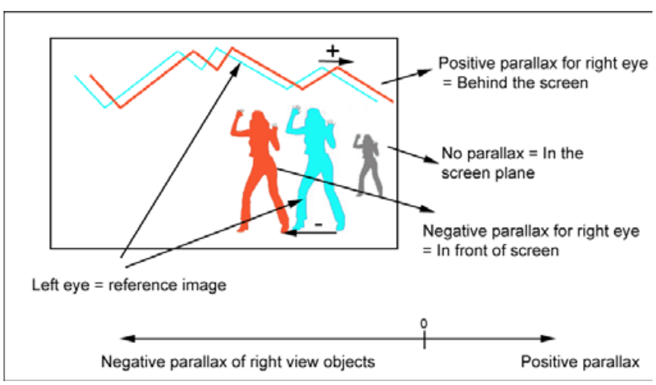

Fig. 1. Positive and negative parallax.

An object has a positive parallax when its right representation on the screen is to the right of its left representation.

Conversely, negative parallax occurs when the right representation is on the left of its reference representation.

When an object is presented without any parallax, the object seems to be located in the screen plane, where both our eyes are focusing. If the object has a positive parallax equal to the distance between our two eyes, the lines of sight of both eyes are parallel and the object appears as being at infinity. An object with negative parallax forces our eyes to cross their viewing direction at some point in front of the screen, and the objects seems to float in the air in front of the screen.

2. COMFORT AND HEADACHES

Headaches are often cited as the main drawback of stereoscopic movies. However, only "bad 3D" gives headaches to the audience, not "good 3D". However, producing only "good 3D" is not so easy. The two main sources of physiological discomfort are related to parallax.

2.1. "Beyond infinity" parallax

Presenting an object on screen with a positive parallax larger than our interocular distance (65 mm for a normal adult) forces our eyes to diverge [6]. This never occurs in the real world and corresponds to objects located "beyond infinity." This error occurs more frequently than expected: If a producer is making a film for a theme park theatre with a 5-meter-wide-screen, he will use a 65 mm parallax on screen to present distant mountains. The mountains will appear at the horizon.

Let's now use the same movie in a large theatre with a 20-meter screen. The landscape may look gorgeous on the big screen, but the mountains parallax is now multiplied by 4 and reaches 260 mm. All viewers will try to focus their gazes on the distant mountains and are going to get major headaches caused by the divergence within a few minutes.

2.2. "Very close" parallax

Presenting an object on screen with a large negative parallax simulates the presence of an object very close to the viewer. It is usual to avoid parallax values giving any object a position closer to the viewer than 20% of the distance between the screen and the viewer. For example, if a viewer is 20 meters from a theatre screen, the closest object in a movie should not appear to be closer than four meters from him/her. Any closer will cause too much eye crossing and will favor the occurrence of headaches.

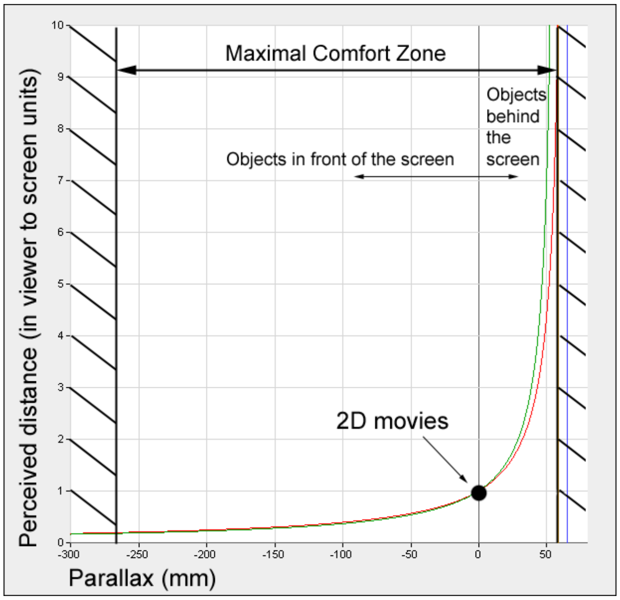

Fig. 2. Parallax vs. perceived distances and comfort zones for IMAX, movie screen, TV, and mobile devices. The red curve is for adults with a 65 mm interocular distance (i.o.d); the green curve is for children with a 10% smaller i.o.d.

2.3. The comfort zone

Let's suppose that the viewer is at the best possible place in a typical movie theater: The screen is 10 meters wide, the viewer is located 13 meters from the screen (2.5 times screen height), and the projected image is 2000 pixels wide by 1080 pixels high. The parallax comfort zone goes from –260 mm to 65 mm or from -52 to +13 pixels to present objects at distances from 2.6 meters from the viewer to infinity. Of course, zero parallax will put the object in the screen plane at 13 meters from the viewer.

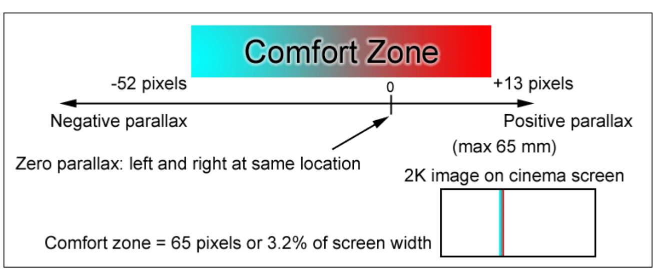

Fig. 3. Parallax comfort zone for 2K cinema.

It is reasonable to suppose that any 3D producer will fine tune her/his movie for a typical theater such as the one described above. S/he can balance shots between 'through the window' where the scene appears entirely behind the screen plane and 'intrusive proximity' where objects are thrown at the viewer. Both styles will be used to convey different artistic feelings when the instant is deemed appropriate. Most of the 3D movies distributed in digital are thus expected to use the full parallax range available, going from -52 to 13 pixels, or 3.2% of the 2000 pixels (2K) image width.

3. WHAT HAPPENS DURING PROJECTION ON A DIFFERENT SCREEN?

3.1. IMAX screens

Let's imagine we are showing a movie intended for a 10-meter screen in a larger venue such as an Imax theater.

A typical IMAX theatre has a 22 x 16.1 meter screen (but the largest reaches 35 x 29 meters) The typical IMAX viewer position is relatively closer to the screen, typically twice the screen height, or 32 meters. The parallax comfort zone goes from -260 mm to 65 mm or from -24 to + 6 pixels to present objects at distances ranging from 6.4 meters from the viewer to infinity.

The previous movie using a parallax range from -52 to 13 pixels will present objects on the IMAX screen with parallax ranging from –572 mm to +143 mm. The corresponding objects will be perceived by the viewer as being at 3.26 meters from him/her for close objects (10% of screen distance) and far 'beyond infinity' for remote landscapes, creating discomfort in both cases.

On a screen larger than initially planned for, the 3D effect is exacerbated and the immersive experience is clearly compromised by discomfort.

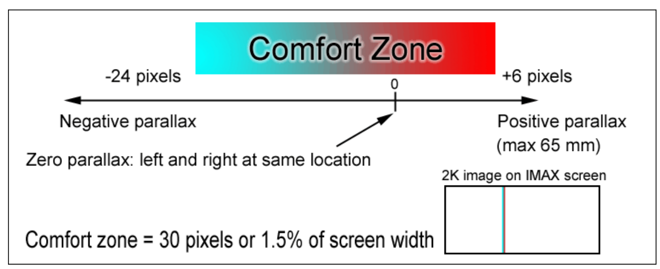

Fig. 4. Parallax comfort zone for IMAX.

3.2. TV screens

Now, let's imagine we are showing the same movie on a smaller screen such as a TV set. Today's 3D-ready TV sets are typically 50 inches flat screens, but front or rear projections on 70 to 100 inches screens are also common in high-end home cinemas. Let's take the 50 inch 16:9 TV set as an example. The screen width is 1 meter and the typical viewer sits some 3 meters away. The -260 mm to +65 mm parallax comfort zone is translated to -520 to + 130 pixels, but the large risk of interference between close objects and the sides of the screen restricts their position in practice to at most half the screen distance or 1.5 meter from the viewer. The real comfort zone is thus reduced to the -260 to +130 pixels interval.

The parallax range used in the cinema movie described above translates in the TV set case to shifts going from -26 mm to +6.5 mm, well within the comfort area. The corresponding objects will be perceived as being from 2.14 meters from the viewer for close objects (closer to the screen than to the viewer) to only some 27 meters behind the screen, which is not that far for a distant landscape. The 3D effect is sort of compressed toward the screen plane and loses part of its impact as the whole parallax comfort zone is not fully used.

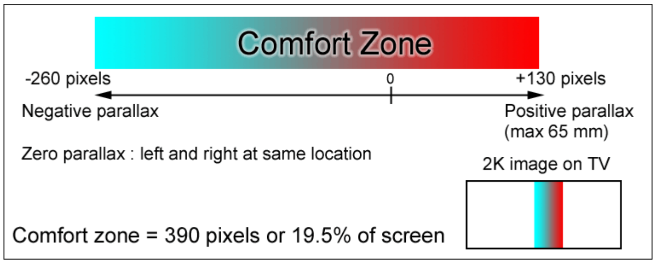

Fig. *5*. Parallax comfort zone for TV.

However, a significant difference takes place here when compared with the previous case. In a large movie theatre, the screen is far enough to let the viewer's eyes focus almost as if he/she were looking to the horizon and thus the convergence and focus of the eyes are closely correlated. With a small TV set located only a few meters from the viewer, focus and convergence are no longer correlated: The eyes will naturally focus on the screen plane, even if they converge 27 meters away. This decorrelation may cause some discomfort (usually not so troublesome), but the brain tries to fuse both feelings and usually takes as believable a closer-than-in-the-real-world horizon.

With the use of screens smaller than originally intended, the 3D feeling of the viewer stays in the 'comfort zone' described above but the depth impression is reduced, especially for the part of the scene behind the screen plane. The added focus-convergence decorrelation effect adds a feeling of looking inside a box located behind the screen and not going up to infinity. If the movie offers frequent intrusions in the volume in front of the screen, this feeling is reduced. For some viewers, the decorrelation effect reduces the acceptable comfort zone to less than the theoretical value given here.

3.3. Portable devices' screens

Displaying cinema content on small devices is almost never satisfactory, as the screen resolution is greatly reduced and viewing and hearing conditions are seldom as good as in a movie theatre or in front of a TV set. The situation is not better with 3D movies. If displayed on a 10 centimeter screen, a typical 3D movie will give a very shallow depth feeling, obviously within the parallax comfort zone, but not really satisfactory because of the extreme "dwarfing effect."

The parallax comfort zone for a small device is theoretically larger than the whole screen width. Using Apple's iPhone as an example, the screen width is 75 mm and the viewing distance is typically 250 mm. The screen pixel count is 480 x 320 pixels.

The main constraint dictating the real size of the comfort zone is not limited by perceived depth as in the movie theatre and TV cases, but is the correlation between the convergence and focus of both eyes. If this correlation is completely disrupted, the brain is no longer able to reconstruct a coherent perception of a 3D world. This may occur when the eyes converge on mountains at the horizon while at the same time focusing on a screen only 250 mm away. The comfort zone is thus restricted by this constraint to a zone estimated at between -4% or +4% of the screen width, or -20 to +20 pixels.

Movie content produced with 2000 pixel wide images is mandatorily reduced to 480 pixels. So, the 40 pixel iPhone comfort zone corresponds to a 166 pixel zone on the original 2K image and falls somewhere between the ranges allowed for movie theatres and TVs. As a result, cinema content displayed on mobile device stays in the comfort zone, but the perceived depth is extremely shallow and the general feeling is the same as if the viewer looked inside a small box, or just through a small window and into a small world with close horizons.

On the same small screens, 3D content produced for TV could cause some discomfort, mainly if the far away perspectives are preeminent.

Creating truly eye-catching 3D movies for small devices will need a specific approach targeting small screens only. However, such content is expected to be accepted as TV content if originally shot in a good enough resolution (typically around 2000 pixel wide as in HDTV) The experience of stereographers in this field is almost non-existent today and is still an experimental playground.

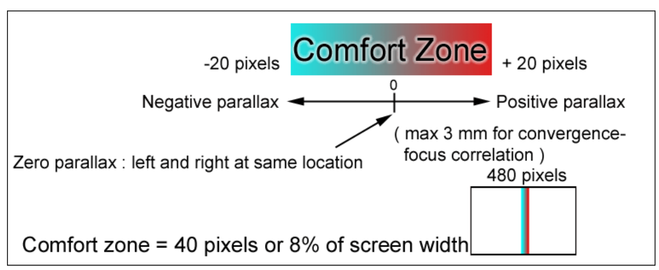

Fig. *6*. Parallax comfort zone for portable devices.

4. CHILDREN

According to MacLachlan [7], the interocular distance for children starts approximately at some 43 mm at birth and grows 1.2 mm each year up to adulthood, when the typical distance of 65 mm is reached. Thus, for young children, 3D content designed with a 65 mm interocular distance is exaggerated and may in some cases cause discomfort and headaches.

Projection of a 3D movie produced for a 10 meters screen					
Screen Type	**Screen Width (m)**	**Used Parallax Range**	**Comfort Zone (in Pixels)**	**3D Effect**	**Comfort**
IMAX	22,000	-52 to +13	-24 to +6	Too strong	Not Good
Cinema screen	10,000	-52 to +13	-52 to +13	Perfect	Good
50" TV	1,000	-52 to +13	-26 to +130	Shallow	Good
iPhone	0,075	-52 to +13	-84 to +84	Good	Good

Note : All pixel values given on the original 2K image before optional rescaling

Fig. *7*. 3D effect and observed comfort on various types of screens for a movie produced for a 10-meter-wide cinema screen.

However, children's brains are more adaptable and may learn to 'catch the 3D' more easily, even in suboptimal cases. Nevertheless, 3D content targeting young audience should reduce its allowed "depth budget" by around 10% to minimize adverse effects.

5. CONCLUSIONS

The best immersive experience is reached in big theaters with screen sizes over 8 meters. The 3D feeling is optimized if the content producer is using the whole available "depth budget" without going outside the parallax comfort zone. As the range of allowed parallax values depends on the screen size, the largest targeted screen must be known in advance of the shooting.

Presenting the same content on a larger screen will increase the 3D feeling beyond the limits of the comfort zone. Headaches become a distinct possibility if intrusions of very close objects are frequent, or if far-away horizons are visible for long periods of time.

Presenting the same content on a smaller screen will still give a 3D feeling that is comfortable, but the perceived depth range will not be optimal. Scenes may appear shallow, with horizons closer than expected in real life, giving the viewer the sensation of a giant observing a miniature world.

Optimal cinema content has to be prepared with a maximum screen size in mind. In general, repurposing the same content for TV will be suboptimal but not trouble inducing. Content directly optimized for broadcast will be more impressive on TV, but is banned forever from large movie theaters, where the exacerbated depth feeling will cause discomfort and headaches.

On portable devices such as smart phones, TV and cinema content will be acceptable, but the perceived depth will become extremely shallow. The dwarfing effect will be very perceptible, giving the feeling of looking into a small world enclosed in a box the size of the screen. Content created specifically for small devices will appear more natural, as if the portable device acted as a small window on a small world located behind.

In all cases, movies intended for small children should be prepared with parallax values some 10% smaller than for those for a typical adult audience. This will reduce the depth feeling for adults slightly but avoid discomfort for the younger audience. This is often overlooked by producers, but may be essential to convince future generations that 3D is easy and pleasant to watch.

6. FORMULAS

The two perceived distance - parallax curves in Figure 2 are given by the following formulas:

Adults : $y = 1/((65-x)/65);$

Children : $y= 1/((65*0.9-x)/(65*0.9))$

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