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Comparison of Immersive Feeling Effects between Three Wide-angle Image Projection Techniques

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Abstract: This investigation compares three wide-angle image projection techniques, “simple enlargement,” “video mosaicing” and “pseudo wide-angle images”, to find the most effective technique for producing an immersive feeling. We conduct an assessment of these techniques by a subjective evaluation using questionnaires. The results of the assessment are examined by Steel’s test and factor analysis. According to all the results, the pseudo wide-angle images technique provides the most immersive feeling effects out of the three wide-angle image projection techniques. The most effective technique is useful for changing living rooms into human-scale immersive image theaters.

Keywords: *Wide-angle image, Immersive feeling, Assessment, Entertainment*

1. INTRODUCTION

Studies on immersive projection environments have been actively conducted and hardware for such environments, such as D-vision, has been developed [1,2]. However, not all challenges have been overcome; software for making immersive images for these environments still requires special skills and equipment. For example, 3D scenes with complicated computer graphics (CG) are rendered using professional software, and well-calibrated cameras are needed for shooting surrounding images.

In usual wide-angle image projection, we just optically enlarge input images up to the size of the projection plane (normally screen size). However, if the size of the projected image is larger than the human scale, when projecting the images on a wall in a living room for example, it might be better to project images that have a wider field of view than the input images, but this process is more involved than simply enlarging the input images.

For images with a wider field of view, it is necessary to create peripheral images from the input images. There are wide-angle image projection techniques for converting ordinary input images, such as video images and existing CG content, into images that are combined with peripheral images, without requiring special skills or equipment [3-7].

In this paper, we examine the effectiveness of adding peripheral images to original images in wide-angle image projection. We compare two wide-angle image projection

techniques that create peripheral images, and the “simple enlargement” wide-angle image projection technique. The two wide-angle image projection techniques are our proposed technique, “pseudo wide-angle images [3-5],” and a well-known technique, “video mosaicing [6,7].” In our investigation, immersive feeling effects of the three wide-angle image projection techniques are analyzed with a non-parametric multiple comparison method, Steel’s test, and with factor analysis. Then, we find the best wide-angle image projection technique to bring immersive feeling effects into a human-scale immersive projection environment.

2. WIDE-ANGLE IMAGE PROJECTION TECHNIQUES

We compare wide-angle image projection techniques that can create wide-angle images from ordinary images without special skills or equipment. We propose our “pseudo wide-angle images” technique, and describe the most common, simplest technique, “simple enlargement,” and a well-known technique for creating peripheral images, “video mosaicing.”

2.1 Simple Enlargement

The simplest way to make wide-angle images from ordinary images is to optically enlarge the ordinary images without any image processing. The enlarged images do not include any additional information compared to the ordinary images; however, this technique

Figure 1: Simple enlargement

Figure 2: Models for generating the peripheral image
((a) Flat model for video mosaicing, (b) Pseudo depth model for pseudo wide-angle images)

is the most common way to have large wide-angle projected images. In this paper, we call this technique “simple enlargement.” Figure 1 shows the concept of simple enlargement.

2.2 Video Mosaicing [6,7]

Employing a well-known technique called “video mosaicing,” we can construct wide-angle versions of the ordinary images using additional information. The wide-angle images are created by combining the ordinary images with their peripheral images. For each ordinary image frame, a peripheral image is generated from the past (ordinary) image frames. This technique provides us with more informative projected images than simple enlargement does.

2.3 Pseudo Wide-Angle Images [3-5]

Pseudo wide-angle images are created in a similar way to video mosaicing, except they are based on a pseudo depth model. When generating the peripheral image from the past image frames, we construct a pseudo depth model with the present image frame to give a sense of depth in the wide-angle images. We call this technique “pseudo wide-angle images.” Figure 2 shows models for generating the peripheral image. Figure 2(a) is a flat model for video mosaicing and Figure 2(b) a pseudo depth model for pseudo wide-angle images. As shown in Figure 2(a), the video mosaicing technique uses a flat model, so the algorithm used to generate the peripheral image requires fewer steps than that used for the pseudo wide-angle images technique, but the “realness” of the peripheral

Figure 3: Pseudo wide-angle images (Top: image frames obtained using a walk-through, Bottom: Extracting and mapping the peripheral images by using a pseudo depth model with the present image frame)

image is also less than the pseudo wide-angle images technique. Figure 3 describes the concept of pseudo wide-angle images. Details of the pseudo wide-angle images technique including fast calculation with a GPU are explained in our previous work [5].

3. ASSESSMENT OF TECHNIQUES

In the assessment of wide-angle images on immersive feeling effects etc., the most popular and basic technique is a subjective evaluation that uses questionnaires, followed by statistical analysis, such as factor analysis [8,9]. Measurement of eye movements and posturography can also be used for analyzing physical effects [10,11], but in this study, we adopted the subjective evaluation using questionnaires and factor analysis. We plan to assess the techniques using the other assessment methods in the future.

In our assessment, we selected nine images with different content: three video images and six CG images, including a driving game and a flight simulator game, as shown in Table 1. These images were projected by the simple enlargement, video mosaicing and pseudo wide-

Table 1: Images with different content

Categories (length)	Scenes
Video (30 sec.)	Walking in a corridor
	Driving in a residential area
	Driving in woods
CG animation (30 sec.)	Walking in a corridor with simple objects
	Walking in a corridor with complex objects
	High-speed driving on a circuit
	Plane flying over a mountain range
CG game (120 sec.)	Driving game (with subject's playing)
	Flight simulator game (with subject's playing)

angle images techniques. The order of the nine images was fixed but the order in which the projection techniques were displayed was random for the individual images.

Every images in each category except the CG games was first projected without its peripheral images for five seconds as benchmark images, then its corresponding wide-angle images were projected for ten seconds. To test several game operations, the CG games were projected longer than the other images were. The projection time for the CG games was twenty seconds at first for the benchmark images, then forty seconds for the wide-angle images. Note that there is no noticeable difference in the scenes between the benchmark images and the wide-angle images. The pair of benchmark images and wide-angle images was projected twice for the length of every images.

In order to present wide-angle images, we used "D-vision [2]" in a dark room. The size of the D-vision was 6.3 m × 4.0 m × 1.5 m (Width × Height × Depth), and the brightness of each projector installed in D-vision was 3000 ANSI lm. The aspect ratio of the presented images was 4:3. The horizontal viewing angle was 60 degrees for the benchmark images, and 120 degrees for the wide-angle images. The viewing distance was 1.5 m. Figure 4 shows examples of the projected images using D-vision. Figure 4(a) shows the video images projected without their peripheral images. Figure 4(b) shows the pseudo wide-angle video images of Figure 4(a).

Fourteen men and six women in their twenties participated in the assessment. For each of the projected images, the subject was asked how he/she felt about the wide-angle images compared to their benchmarks. The subject expressed his/her feelings using a list of chosen assessment words. As shown in Table 2, six assessment words were selected to describe an immersive feeling and four words were selected to describe an uncomfortable feeling. Two more assessment words were added for evaluating the enjoyment of the CG games. For every assessment

(a) Images without their peripheral images

(b) Pseudo wide-angle images

Figure 4: Projected images**Table 2:** Assessment words

Assessment words	
Immersive	Immersive feeling
Powerful	
Impressive	
Perspective	
Expansive	
Spacious	
Uncomfortable	Uncomfortable feeling
Eye-friendly	
Wearisome	
Favorable	Enjoyment of the game
Enjoyable	
Speedy	

word, the subject was asked whether the strength of the feeling from the wide-angle images was more than that from its benchmark, and gave a score for each assessment word on a 7-point Likert scale where "strongly disagree", "neutral," and "strongly agree" were assigned the numbers -3, 0 and +3, respectively.

4. RESULTS AND CONSIDERATIONS

We computed the average score of the twenty subjects for each assessment word for every projected images. Note that as to the average scores for the assessment words "Uncomfortable" and "Wearisome", we change their plus / minus signs so the positive feelings have the positive scores. In only two cases out of all the comparisons

between the pseudo wide-angle images technique and the simple enlargement technique (7 images $\times$ 10 assessment words + 2 CG games $\times$ 12 assessment words = 94 cases), the average scores of both techniques were equal. For the word “powerful” for the “walking in a corridor” images, the score of the pseudo wide-angle images technique was 0.05 lower than that of the simple enlargement technique. In all other cases, the pseudo wide-angle images technique scored higher than the simple enlargement technique.

The comparisons between the pseudo wide-angle images technique and the video mosaicing technique showed that the pseudo wide-angle images technique scored higher in all cases except in nine cases of the driving game and in

four cases of the word “wearisome.”

We also examined whether a significant difference existed between the three techniques according to a non-parametric multiple comparison method. Steel’s test highlights a significant difference between scores in each comparison area. A significant difference is defined as 5 %. Results of Steel’s test are shown in Tables 3 and 4. For all images, a significant difference between the pseudo wide-angle images technique and the simple enlargement technique appeared for five or more assessment words. A significant difference between the pseudo wide-angle images technique and the video mosaicing technique occurred for more than three assessment words for four images.

Table 3: Results of Steel’s test between the pseudo wide-angle images and the simple enlargement (circles indicate the significant differences between their average scores on a significant level of 5 %)

Images	Video			CG animation				CG game	
	Walking in a corridor	Driving in a residential area	Driving in woods	Walking in a corridor with simple objects	Walking in a corridor with complex objects	High-speed driving on a circuit	Plane flying over a mountain range	Driving game (with subject’s playing)	Flight simulator game (with subject’s playing)
Immersive	○	○	○	○	○		○	○	○
Powerful			○		○		○		○
Impressive	○	○	○	○	○		○	○	○
Perspective	○	○	○	○	○	○	○	○	○
Expansive	○	○	○	○	○		○	○	○
Spacious		○	○	○	○	○	○	○	○
Uncomfortable		○	○	○	○		○	○	○
Eye-friendly	○	○	○	○	○	○	○	○	○
Wearisome	○	○	○	○	○	○	○	○	○
Favorable	○	○	○	○	○	○	○	○	○
Enjoyable								○	○
Speedy								○	○

Table 4: Results of Steel’s test between the pseudo wide-angle images and the video mosaicing (circles indicate significant differences between their average scores on a significant level of 5 %)

Images	Video			CG animation				CG game	
	Walking in a corridor	Driving in a residential area	Driving in woods	Walking in a corridor with simple objects	Walking in a corridor with complex objects	High-speed driving on a circuit	Plane flying over a mountain range	Driving game (with subject’s playing)	Flight simulator game (with subject’s playing)
Immersive	○	○			○	○			○
Powerful		○			○	○			○
Impressive	○	○	○		○				○
Perspective		○			○				
Expansive		○				○			○
Spacious		○	○		○				
Uncomfortable		○				○	○		
Eye-friendly		○		○	○				
Wearisome		○							
Favorable		○		○	○	○			
Enjoyable									
Speedy									

In Table 3, the assessment word “powerful” shows fewer significant differences than the other assessment words. It is possible that the simple enlargement technique magnified the images more than the pseudo wide-angle images technique and the magnified images alone were enough to give a powerful impression.

The comparisons between the pseudo wide-angle images technique and the video mosaicing technique differed for the driving game. As shown in Table 4, there is no significant difference in score for any assessment word. On these results, we still need to investigate. The four cases in which video mosaicing technique scored higher than the pseudo wide-angle images technique for the word “wearisome” came from the “walking in a corridor,” “driving in woods,” “walking in a corridor with simple objects” and “walking in a corridor with complex objects” images. Since there is no significant difference in score in any of these cases, these results are insignificant.

In Table 4, the “driving in a residential area,” “walking in a corridor with complex objects” and “high-speed driving on a circuit” images show more significant differences than the other images. This means that the pseudo depth model used for the pseudo wide-angle images worked effectively, especially with the images that contained complex peripheral images. Also, for the assessment words “immersive,” “impressive,” “powerful” and “favorable,” the pseudo wide-angle images technique scored significantly higher than the video mosaicing technique. Since these assessment words evaluate important feelings for wide-angle image projection, this shows that the pseudo wide-angle images technique has a strong advantage over the video mosaicing technique.

Next, we performed a factor analysis using an unweighted least-squares method with promax rotation. Two factors were extracted according to the number of factors whose initial eigenvalues were over 1.0. This is a common rule used to decide how many factors to extract.

Table 5: Results of factor analysis (an unweighted least-squares method with promax rotation)

Assessment words	“Projection Effect”	“Comfort”
Powerful	.962	-.284
Impressive	.804	-.107
Expansive	.801	.011
Spacious	.776	.089
Perspective	.709	.059
Immersive	.705	.162
Wearisome	.184	-.751
Eye-friendly	.233	.699
Uncomfortable	.147	-.692
Favorable	.455	.536
Factor Correlation		.713

Figure 5: Factor Scores

The two factors were named “projection effect” and “comfort,” based on the related assessment words with factor loadings in Table 5. Figure 5 depicts a scatter plot of factor scores. The horizontal axis is “projection effect” and the vertical axis is “comfort.” It can be seen from this figure that in these terms, the pseudo wide-angle images technique was the best among the three wide-angle image projection techniques, and the video mosaicing technique was better than the simple enlargement technique.

As future work, in order to analyze what components of images are related to the subjects’ feelings, the variety of images needs increasing and the presentation time needs more variation. Also, we need to conduct experiments with other assessment methods such as eye tracking and posturography.

5. CONCLUSIONS

With the aim of changing living rooms into human-scale immersive image theaters, we needed to find a wide-angle image projection technique that was effective in producing an immersive feeling. According to all the results of this assessment, the pseudo wide-angle images technique provided the most immersive feeling effects out of the three wide-angle image projection techniques.

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