3D Depth Analysis Following Distance and Location for the 3D Image Control Resulting from Three-dimensional Effect Felt by User

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Abstract

After the release of the film, 'Avatar'recently, a new paradigm is emerging in the 3D contents industry worldwide due to the expansion of the 3D contents production. Along with the rapid growth of the 3D contents industry, individual nations are stepping up the effort to develop 3D technology and to secure upper hand in the standardization effort in order to secure the leading position in the marketing sphere. As a result, transformation from 2D to 3D is taking place in the diverse industry areas such as TV, S/W, 3D game contents and others as the 3D technology is being used in diverse areas. However, 3D syndromes such as fatigue of the eyes result when 3D image is watched for a long time since the method of using merely the disparity of two eyes is used when watching 3D image to this day. In addition to this problem, there is a systemic level problem, which is the need to maintain specific distance and location in order to feel the 3D effect correctly. Accordingly, this research paper seeks to leverage the change in the 3D image's Depth level to present 3D Depth level analysis index that will enable users to feel the three-dimensional effect and engagement level most effectively depending on distance and location, and to capitalize the findings to present 3D image control system that can adjust 3D Depth following the three-dimensional effect felt by user.

Keywords: *Depth level, Image control system, 3D effect, three-dimensional effect start, engagement*

1. Introduction

As the worldwide 3D contents industry is becoming vitalized, there are many researches that are carried out actively to secure the upper hand in the 3D contents industry. In particular, interest on the 3D multi-dimensional image is increasing significantly as the film, 'Avatar'was very successful in the box office. Currently, the key 3D image method is one that leverages eyeglasses based on the method of using the disparity of two eyes in order to observe two images at the same time, which in turn is used to produce synthesized 3D image [1]. This method enables users to feel the multi-dimensional image that provide sense of depth and sense of distance. Accordingly, this method is used often for the 3D TV and at the movie theaters these days. Likewise, the physiological factors that enable human beings to feel the three-dimensional effect involves viewing 3D image, mostly through the eyes of the human beings. This method is characterized by side-effects such as the eyes getting fatigued easily [2] and causing dizziness or vomiting [3]. Moreover, the reality today is that there are no suitable solutions for these problems as of today. Another problem is that users can feel the 3D three-dimensional effect only when they maintain specific distance and location in order to effectively feel the 3D three-dimensional effect.

Accordingly, this research conducts 3D Depth analysis based experiment to control three-dimensional effect felt by user analysis and three-dimensional effect following distance and location for the configuration of the environment that will minimize fatigue of the eyes and that will enable users to feel the three-dimensional effect most effectively [4].

2. 3D Image Technology Trend [5]

The basic principle of the 3D image can be referred to that which considered the disparity of two eyes, just like the human eyes. The distance between the human eyes is 65mm. Likewise, the left and right eyes are different retinas. Human beings perceive form multi-dimensionally while the brain interprets this fine difference. At this time, the difference of the form that the retinas of the two eyes detect, is called the disparity of two eyes. This can be considered the most important element for feeling the three-dimensional effect. The core of the three-dimensional effect provided by the disparity of two eyes can be considered as the sense of depth or sense of distance. In other words, the brain perceives 2D form, perceived by each of the eyes according to the disparity of two eyes as multi-dimensional image. Through this perception process, human beings gain perspective and presence of the objects and images. Indeed, three-dimensional effect is what expresses sense of depth, sense of distance, perspective and others in a comprehensive manner, and high three-dimensional effect plays the role of increasing the sense of reality when it comes to image. For the users to recognize 3D image, it is necessary to have them feel like the right and left eyes perceive the images on the right and left, respectively. This method can be classified into the eyeglasses method and non-eyeglasses method depending on whether special multi-dimensional eyeglasses are used or not. In case of the eyeglasses method, it can be divided mainly into Anaglyph method (Red-Cyan method), polarized light eyeglasses method (passive method) and shutter eyeglasses method (active method) depending on the method used to transmit multi-dimensional image and on which method users utilize to embrace multi-dimensional image.

3. 3D Depth analysis for users to feel the effect following distance and location in order to realize effective three-dimensional effect

3.1. Environmental Factors

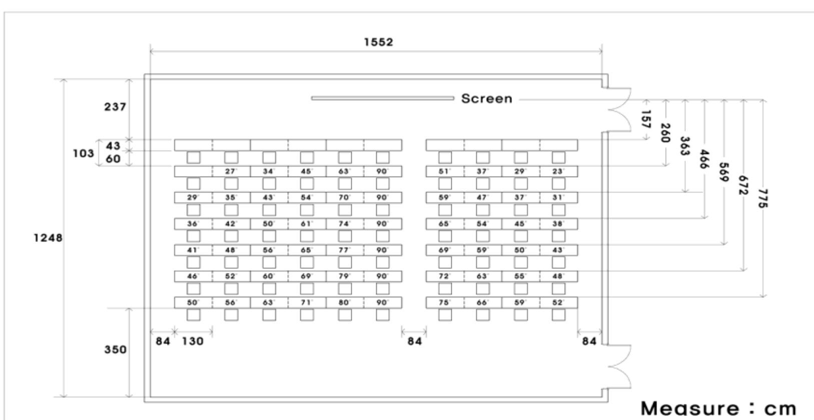


Figure 1. Experimental Environment

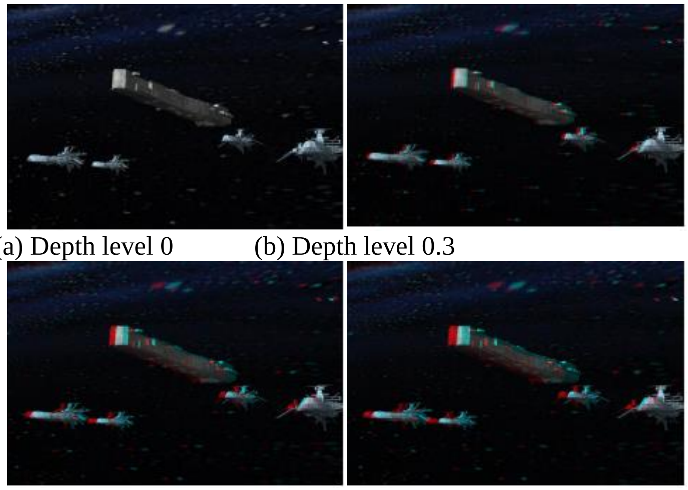
To analyze 3D Depth level of images, distance and location that will enable large number of viewers of the multi-dimensional images to view them effectively, this research conducted the experiment in a university's lecture hall, targeting large number of people, and external factors (light, noise etc.) were minimized to increase the engagement level for the image viewing. To increase the reliability level of the experiment, distance was measured for each of the locations where 3D images were viewed, targeting lecture hall and subjects. Overall experiment environment is shown on Figure 1.

Figure 2. View of the users wearing Anaglyph eyeglasses prior to conducting the experiment

Figure 2 shows the users wearing Anaglyph eyeglasses for the 3D image viewing prior to the 3D Depth analysis experiment conducted to study users' perception following the change in 3D Depth.

3.2. Methods

Figure 3 is a capture of parts of the image used for the 3D Depth analysis experiment conducted to study users' perception following the change in 3D Depth. The images of the same scenes from (a) to (d) were changed depending on Depth level to change three-dimensional effect. Subjects were then made to view them. Images were changed by increasing by 0.05 level from level 0 to level 1 to transform the 3D Depth. In case of level 0, it manifests the 2D form image devoid of three-dimensional effect. In case of level 1, it signifies the image with the image that will appear to the left eye and the right eye and that which was separated completely. Moreover, each of the images that appear on the left eye and the right eye get separated by 5% from the complete several overlaps when 3D Depth increases by 0.05 level. As such, images are shown to the subjects through the REd-Cyan eyeglasses.



(a) Depth level 0 (b) Depth level 0.3

(c) Depth level 0.6 (d) Depth level 0.9

Figure 3. 3D images used for the experiment

Experiment conducted by this research was conducted according to the following stages.

□ Stage 1

While preparing for the 3D image to use during the experiment, each of the subjects were handed a data sheet where they can record the Anaglyph eyeglasses and feel for the three-dimensional effect. Then, they were asked to enter into the premise so that they could view the 3D image.

□ Stage 2

Subjects were shown image of the 3D Depth level 0 for one minute. When the image ended, subjects were asked to record on the data sheet whether they felt the three-dimensional effect.

□ Stage 3

For the sake of the next stage experiment, subjects were asked to rest for one minute to minimize eye fatigue.

□ Stage 4

This stage was conducted the same way as Stage 2 and Stage 3. When image ended, subjects were asked to view the 3D image with 3D Depth level increased by 0.05 once again for one minute. Then, they were asked to rest for one minute and to continue to repeat the process until the level turned to level 1. To analyze 3D three-dimensional effect following subjects' distance and location, entire experiment process was repeated while the subjects' location was re-placed.

4. Experimental Results

4.1. Analysis of the time when the feel for the three-dimensional effect started

Figure 4 shows the results on the analysis of the time when the three-dimensional effect was felt following the distance and location of the subjects tested for this research. Figure that appears on Figure 4 (for example, 0.3) shows the level of separation of the images that will be shown to the left eye and the right eye by factoring in the disparity of two eyes. In case of 0, the two images are overlapped completely. In case of 1, the two images were separated completely.

	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Average	Total average	Rank	Proportion
Row 1				0.9	0.4	0.3	x	0.45	1	0.61	0.61	3	9/10
					0.55	0.65	0.6	0.7		0.62			
Row 2		x		0.6	0.5			x		0.55	0.61	2	4/6
				0.55	0.8					0.67			
Row 3			0.75	0.9		0.4		0.8	1	0.77	0.72	5	7/7
				0.9				0.45		0.67			
Row 4	0.65	0.55		0.4	0.2		0.45	0.9	0.7	0.55	0.5	1	10/12
		0.45		0.6	x		x	0.35		0.46			
Row 5	0.8			0.6	x	0.9		x	1	0.82	0.86	7	6/9
					x	0.8		1		0.9			
Row 6		0.9	0.45	0.45			0.35	0.7	1	0.64	0.7	4	8/10
		x	1				x		0.55	0.775			
Row 7	1	x	0.7	0.8		0.75	0.35	0.8		0.73	0.81	6	9/12
		0.8	1			x	0.9	0.9		0.9			
1st average	0.81	0.72	0.63	0.66	0.36	0.58	0.38	0.73	0.94				
2nd average	x	0.62	1	0.68	0.67	0.72	0.75	0.68	0.55				
Total average	0.81	0.67	0.81	0.67	0.52	0.65	0.56	0.7	0.74				
Rank	9	5	8	4	1	3	2	6	7				
Proportion	3/3	4/7	5/5	10/10	5/8	6/7	5/8	10/12	6/6				

Figure 4. Analysis of the time when the users start to feel the three-dimensional effect by distance and location

According to Figure 4, experiment environment of the Figure 1 demonstrates that the 3D Depth level is low when it comes to the feel for the three-dimensional effect when users are closer to the screen. In terms of the distance, the effect is optimal while users are at the Row 1 and Row 2. Moreover, 3D Depth level was low when it comes to the feel for the three-dimensional effect when users were situated at the center of the screen. In terms of the location, the order was Column 4, Column 5 and Column 8. Moreover, the analysis showed that the average 3D Depth level from which subjects start to feel the three-dimensional effect is 0.28 level.

4.2. Analysis of the time when users stop feeling the three-dimensional effect

Figure 5 shows the analysis on the time when the subjects stop to feel the three-dimensional effect following distance and location. Figure shown on Figure 5 (for example, 0.3) factored in the disparity of two eyes to demonstrate the level of separation of the images to be shown separately to the left and right eyes. In case of 0, the two images were overlapped completely. In case of 1, the two images were separated completely. The analysis shows that the three-dimensional effect is felt continually even when the level of separation of the two images increases when users move to the center of the left and right sides from the center of the screen. In case of the center seat, it is possible to know that the users feel as the separated two images instead of feeling the images as multi-dimensional images when the level of separation for the two images increase. The distribution in terms of the location when it comes to the results of this experiment conducted targeting subjects in groups produced this order; Row 1, Row 3 and Column 8, which demonstrate that the separation level (3D Depth level) of the image that ends when it comes to the feel for the three-dimensional effect is high. Analysis following distance when it comes to the separation level (3D Depth level) of the image when the feel for the three-dimensional effect ends was low in this order; Column 4, Row 2 and Row 1.

	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Total
Row 1				1,1	1,1	1,1	1,1	0,1	1,0	10
					1,1	1,1	1,1	1,1		
Row 2		1,1		1,1	1,1			1,1		6
				0,0	1,0					
Row 3			1,1	1,0		1,1		1,0	0,0	7
				0,0				1,1		
Row 4	1,1	1,0		1,1	1,1		1,1	1,1	1,1	12
		1,0		0,1	1,0		1,0	0,1		
Row 5	0,1			1,0	1,0	0,1		1,1	0,1	9
					1,0	0,1		0,0		
Row 6		0,1	1,1	1,1			1,0	1,1	1,1	10
		1,1	0,0				1,0		0,1	
Row 7	0,0	0,1	1,1	1,0		1,0	1,1	1,0		12
		0,0	0,0			0,0	1,1	0,1		
Total	3	7	5	10	8	7	8	12	6	66

Figure 5. Analysis of the time when the feel for the three-dimensional effect ends following distance and location

The difference in the level of three-dimensional effect felt in actuality following the distance and location, studied by this research, was significantly affected by location while effect by distance was low. Moreover, when both distance and location were factored in, it is possible to see that less than 0.68 level on average is suitable when it comes to the image separation level (3D Depth level) when there were are many viewers.

4.3. Analysis on the degree of the feel for three-dimensional effect depending on whether eyeglasses are worn or not

Figure 6 shows the analysis on whether there is a difference in the degree of the feel for three-dimensional effect depending on whether subjects wear eyeglasses or not. In actuality, 3D contents that are produced and distributed today utilize the method in which multi-dimensional eyeglasses have to be worn. This method, however, inconveniences those who have to wear eyeglasses due to poor eyesight and appear to affect on how they feel the three-dimensional effect. However, there is no research that studied this issue. Thus, this research conducted an experiment on the effect of eyeglasses on the feel for the three-dimensional effect when they wear multi-dimensional eyeglasses. As for the figures that are shown on the below shown Figure 6 (1,1), (1,0), the value that was indicated first (1 or 0) represent whether subjects wear eyeglasses or not while the value indicated in the back (1 or 0) showcase whether they feel the three-dimensional effect. In case of the subjects who wear eyeglasses, 1 was used to represent the subjects who have to wear eyeglasses due to poor eyesight while 0 was used to represent subjects who do not wear eyeglasses. In case of the feel for the three-dimensional effect, 1 refers to the instance in which three-dimensional effect was felt while 0 refers to the instance in which three-dimensional effect is not felt.

Results of the experiment demonstrate that the maximum image separation level (3D Depth level) that the subjects who wear eyeglasses could feel was 0.73 on average. In case of the subjects who do not wear eyeglasses, maximum image separation level (3D Depth level) that they could feel optimally was 0.64 on average. In other words, images could not be perceived multi-dimensionally by the subjects regardless of whether they wear eyeglasses or not when the image separation level was 0.73 or more. Instead, the image was perceived as two separated images.

	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Total
Row 1				1,1	1,1	1,1	1,1	0,1	1,0	10
					1,1	1,1	1,1	1,1		
Row 2		1,1		1,1	1,1			1,1		6
				0,0	1,0					
Row 3			1,1	1,0		1,1		1,0	0,0	7
				0,0				1,1		
Row 4	1,1	1,0		1,1	1,1		1,1	1,1	1,1	12
		1,0		0,1	1,0		1,0	0,1		
Row 5	0,1			1,0	1,0	0,1		1,1	0,1	9
					1,0	0,1		0,0		
Row 6		0,1	1,1	1,1			1,0	1,1	1,1	10
		1,1	0,0				1,0		0,1	
Row 7	0,0	0,1	1,1	1,0		1,0	1,1	1,0		12
		0,0	0,0			0,0	1,1	0,1		
Total	3	7	5	10	8	7	8	12	6	66

Fig. 6. Analysis of the feel for the three-dimensional effect depending on whether subjects wear eyeglasses or not

5. Conclusion

This research conducted experiment, targeting 33 subjects in order to analyze the 3D Depth level depending on distance and location to mitigate the fatigue of the users' eyes and to enable them to feel the three-dimensional effect and engagement level in the most effective manner by changing the 3D Depth level and subjects' location and distance.

As shown on Figure 7, two experiments were conducted targeting 33 subjects. As a result, it is possible to see that the distribution of the 3D Depth level for the start and end of the feel for the three-dimensional effect starts and ends at the average of 0.28 and 0.68, respectively.

Depth level	Three-dimensional effect start	Three-dimensional effect end
0	1	
0.05	8	
0.1	3	
0.15	7	
0.2	4	1
0.25	7	
0.3	5	1
0.35	1	3
0.4		3
0.45	4	6
0.5	1	1
0.55		4
0.6	2	4
0.65	1	2
0.7		4
0.75		2
0.8	2	7
0.85		
0.9	1	8
0.95		
1	1	8
X	18	12
Minimum	0	0.2
Maximum	1	1
Average	0.28	0.68

Figure 7. Distribution of the 3D Depth level for the start and end of the feel for the three-dimensional effect following Depth level

Figure 8 shows the analysis on whether subjects feel the three-dimensional effect depending on whether they were eyeglasses or not, which demonstrates that the subjects who wear eyeglasses are more familiar when it comes to feeling the three-dimensional effect compared to those who do not wear eyeglasses.

Analysis demonstrates that the subjects who wear eyeglasses experience approximately 10% longer three-dimensional effect following the separation of images. However, the difference appears to be minimal. This shows that it is not necessary to take the issue of whether subjects wear eyeglasses or not too seriously when developing automatic 3D image control techniques and game contents going forth.

number of people who could feel the three-dimensional effect (wear eyeglasses normally)	30 (people)
number of people who could not feel the three-dimensional effect (wear eyeglasses normally)	11 (people)
number of people who could feel the three-dimensional effect (do not wear eyeglasses normally)	16 (people)
number of people who could not feel the three-dimensional effect (do not wear eyeglasses normally)	9 (people)
maximum selectance of the image that enables people to feel the three-dimensional effect (wear eyeglasses normally)	0.73 (73%)
maximum selectance of the image that enables people to feel the three-dimensional effect (do not wear eyeglasses normally)	0.64 (64%)

Figure 8. Analysis of the degree of the feel for three-dimensional effect depending on whether eyeglasses are worn normally

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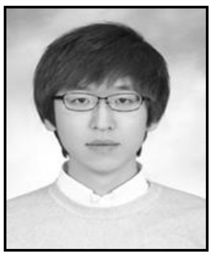

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