

EFFECT OF BRIGHTNESS ON THE QUALITY OF VISUAL 3D PERCEPTION

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ABSTRACT

Over the years, a consensus has been reached that the introduction of 3D entertainment can only be a lasting success if the perceived image quality and the viewing comfort are better than those of conventional 2D television. There are different factors that affect the perceived quality of 3D content. In this paper, our objective is to obtain a good understanding of the effect that brightness has on the visual quality of 3D videos and compare it to that of the 2D. We capture outdoor and indoor scenes with different exposures and we perform subjective evaluation to investigate how brightness affects the perceived quality of the 3D experience.

Index Terms— Brightness, 3D TV, quality of experience, 3D perception

1. INTRODUCTION

Three-dimensional (3D) displays can drastically enhance the viewer's quality of experience by introducing a level of immersive reality never been present before. The increasing number of 3D-enabled movie theaters and the introduction of 3D TV to the consumer market are driving the need for more 3D content. Over the years, a consensus has been reached that the introduction of 3D entertainment can only be a lasting success if the perceived image quality and the viewing comfort are better than those of conventional 2D television. The era of user-centric multimedia has already begun, and quality plays a central role in it. Attention to the quality of 3D content is even more important since low-quality 3D videos can produce eye strain, headache, and generally unpleasant viewing experience for the viewers [1]. In general, 3D content production needs different considerations and provisions beside the ones found in the conventional 2D video production (due to involvement of visual 3D perception). Capturing visually pleasing 3D video is challenging in both the commercial and research settings [2]. There are many factors and parameters that affect on the perceptual quality of 3D media. While the effects of

different acquisition parameters on the 3D perception have been studied before, their influence on the perceived quality for a viewer has not been assessed quantitatively. More research and studies are required to improve our understanding of the different factors that affect a viewer's perception of 3D video content. This understanding will help us identify critical testing scenarios that are not addressed in existing standard recommendations. To this end, researchers have studied the effect that changing the baseline of stereo cameras has on the perceptual quality of captured videos [3]. Another study investigates the relation between the object's distance from the camera and the quality of perceived images when watched on different size of displays [4]. Another important factor that may affect the visual comfort and quality of 3D content is brightness [2].

In this paper, our objective is to obtain a good understanding of the effect that brightness has on the visual quality of 3D content and compare it to that of the 2D. This understanding will help us identify criterions related to brightness and utilized them in the 3D production pipeline in order to enhance the viewers' 3D quality of experience. In our study, we capture outdoor and indoor scenes with different exposures and then we run subjective quality assessment experiments to test how brightness levels affect the perceived quality of the 3D content. Mean opinion scores from users of stereoscopic content will be taken into account in order to produce reliable results.

The rest of the paper is structured as follows: Section 2 elaborates on our experimental setup. Subjective evaluations are presented in Section 3. Section 4 includes analysis of our experimental results, followed by conclusions drawn in Section 5.

2. EXPERIMENTAL SETUP

In our experiment, we aim at investigating the effect of brightness on the perceptual quality of 3D content and compare it with that of 2D video. For this comparison, the 2D version and 3D version of similar scenes in different light exposure levels are required. To capture such test video sequences we use two identical full HD cameras (Sony HDR-XR500V 1080 60i NTSC) with baseline distance of 9cm. Fig. 1 shows the stereo camera setup used in our

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Fig.1 Stereo camera setup consisting of two identical HD.

experiment. We used the same settings on both cameras, which were aligned in parallel and attached to a bar that was custom-made for this purpose. Subsequently, the bar was secured to a tripod. Since zoom lenses may differ [3] [5], only the extreme ends of the zoom range were used to avoid any zoom correction post-processing.

In order to secure temporal synchronization of the two cameras, a single remote control was employed to activate both of them at the same time instance. The synchronization of video sequences is further confirmed by comparing the individual corresponding frames from the stereo pair. Even though the cameras are carefully lined up, the recorded videos may require rectification to compensate for vertical, horizontal and rotational misalignments that hamper the

perceptual quality of 3D content.

We set the exposure adjustment of the cameras on manual mode and capture each scene using several different exposure levels. In order to guarantee that brightness is the only varying parameter among all different exposures, we make sure that the scenes are relatively similar in content, object motion and camera movement. This guarantees the consistency needed in our comparisons. The exposure levels are chosen between very bright to very dark levels; the number of steps varies depending on the brightness of the scene that is captured. As expected, outdoor scenes captured during daytime allow for a wider range of exposures.

3. SUBJECTIVE EVALUATION

The subjective evaluation was performed to investigate the effect of picture brightness on 3D visual perception and then compare it to that of 2D videos. For this experiment, six stereoscopic test sequences were used (two outdoor and four indoor). Fig. 2 shows a snapshot of our captured sequences. Indoor scenes were captured at six different levels of camera exposures (very dark to very bright). Since outdoor scenes allow a wider range of brightness, the number of exposure levels for the outdoor sequences was increased to eight. In both cases, outdoor and indoor, each sequence is approximately 10 seconds long.

The viewing conditions were set according to the ITU-R Recommendation BT.500-11 [6]. Eighteen observers participated in our subjective tests: six females and twelve males, ranging from 23 to 63 year old. All subjects have none to marginal 3D image and video viewing experience.



Fig. 2 Snapshot of captured video scenes.

A 65" Full HD 3D display (©Panasonic, Plasma. TC-P65VT25) was used in our experiment. Based on our own subjective tests of many 3DTV sets, the above display offers the best crosstalk reduction performance and that is the reason it was chosen for our tests.

At the beginning of the experiment the "Running" test sequence was played starting from a very bright exposure to a very dark exposure to help viewers become familiar with the test process and show them the quality-change range expected. Note that "Running" was excluded from the subsequent testing process.

Our tests included two steps: rating the perceptual quality of 3D content in different exposure levels and grading the quality of the same content in 2D format. In order to maintain similar brightness conditions for both cases (3D and 2D), the left view of the captured video sequences was chosen and displayed to both eyes in the 2D case and the viewers were asked to use the glasses while watching the 2D video sequences.

After the training sequence, the viewers were first shown each stereoscopic test sequence in random order of exposure levels. Between different exposures, there was a three-second gray interval that allowed the viewers to grade the perceptual quality of 3D content from 1 to 10 (continuous scale) and prepare their eyes for watching the next sequence. Once all the stereoscopic sequences were played, there was a break interval of 5 seconds followed by the 2D sequences. The same process was followed in this case - the same sequence was shown in random order of brightness, with 3-

second intervals between each sequence - with the viewers asked to rate the video quality of the 2D content.

4. RESULTS AND ANALYSIS

After collecting the experimental results, we removed the outliers (there was one outlier) based on the TU-R Recommendation BT.500-11 [6] and then the mean opinion scores from viewers are calculated. Fig. 3 shows the results with 95% confidence interval.

A general observation that applies to outdoor and indoor scenes is that the video sequences with brightness levels around the mid-band are more appealing to the viewers in both the 2D and 3D cases (rating scores are more than 6). Note that the exposure range is wider for the outdoor scenes and the highest brightness level for outdoors cannot be reached for the indoor scenes. Another fact is that as the brightness is increased (a result achieved by using different camera exposure settings), this effect is more localized in the outdoor case. Regarding the indoor scenes, we observe that for scores above 6 (over which the quality may be regarded acceptable), the quality of the 3D experience increases as the brightness increases. Similar results are witnessed in the 2D case, with scores following the same pattern. If we would like to conclude something more from these findings, we could say that the 3D experience adds a bit more quality overall, although the difference is not very large.

For the outdoor sequences, we observe that the extreme

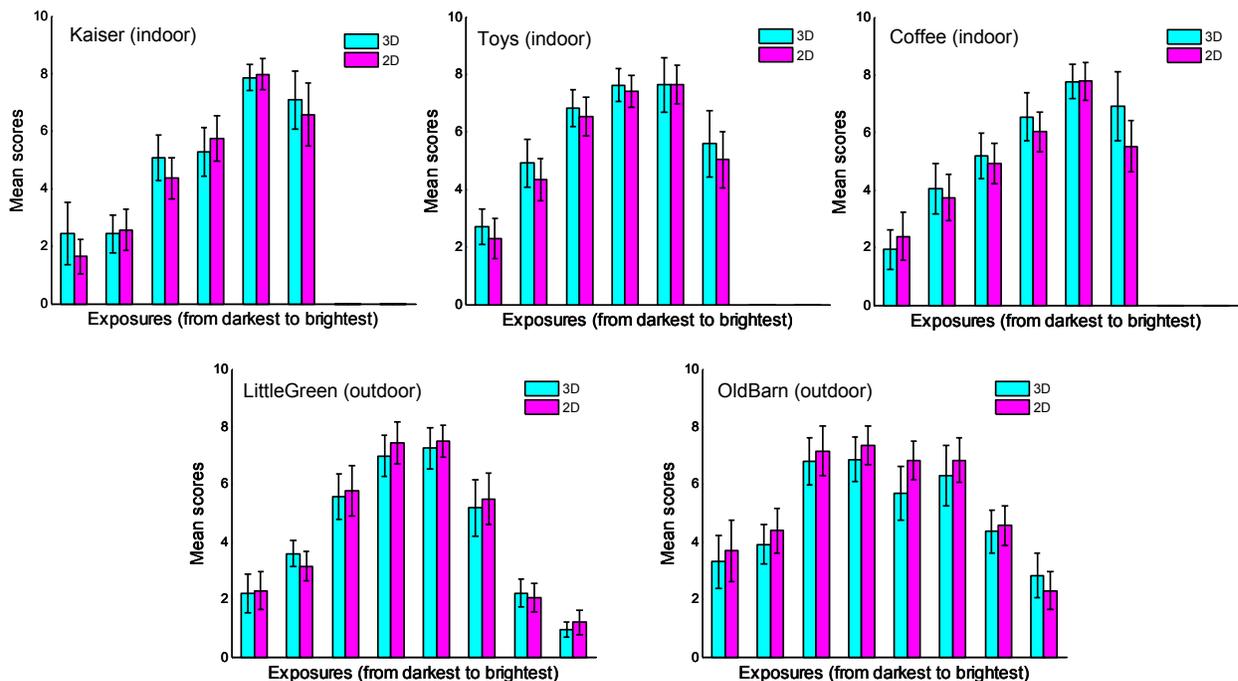


Fig. 3 Subjective test results.

levels of brightness, very dark and very bright, result in unacceptable quality. For the mid-band section, the quality stays at acceptable levels, with very small variations. The 2D performance is almost identical, with 2D ratings slightly higher than those of 3D in this case. The main reason for this deviation from the indoor case is the actual content of the outdoor scenes. The objects with depth in the latter case are relatively darker than the background. In fact, a large portion of the background – more so in the “OldBarn” sequence than the “LittleGreen” – is the sky, which in both cases is very bright and lacked detail. According to the viewers, the lack of detailed information in the background (i.e., overexposed sky) drastically reduced the level of depth illusion, hampering the 3D perception when watching stereoscopic content.

Given the above observations, our future research will focus on conducting subjective tests with a much larger variety of content, employing special lighting equipment in order to explore any possible case of brightness for foreground and background in outdoor and indoor conditions.

5. CONCLUSION

The era of user-centric multimedia has already begun, and quality plays a central role in it. Attention to the quality of 3D content is even more important since low-quality 3D videos can produce eyestrain, headache, and generally unpleasant viewing experience for the viewers. Brightness is one of the important factors that affect the visual comfort and quality of 3D videos. In this study we addressed the problem of understanding the effect of brightness on the quality of experience of viewers for 3D content.

According to our results, a general observation that applies to outdoor and indoor scenes is that the video sequences with brightness levels around the mid-band are more appealing to the viewers in both the 2D and 3D cases. Regarding the indoor scenes, we observe that the quality of the 3D experience increases as the brightness increases. For the outdoor sequences, the quality stays at acceptable levels for the mid-band section of brightness, with very small variations.

The quality ratings for 2D are almost identical to those for 3D. However, it seems that in the indoor cases 3D slightly enhances the quality of experience over 2D, while the opposite was evident in the outdoor cases. This is directly related to the lack of detailed information in the background of the captured scenes, which drastically reduced the level of depth illusion, hampering the 3D perception when watching stereoscopic content.

Our future research will focus on conducting subjective tests with a much larger variety of content, employing special lighting equipment in order to explore any possible case of brightness for foreground and background in outdoor and indoor conditions.

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