Assessing the Effects of Ambient Illumination Change in Usage Environment on 3D Video Perception for User Centric Media Access and Consumption*

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Abstract. For enjoying 3D video to its full extent, access and consumption of 3D content should be user centric, which in turn ensures enhanced quality of user experience. The experience nevertheless is easily influenced by several factors, including content characteristics, users' preferences, contexts prevailing in various usage environments, etc. Utilizing ambient illumination as an environmental context for the purposes of efficient provision of 3D video to users has particularly not been studied in literature in detail. This paper investigates the effects of ambient illumination on 3D video quality and depth perception for utilizing this information as one of the key context elements in future user centric 3D access and consumption environments. Subjective tests conducted under different illumination conditions demonstrate that the illumination of the viewing environment encircling the users has significant effects on the perceived 3D video quality as well as depth perception.

Keywords: User centric 3D video, ambient illumination, usage environment, subjective quality assessment.

1 Introduction

Content distribution and access in heterogeneous usage environments have posed significant research and technology development challenges for delivering media to a wide range of users for a long time. These challenges have been exacerbated not only by the existence of different networking infrastructures, diverse user terminals, and numerous media content representations, but also by the users themselves and their various preferences and high levels of expectations. In turn, this has led the research efforts to focus on user centricity while providing media services rather than conventional purely technology orientated service provisions.

User centricity in media services is an all-encompassing concept, in which complying with regulations, standards, technological requirements, etc as well as decoupling such technologies from the users and making them as seamless and easy-to-use as possible are all inherently essential. While addressing all of these,

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responding to the user needs, requests and preferences while also paying attention to the usage environment conditions are certainly a major part of providing user centric media services successfully.

In recent years, users have increasingly become producers of large quantities of media content in addition to their traditional consumer roles, and thus a new term: *"prosumers"* has been coined to reflect the changing roles of the users. Consequently, this has resulted in an explosion of user generated content exchanged and distributed across the Internet. The media content, either user generated or created by professionals, is abundant and readily available for the consumption of a wide variety of users. Today's Internet access makes the content sharing and exchange possible, yet Future Media Internet will allow a wide range of new applications to be realized with support for ubiquitous media-rich content service technologies. 3D video is one of them, and has already made its way to becoming a world-wide success story.

The stereoscopic viewing ability of humans has always been the driving force behind the efforts for bringing 3D video technologies to reality. 3D video capture, representation, coding, transmission, rendering, etc are some example technologies to name [1]. Although several developments in these technologies have been made today, there are still many areas that need to be improved through vigorous research. For enjoying the 3D video to its full extent, access and consumption of 3D content should be user centric, which in turn ensures enhanced quality of user experience. Thus, user centric 3D video adaptation is one of the key areas that requires in-depth investigations for enabling next generation networked and pervasive 3D media environments, which will be available over the Future Media Internet.

The overall target of the user centric 3D video adaptation is to maximize user experience in terms of perceived quality and depth perception [2]. Hence, as a first step, it is necessary to determine the contextual factors that can affect the 3D video quality and depth perception during its consumption, so as to assist adaptation and efficient provision of 3D video to users for achieving this target. Particularly, the effects of varying ambient illumination context in the content usage environment surrounding the user on the use and experience of 3D video have not been thoroughly investigated in literature. In this paper, these effects are studied, assessed, and a set of notable findings is clearly highlighted. Based on the subjective tests employed involving a group of viewers, changes in the illumination conditions have been observed to affect users' quality of 3D video content viewing and consumption experiences. The knowledge gained through this assessment work is envisaged to be valuable for exploiting in developing user centric 3D video adaptation strategies, which will lead the path to successful provision of 3D video to users with various requirements and preferences.

Contextual data for ambient illumination can be gathered through light sensors placed on user devices, which collect information on the level of brightness in a consumption environment. Color-plus-depth map 3D video representation is employed for the research carried out in the paper since it has many advantages compared to the left and right 3D video representation, and has also been highly exploited in research and standardization activities to date [1] [3].

This paper is organized as follows. The subjective assessment test method is described in Section 2. Section 3 presents the results of the assessments, elaborates on them, and outlines a number of suggestions for exploiting the observations made from the analysis of the results. Finally, Section 4 presents the conclusions and future work.

2 Subjective Assessment Tests

In this section, the details of the test set-up and methodology followed to conduct the subjective experiments for assessing the video quality and depth perception during the user centric access and consumption of a range of 3D video sequences under different ambient illumination conditions in the usage environment are described.

In the experiments, a 42” Philips multi-view auto-stereoscopic display, which has a resolution of 1920 × 1080 pixels, was used to display six 3D video test sequences that are called as: *Interview*, *Chess*, *Windmill*, *Ice*, *Advertisement*, and *Eagle*. The thumbnails of these sequences are depicted in Fig. 1. The color texture and depth map sequences of the 3D video clips were of High Definition (HD) resolution (i.e., 1920 × 1080 pixels) at 25 fps. The Joint Scalable Video Model (JSVM) reference software version 9.13.1 was used to encode the sequences [4]. Four different channel bandwidths (i.e., 512, 768, 1024, and 1536 kbps) were selected as target bit rates. 80% of the target bit rate was allocated for the color sequences and the remaining bit rate (i.e., 20%) was allocated for the depth map sequences while performing the experiments [5]. The lengths of the videos were set to 5 seconds, which complies with the International Telecommunication Union (ITU)’s recommendation for subjective quality assessment experiments [6].

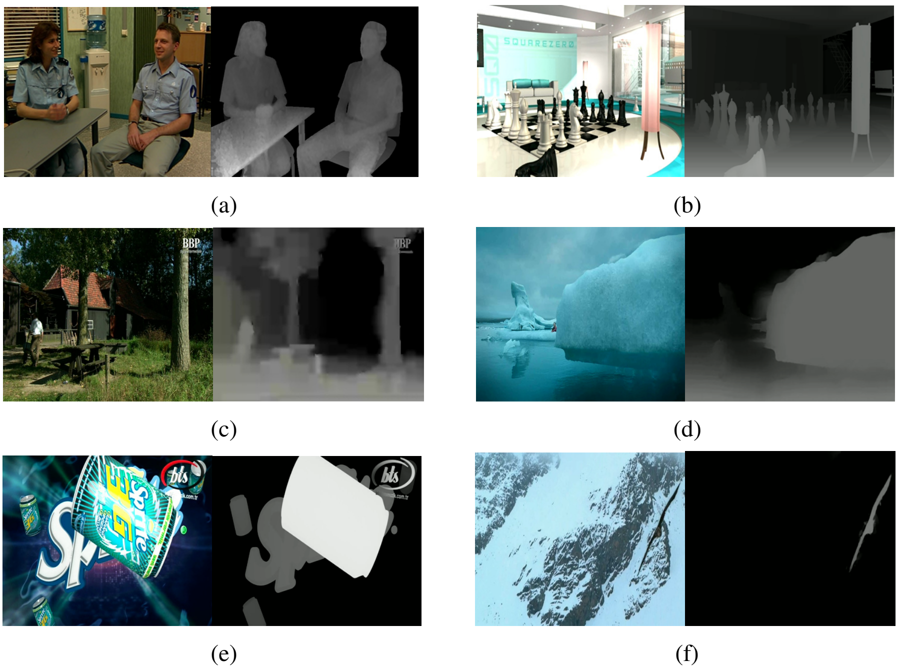


Fig. 1. Color texture and associated depth map of the (a) *Interview* (b) *Chess* (c) *Windmill* (d) *Ice* (e) *Advertisement* (f) *Eagle* sequences

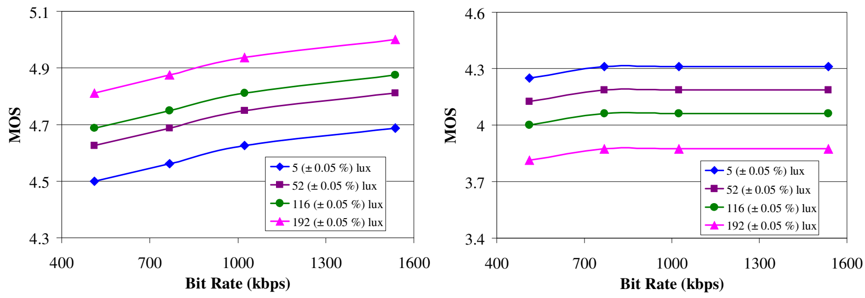
The effects of the ambient illumination on perceptual quality and depth perception were assessed under four different ambient illumination conditions (i.e., 5, 52, 116, and 192 lux), created by the self-contained media laboratory facilities of I-Lab, University of Surrey. 5 lux corresponds to a dark condition, while 192 lux indicates a bright light environment. These conditions were measured using a Gretag Macbeth Eye-One Display 2 device [7]. 16 volunteers (5 females and 11 males) participated in the experiments. They were all non-expert viewers, whose ages ranged from 20 to 35. Their eye acuity was tested against Snellen eye chart and the stereo vision was tested with the TNO stereo test. All of them surpassed 0.7 eye acuity and 60 seconds of arc stereo vision levels, respectively. Furthermore, their color vision was verified with the Ishihara test, and all viewers were reported to have good color vision [1]. The subjective tests were conducted with each viewer to assess all of the test sequences individually, which were randomly ordered for each environment condition to avoid any potential prejudices. The subjects were asked to assess both the video quality and depth perception by comparing the impaired video sequences with the reference ones. Following the experiments, the Mean Opinion Scores (MOSs) [6] obtained from all of the viewers were computed. A score of 5 in the MOS assessment scale means the impaired video has the same perceptual quality or depth perception as the reference one, while a score of 1 means very annoying presentation. The tests lasted 20 minutes on average, including the initial training session.

3 Results and Elaboration on Observations

In this section, the results of the subjective experiments are analyzed for the six test sequences in detail firstly. Subsequently, observations on the results are elaborated, and the application areas, in which such observations can be exploited, are discussed.

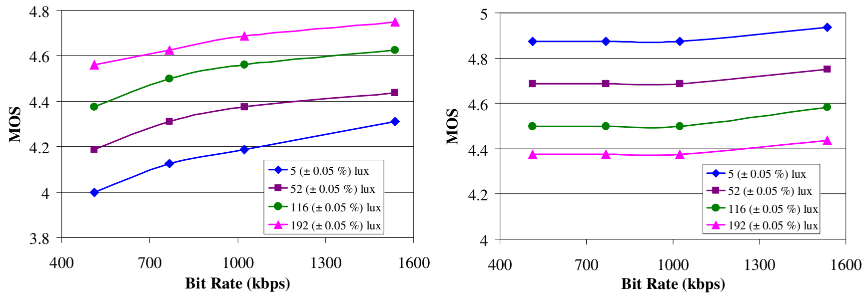
3.1 Results and Discussion

Figs. 2-4 illustrate the bit rate versus MOS results reported on the viewers' video quality and depth perception assessments for the 3D *Interview*, *Chess*, and *Windmill* sequences, respectively. It can be observed from the video quality results presented on the left-hand side graphs (i.e., the (a) figures) that the video sequences viewed under different ambient illumination conditions have demonstrated an increasing perceptual quality rating pattern as the amount of light in the environment increases across all of the bit rate range that was considered in the experiments. Here, the perceived video quality presents the lowest subjective scores in the 5 lux environment compared to those in the other environments regardless of the varying bit rate. When the ambient illumination increases (i.e., from 5 lux to 52 lux; to 116 lux; and to 192 lux), the subjective scores given by the viewers also increase. This is due to the fact that the size of the iris responds to the amount of ambient light entering into the eye, which directly influences the sensitivity of the Human Visual System (HVS) towards perceiving finer details in the visual content [8]. It is therefore no surprise that in the 5 lux (i.e., dark) environment, the HVS becomes more sensitive to detecting quality related problems while watching a video clip due to enlarged iris. In such an environment, the compression artifacts in the 3D visual scene are more visible to the eye than in the other environments. Thus, when the amount of ambient illumination in the consumption environment increases, the corresponding sensitivity of the HVS decreases due to reducing iris size, which allows for adjusting to more ambient light entering into the eye. As a result, the compression artifacts start becoming less and less distinguishable to the viewers' eyes.



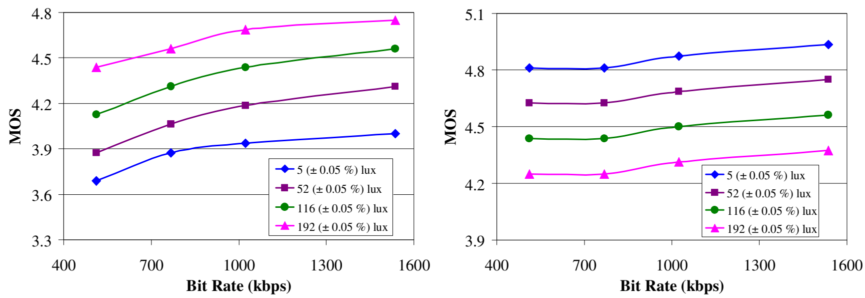
(a) (b)

Fig. 2. The *Interview* sequence bit rate versus MOS under different ambient illumination conditions (5, 52, 116, and 192 lux) for (a) video quality (b) depth perception



(a) (b)

Fig. 3. The *Chess* sequence bit rate versus MOS under different ambient illumination conditions (5, 52, 116, and 192 lux) for (a) video quality (b) depth perception



(a) (b)

Fig. 4. The *Windmill* sequence bit rate versus MOS under different ambient illumination conditions (5, 52, 116, and 192 lux) for (a) video quality (b) depth perception

Interestingly, as can be observed from the depth perception results presented on the right-hand side graphs (i.e., the (b) figures), the video sequences viewed under different ambient illumination conditions have demonstrated a decreasing depth perception rating pattern as the amount of light in the environment increases across all of the bit rate range. Indeed, the perceived depth presents the highest subjective scores in the 5 lux environment when compared with those in the other environments regardless of the varying bit rate. When the ambient illumination increases (i.e., from 5 lux to 52 lux; to 116 lux; and to 192 lux), the subjective scores given by the viewers reduce. These results reveal that the lower the amount of ambient illumination in the 3D video access and consumption environment the better the depth perception MOS ratings are. This can be explained as follows: increased ambient illumination conditions do not necessarily contribute towards producing better 3D view effects to the HVS [9]. This is due to the fact that increased ambient illumination in the environment leads to reduced sensitivity to detecting sharpness, shadows, reflections, contrast differences, etc in the visual content, all of which are essential cues to enhance depth perception in 3D video. Although the depth related problems may be more eye-catching in a darker environment, as per the previous video quality discussions, the test results show that the viewers tend to overlook those impairments in the individual depth cues to favor the overall depth sensation received while watching 3D content in dark due to more prominent visibility of these cues [6, 10].

Furthermore, the experimental results have shown that as the encoding bit rates of the 3D video test sequences increase, both the perceived video quality and depth perception ratings improve. The improvement is larger for the video qualities for the increasing bit rate whereas there are several saturation levels in the depth perception results, observed with flat areas across the changing bit rate range. This is because, it is common knowledge that the compression quality of color texture visual content enhances with finer quantization in video coding, yet an increase in bit rate of depth maps does not reveal further depth information beyond what is already available.

Similar observations have been made on the video quality and depth perception results for the remaining 3D video test sequences, namely *Ice*, *Advertisement*, and *Eagle*. Due to space constraints in the paper, their individual bit rate versus MOS graphs have not been presented. Instead, the absolute MOS values obtained for the entire set of sequences are shown in Table 1, which support the observations reported.

3.2 Summary of Observations and Potential Exploitation of Knowledge Gained

The observations made during the experiments can be summarized as follows:

- When the ambient illumination in the usage environment for user centric 3D video access and consumption increases, the video quality perception ratings of the viewers also increase. The idea behind this observation is that in a well-lit environment, the visual artifacts (due to compression, transmission, rendering, etc) in the 3D content cannot be easily detected by the human eye as much as they can be noticed while viewing the same content in a dark environment.
- Conversely, when the ambient illumination in the environment increases, then the depth perception ratings of the viewers decrease, as brighter light conditions hinder the clear visibility of the essential cues (e.g., sharpness, shadowing, reflection, contrast, etc) that enhance the overall depth sensation in 3D content.

- When the bit rate of the 3D video increases, the MOS ratings associated with the video quality increase sharply, while the depth perception MOSs are presenting a mix of both smooth regions and areas of gradual increase.

In future research, the above-listed observations on the video quality and depth perception results, which provide useful hints for exploiting the HVS sensitivity to 3D video perception, can be utilized for realizing the development of:

- 3D media quality of experience enhancement solutions.
- Improved 3D media transmission and communication systems.
- Tailored user centric 3D video adaptation strategies.
- Easy-to-use/deploy 3D display and customized 3D rendering technologies.
- Personalized user centric 3D media access and consumption environments.

Table 1. Subjective assessment results

3D Video	Ambient Illum. (lux)	Bit Rate (kbps)	MOS		3D Video	Ambient Illum. (lux)	Bit Rate (kbps)	MOS	
			Video Quality	Depth Perception				Video Quality	Depth Perception
Interview	5	512	4.500	4.250	*Ice*	5	512	3.562	4.625
		768	4.562	4.312			768	3.625	4.687
		1024	4.625	4.312			1024	3.687	4.687
		1536	4.687	4.312			1536	3.875	4.687
	52	512	4.625	4.125		52	512	3.687	4.500
		768	4.687	4.187			768	3.812	4.562
		1024	4.750	4.187			1024	3.937	4.562
		1536	4.812	4.187			1536	4.125	4.562
	116	512	4.687	4.000		116	512	3.875	4.437
		768	4.750	4.062			768	4.062	4.500
		1024	4.812	4.062			1024	4.187	4.500
		1536	4.875	4.062			1536	4.375	4.500
	192	512	4.812	3.812		192	512	4.125	4.375
		768	4.875	3.875			768	4.375	4.437
		1024	4.937	3.875			1024	4.562	4.437
		1536	5.000	3.875			1536	4.750	4.437
Chess	5	512	4.000	4.875	*Advertisement*	5	512	2.875	4.875
		768	4.125	4.875			768	3.062	4.875
		1024	4.187	4.875			1024	3.187	4.937
		1536	4.312	4.937			1536	3.312	4.937
	52	512	4.187	4.687		52	512	3.125	4.625
		768	4.312	4.687			768	3.312	4.625
		1024	4.375	4.687			1024	3.437	4.750
		1536	4.437	4.750			1536	3.625	4.750
	116	512	4.375	4.500		116	512	3.437	4.375
		768	4.500	4.500			768	3.625	4.437
		1024	4.562	4.500			1024	3.812	4.437
		1536	4.625	4.583			1536	3.937	4.437
	192	512	4.562	4.375		192	512	3.812	4.250
		768	4.625	4.375			768	4.062	4.250
		1024	4.687	4.375			1024	4.250	4.375
		1536	4.750	4.437			1536	4.500	4.375

Table 1. (*Continued*)

Windmill	5	512	3.687	4.812	*Eagle*	5	512	4.000	4.750
		768	3.875	4.812			768	4.187	4.812
		1024	3.937	4.875			1024	4.375	4.875
		1536	4.000	4.937			1536	4.437	4.937
	52	512	3.875	4.625		52	512	4.187	4.687
		768	4.062	4.625			768	4.250	4.750
		1024	4.187	4.687			1024	4.437	4.812
		1536	4.312	4.750			1536	4.562	4.812
	116	512	4.125	4.437		116	512	4.312	4.562
		768	4.312	4.437			768	4.375	4.562
		1024	4.437	4.500			1024	4.562	4.625
		1536	4.562	4.562			1536	4.687	4.625
	192	512	4.437	4.250		192	512	4.375	4.375
		768	4.562	4.250			768	4.437	4.437
		1024	4.687	4.312			1024	4.625	4.500
		1536	4.750	4.375			1536	4.812	4.562

4 Conclusions and Future Work

In this paper, the effects of ambient illumination in the usage environment on the perceptual video quality and depth perception of 3D video sequences for user centric 3D video access and consumption have been investigated. The results of the investigations have revealed that ambient illumination has significant effects on the perceptual video quality and depth perception. Based on the subjective tests conducted with a group of viewers, it has been observed that when the ambient illumination in the content access and consumption environment increases, the MOS ratings of the viewers for the perceived video quality also increase. Conversely, it has also been noted that when the ambient illumination increases, the perceived depth MOS ratings of the viewers decrease. These observations provide a notable set of findings for realizing an enhanced support for networked user centric 3D media access and consumption methods, and thus can be exploited in quite a wide range of areas. Our future work comprises developing smart 3D video adaptation strategies by utilizing the knowledge gained through the experiments discussed in this paper.

References

1. Hewage, C.T.E.R., Worrall, S.T., Dogan, S., Villette, S., Kondoz, A.M.: Quality Evaluation of Color Plus Depth Map-Based Stereoscopic Video. IEEE J. Select. Topics in Sig. Process.: Visual Media Quality Assessment 3(2), 304–318 (2009)
2. Kim, M.B., Nam, J., Baek, W., Son, J., Hong, J.: The Adaptation of 3D Stereoscopic Video in MPEG-21 DIA. Elsevier Sig. Process. Image Commun. J. Special Issue on Multimedia Adaptation 18(8), 685–697 (2003)
3. ISO/IEC JTC 1/SC 29/WG 11: Committee Draft of ISO/IEC 23002-3 Auxiliary Video Data Representations. WG 11 Doc. N8038 (April 2006)
4. JSVM 9.13.1: CVS Server, `http://garcon.ient.rwth-aachen.de/cvs/jv`

5. Tikanmaki, A., Gotchev, A., Smolic, A., Miller, K.: Quality Assessment of 3D Video in Rate Allocation Experiments. In: IEEE Symposium on Consumer Electronics (April 2008)
6. ITU-R BT.500-11: Methodology for the Subjective Assessment of the Quality of Television Pictures (2002)
7. Gretag Macbeth Eye-One Display 2, `http://www.xrite.com`
8. Frazor, R.A., Geisler, W.S.: Local Luminance and Contrast in Natural Images. Elsevier Vision Research J. 46(10), 1585–1598 (2006)
9. Robinson, T.R.: Light Intensity and Depth Perception. American J. Psychology 7(4), 518–532 (1896)
10. ITU-R BT.1438: Subjective Assessment of Stereoscopic Television Pictures (2000)