

Quality Assessment of 3D Videos: A Review of Applications in Medical Imaging, Surgical Navigation, and Clinical Visualization

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ABSTRACT

Colour plus depth map based stereoscopic video has attracted significant attention in the last 10 years, as it can reduce storage and bandwidth requirements for the transmission of stereoscopic content over wireless channels such as mobile networks. However, quality assessment of coded 3D video sequence can currently be performed reliably using expensive and inconvenient subjective tests [1]. The main goal of many subjective video quality metrics is to automatically estimate average user or viewer opinion on a quality of video processed by the system. However, measurement of subjective video quality can also be challenging because it may require a trained expert to judge it. Many subjective video quality measurements are described in ITU-T recommendation BT.500. Their main idea is the same as in Mean Opinion Score for video sequences which are showed to the group of viewers and then their opinion is recorded and averaged to evaluate the quality of each video sequence. Optimization of 3D video systems in a timely manner is very important, it is therefore necessary that reliable subjective measures are calculated based on statistical analysis. This paper investigates subjective assessment for four standard 3D video sequences. Subjective tests are performed to verify the 3D video quality and depth perception of a range of differently coded video sequences, with packet loss rates ranging from 0% to 20%. The subjective quality results are used to determine more accurately the objective quality assessment metrics for 3D video sequences such as the Average PSNR, Structural similarities (SSIM), Mean Square Error (MSE) etc. The proposed measure of 3D perception and 3D quality of experience (QoE) is shown to correlate well with human perception of quality on a publicly available dataset of 3D videos and human subjective scores. The proposed measure extracts statistical features from depth and 3D videos to predict the human perception and 3D QoE.

KEYWORDS: 3D video, Subjective quality assessment, Stereoscopic video.

1. INTRODUCTION

Quality assessment of 3D video and stereo images is achievable either through subjective assessment or through objective metrics. The best way to assess video quality would surely be to run subjective tests according to standardized protocols, which are defined in order to obtain correct universal and reliable video quality evaluation through participants [2]. With the human viewers as the final receiver for video technology, subjective video quality assessment can yield the perfect and desired quality measures. However, the use of subjective test is time consuming due to subjective test preparation, requirements, cost, and time consumption. Furthermore the analysis of the data collected is not a straight forward, and there is a growing demand to use objective quality assessment (OQA) approach. The existing 2-D objective quality measures of individual colour and depth map sequences may not represent the true image quality as perceived by the human viewers. Although some researchers use peak signal-to-noise ratio (PSNR) for assessing 3-D videos, the limitations of PSNR for 2-D video have been demonstrated [1, 2]. These limitations are likely to be similar for the assessment of image quality in 3-D video; in addition PSNR does not give information about the depth perception. With the OQA approach, computer algorithms are used to estimate the quality of the product instead of human subjects [2]. Therefore we use the subjective quality assessment (SQA) to always confirm the objective quality assessment (OQA) of 3D video sequences or images.

Effort has been devoted by both academics and the industrial communities to develop subjective test models to evaluate both 2D and 3D video sequences, moreover when image and video delivery takes place in an error prone scenario, subjective quality assessment can be used as side information for the image and video server to take the necessary actions to improve the quality of the received data. With the widespread of 3D technology applied to different fields such as sports/life events, films, TV series and documentaries, medical applications, gaming, etc. 3D images and videos need to be processed, transmit and distribute to various users. Therefore, it is

important to define both subjective procedures and objective metrics to assess the quality of the processed stereo videos. Indeed compare to 2D videos, perception of stereo content involves several factors. The multidimensional attributes such as blocking and noise associated with 2-D video cannot be used in measuring the perceptually important qualities of 3-D video such as notion of presence, sharpness, naturalness and depth perception which is related to the sensation of immersion in the 3D visual scene [1]. The different technologies on which 3D displays are based on are different that we consider two issues: The impact of each technology on the observer viewing experience and which factors have to be taken into account to measure 3D video quality and how do they impact on visual perception? Subjective experiments must be conducted to understand these problems and other related problems in the design.

Taking into account these considerations, we limit our study to stereoscopic 3D videos. The subjective assessment is addressed within this context taking care of the heritage of 2D image and video quality assessment. We also use depth information to design our subjective metric for 3D quality assessment.

In this paper, subjective testing using human viewers is used to measure the mean opinion scores (MOS), 3D video satisfaction, user experience, quality of experience(QoE), preference, comfort, depth presences etc on the perceived quality of the reconstructed stereoscopic video based on the designed questionnaire used for the data collection. The perceptual attributes such as overall quality and depth perception are used to measure the response from human observers. The relationship between the perceived overall image quality and the perceived depth is also discussed in this paper. Finally, the perceived attributes of reconstructed stereoscopic video are predicted using different objective quality metric (OQM). The results help to answer important questions concerning the correlation between objective and subjective measurements of 3D video quality, and also concerning the best methods for measuring the quality of 3D video subjectively for error free and error prone channels.

2. SUBJECTIVE STUDIES

In [3], a wide variety of subjective tests to identify how depth information retrieval, crosstalk, depth representation and 3D compression impact on the 3D video quality, naturalness, viewing experience, presence and visual strain are all described. Some experiments on 3D video coding on stereopairs have highlighted that observers give a global score depending on the image/video of the stereopair having the lowest quality. In this paper however, the final viewer Difference Mean Opinion Scores (DMOS) depends on the video having the highest quality. Therefore, the perceived quality of a stereopair whose images have been distorted strictly depends on the applied distortions, which is related to the level of the human visual system (HVS) masking effects. Following the impact of 3D video coding, tests were carried out in order to identify the impact of eye dominance. In [4, 5, 6], no effect of eye dominance was noticed for the image quality evaluation. In [7], it was observed that eye dominance improves the performance of visual search tasks by aiding visual perception in binocular vision, and the eye dominance effect in 3D perception and coding was also analyzed.

In [8] a depth perception threshold model is designed. The impact of the depth information on the perceived 3D image quality is one of the main issues that have to be investigated. Recent studies show that, depth is not related to the perceived 3D effect. However other studies point out the importance of depth for quality perception. In [9], a blurring filter whose blur intensity depends on the depth of the area where it is applied is used to enhance the viewing experience. This was validated in [6] which show that blurring 3D images reduces discrepancy between responses of accommodation and convergence, so that blur increases viewer's experience. Also, methods which aim at enhancing the local depth information on objects are proposed where the algorithm directly impacts on the quality by taking into account depth information.

Research in the field of 3D video quality assessment relies on the availability of subjective scores, otherwise called Mean Opinion Scores (MOS), collected by means of experiments where groups of people are asked to rate the quality of 3D video sequences. In order to gather reliable and statistically significant data, subjective tests have to be carefully designed and performed, and require a relevant number of participants. These test are quite time consuming, however, subjective data are fundamental to test and compare the performance of the objective algorithms, i.e metrics, which try to predict human perception of 3D video quality by analyzing the 3D video streams.

Example of comparative studies of objective video quality metrics are those carried out by VQEG [1, 2], based on the results of two extensive campaigns of subjective tests which involved many laboratories. Unfortunately, the subjective results and the test material used to perform these studies have not been made public, thus VQEG

subjective results cannot be used by independent researchers for testing of more recent and future metrics. Also, many studies are available in literature, reporting results of subjective experiments, such as [3, 4] which investigate quality degradation in 3D video streaming applications, but none of these two provides access to the collected data for usage.

At the best of author's knowledge, the only publicly available databases of subjective results and related test material, in the field of visual assessment, are the LIVE database [12] for standard definition images, and the EPFL database for high resolution images [13]. The first contribution of a public database for video quality evaluation has been proposed by the authors in [13]. This database includes CIF video sequences coded with H.264/AVC reference software and impaired by simulating packet losses over an error-prone channel. The subjective data have been gathered at the premises of two academic institutions: Politecnico di Milano (PoliMI) – Italy, and Ecole Polytechnique Federale de Lausanne (EPFL) – Switzerland. In addition to subjective data, the database includes the original video contents and configuration files used to encode them, the original and corrupted H.264/AVC bitstreams, as well as the network simulator used to generate the test materials.

3. METHODOLOGY

We applied survey methodology for the elicitation of participants/user requirements. Surveys are commonly used as a method to perform subjective analysis of 3D video sequences based on the previously designed questionnaire. It helps us to identify needs, requirements, expectation, overall 3D video quality, viewing comfort, perception, preference and satisfaction of 3D users. The designed survey also helps to identify weakness of this new technology [14]. The designed survey contained 12 sections and background information of each participant. Prior to the use of the questionnaire, an expert evaluation and review was undertaken by Prof. Sadka to and other experts in the field of 3D video communication to improve its content validity. It should be noted that this research was aimed at elicitation of participant's view on the subjective assessment of 3D video. It is neither market research nor cross-cultural research since the samples were not representative of the whole population.

The subjective human trials based on the ITU-R recommendation 500, assessed the quality of compressed 3D videos. The assessors viewed the video clips and were asked to complete the questionnaire immediately afterwards and rate the videos based on answering the questionnaire. After the completion of the sessions, the mean opinion scores (MOS) for each test was calculated and all data was entered into SPSS for analysis.

Equipment used and viewing conditions

In the experiment, we displayed the images and their depth on a HP laptop. The screen had a resolution of 1152x 900 pixels, frequency of 60 Hz x 60 Hz and a measured size of 360 x 270mm. The optical path length is 320mm and the horizontal FOV is 0.8 rad. The monitor is at a viewing distance of 2m. Each subject had to judge all the image scenes. The 3D videos were viewed using stereoscopic shutter glasses. This display a full resolution to each eye. Participants were asked to sit in a particular place to see the 3D effects. The Laptop has 17 inches screen monitor which was used for the video quality scoring. Though a bigger screen size such as 32 or 42 inches would give a better depth perception, but we a limited to the experimental conditions. All the depth images shown are stored as disparity from the original images. Experiment was conducted in a room with minimum light level.

Databases used in the study

The datasets that we used for this experiment are those that have recently been made public by researchers at EPFL [17, 18], Henrich-Hertz- Institute [15] with resolution 720x576 pixels which is the resolution for standard definition TV. These sequences were encoded using 3D MDC-SIMI with QP =5. The original frame rates of these sequences is 25 fps (frames per second) and 250 frames i.e. 10 seconds long sequence. Datasets from Visual Media Research Group at Microsoft Research [16] with resolution 1024 x 768 and frame rate of 15 fps. They are 10 seconds long duration (150 frames). The EPFL 3D video database consists of stereoscopic images. These databases contain 9 scenes imaged at 6 camera distances. We use 4x6 images for training, 2x6 images for validation and 3x6 images for testing. Since we want to show that the proposed method is robust across contents, all possible combinations of the dataset was used to form the above mentioned training, validation and test sets.



(a) Break dancers

(b) Ballet



(c) Interview,

(d) Orbi

Participants

In order to gauge human perception of quality of experience as a function of depth, a total of 25 candidates with 18 males and 7 females were recruited within the Charville Lane estates, Middlesex, UK. Their ages varied from 15 to 50 with a mean age of 23 years. All were non experts based on ITU-R requirement of subjective video test, in that they were not directly involved in 3D video quality assessment or analysis in their normal work, and were not experienced video/image assessors. Their opinion on 3D video quality may differ from those of people accustomed to this technology. Participants were not aware of the purpose of the experiment. They all received a nominal payment of £5 each for participating and taking their time.

Protocol

Prior to the start of the experiment, participants received briefing and have done a trial test. This contains the four 3D videos viewed and rated in the same way as for those in the trial, but these practice trials were not included in the final experimental data analysis. As this was just for familiarity purpose.

The participants after completing the trial session started the main experiment individually. Participants were requested to be as accurate as possible in their judgment of each 3D video but not to spend too much time on each video, although no time limit was imposed. Afterwards they were asked to complete the questionnaire based on their judgment. Answers could not be changed once scores were recorded even before submission.

After the whole experiment and the completion of the questionnaire, participants were debriefed and given a chance to ask questions. The practical viewing of the 3D videos and the completion of the questionnaire took 10 minutes on average and the experiment lasted 3 hours including small breaks and the trial session.

Grading

For each experiment, the 3D videos were rated by participants on a sliding scale of:

- Excellent, Good, Fair, Don't Know, bad
- High impact, moderate impact, less impact, Don't know, No impact.
- Very important, Important, Less important, Don't know, Not important.
- Strongly Agree, Agree, Disagree, Don't know, Strongly disagree.

Participants were asked to assess the overall 3D video quality and overall 3D video Perception (0 to 100 values), column 7 (with heading Values) of Table 1 shows this. All the scales were based on ITU_R five point quality scales [1]. Subjective opinion scores obtained from the above studies were averaged across subjects to produce mean opinion scores (MOS) which are representative of the perceived quality of 3-D experience. Thus a total of 24 videos with associated MOS scores are available as part of the two datasets. The approach to no-reference QoE assessment involves extracting relevant features from these visual stimuli and regressing these features onto the MOS. In order to calibrate the process, we divide these datasets into various train test combinations, train our model and then test how well the learned features perform in assessing the QoE. Find the data set below in Table 1 and 2 respectively.

Table 1: Variable view of the data set

	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure
1	id	Numeric	2	0	Group id	None	None	8	Right	Scale
2	gender	Numeric	2	0	Gender	{1, MALES}	None	8	Right	Nominal
3	age	Numeric	2	0	Participant age	None	None	8	Right	Scale
4	videoqual	Numeric	2	0	3D video quality	{1, Poor}	None	8	Right	Ordinal
5	Comfort	Numeric	2	0	Viewing comfort	{1, Not importa	None	8	Right	Ordinal
6	depth	Numeric	2	0	perceived depth	{1, No impact	None	8	Right	Ordinal
7	presence	Numeric	2	0	feel presence	{1, Strongly di	None	8	Right	Nominal
8	problems	Numeric	2	0	problems associated with 3D viewing	{1, Strongly di	None	8	Right	Nominal
9	perceptions	Numeric	2	0	human perceptions of 3D	{1, No}	None	8	Right	Nominal
10	impact	Numeric	2	0	impact of eye dominance	{1, No impact	None	8	Right	Ordinal
11	users	Numeric	2	0	overall users view(needs, reqs, espec, new tech)	{1, Not importa	None	8	Right	Ordinal
12	qoe	Numeric	2	0	quality of experience	{1, Not importa	None	8	Right	Ordinal
13	preference	Numeric	2	0	3D or 2D	{1, 2D}	None	8	Right	Nominal
14	viewing	Numeric	8	0	type of viewing glasses prefer	{1, Anaglyphic}	None	8	Right	Nominal
15	satisfaction	Numeric	8	0	level of satisfaction	None	None	10	Right	Scale
16	agegp3	Numeric	5	0	Age divided into 3 groups	{1, 15-29}	None	10	Right	Ordinal
17	influence	Numeric	8	2	influence of encoding parameters on viewers experience	None	None	8	Right	Scale

Table 2: Data view of the data set

id	gender	age	videopal	Condit	depth	presence	problems	perception	impact	users	use	preference	viewing	satisfaction	agep3
1	1	15	4	1	4	1	1	1	5	1	5	2	3	50	3
2	2	16	4	1	1	1	5	1	1	2	3	3	1	40	3
3	3	30	5	2	5	2	4	1	4	2	2	2	2	60	2
4	4	16	3	3	5	5	4	1	4	3	3	3	1	30	1
5	5	20	1	3	5	4	3	1	4	5	2	4	2	70	1
6	6	40	2	4	4	3	3	2	4	3	4	3	2	70	1
7	7	50	4	1	3	3	4	2	1	4	5	3	2	80	1
8	8	35	4	1	1	4	4	2	1	3	4	4	3	55	2
9	9	36	4	5	2	4	5	2	3	5	3	3	2	60	3
10	10	38	3	5	4	4	5	2	3	2	4	3	3	80	3
11	11	38	3	5	4	4	1	1	5	4	3	4	3	80	3
12	12	41	3	5	4	5	1	2	1	4	2	2	1	85	1
13	13	42	3	5	1	5	1	2	5	3	4	3	1	70	1
14	14	43	2	5	4	5	1	1	5	2	4	3	2	85	3
15	15	44	2	4	4	5	2	2	5	4	3	3	2	80	2
16	16	45	2	4	1	5	2	1	4	4	5	3	2	55	2
17	17	27	5	4	5	5	2	2	1	5	5	3	2	60	2
18	18	20	3	3	5	5	2	1	2	5	2	3	2	70	2
19	19	23	4	3	4	5	4	2	3	4	5	2	2	80	2
20	20	17	4	2	4	5	4	1	1	3	5	2	3	85	1
21	21	25	4	2	4	2	4	1	1	4	3	3	3	55	1
22	22	19	4	5	3	1	4	1	3	3	4	4	3	40	1
23	23	27	5	5	3	2	4	2	3	1	3	3	3	45	1
24	24	28	4	5	3	2	4	2	4	3	5	1	3	50	1
25	25	29	4	4	3	2	4	2	3	4	5	2	2	80	1

4. MEAN OPINION SCORES AND CONFIDENCE INTERVAL

After screening, the results of the test campaign can be summarized by computing the mean opinion score (MOS) for each test condition as:

$$MOS_j = \frac{\sum_{i=1}^N m_{ij}}{N} \tag{1}$$

Where N is the number of subjects and m_{ij} is the score by subject i for the test condition j .

The relationship between the estimated mean values based on a sample of the population (i.e the subjects that took part in our experiment and completed the survey questionnaire) and the true mean values of the entire population is given by the confidence interval of estimated mean [17]. The $100 \times (1-\alpha)\%$ confidence interval (CI) for mean opinion scores were computed using the student t-distribution below:

$$CI_j = \left(\frac{t(1-\alpha)}{2}, N \right) \cdot \frac{\sigma_j}{\sqrt{N}} \tag{2}$$

Where

$$\frac{t(1-\alpha)}{2}, N$$

is the *t-value* corresponding to a two-tailed t-Student distribution with N-1 degree of freedom and a desired significance level α (equal to *1-deg of confidence*). N corresponds to the number of subjects, and σ_j is the standard deviation of a single test condition across subjects and or participants. The interpretation of a confidence interval is that if the same test is repeated for a large number of times, using each time a random sample of the population, and a confidence interval is constructed every time, then $100 \times (1-\alpha)\%$ of these intervals will contain the true value. We computed our confidence intervals for an α equal to 0.05, which corresponds to a degree of significance of 95%. The result from the study clearly shows that the experiments and or questionnaire have been properly designed, since the subjective rates uniformly span the entire range of quality levels. Also, the confidence intervals are reasonably small, thus prove that the effort required from each participant was appropriate and participants were consistent in the grading.

5. RESULTS & ANALYSIS

Fig. 2 shows the histogram plots for MOS of 3D video quality based on gender with grading on the upper right hand. Fig. 3 shows plot for MOS of human perception of 3D video. Table 3 shows the frequency table of the level of satisfaction and fig. 4 shows the pie chart distribution for the level of satisfaction of the participants with the 3D videos.

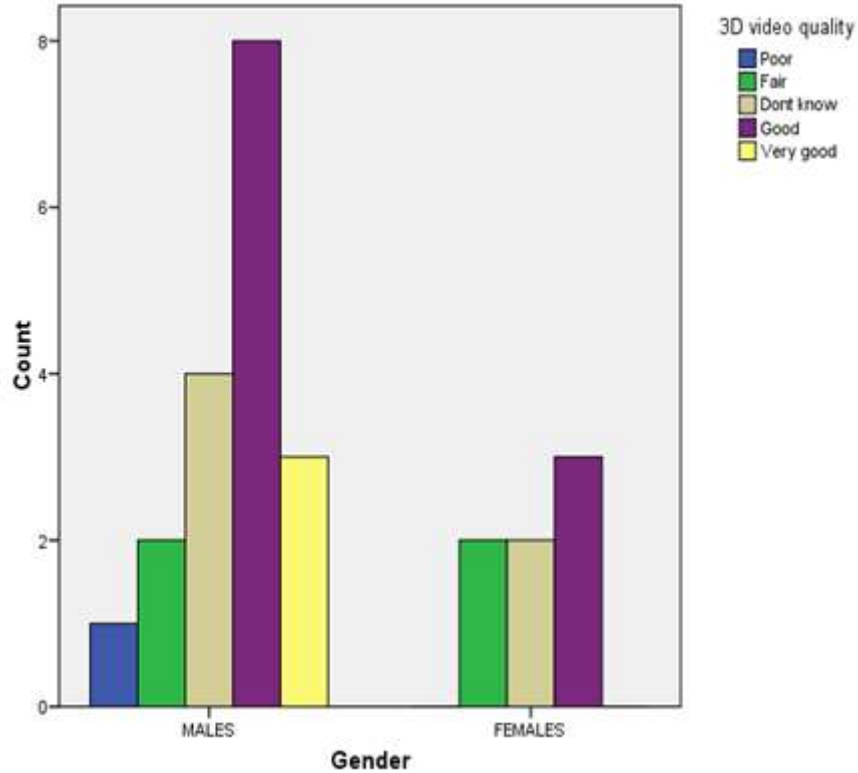


Figure 2: Histogram for Subjective assessment of 3D video quality

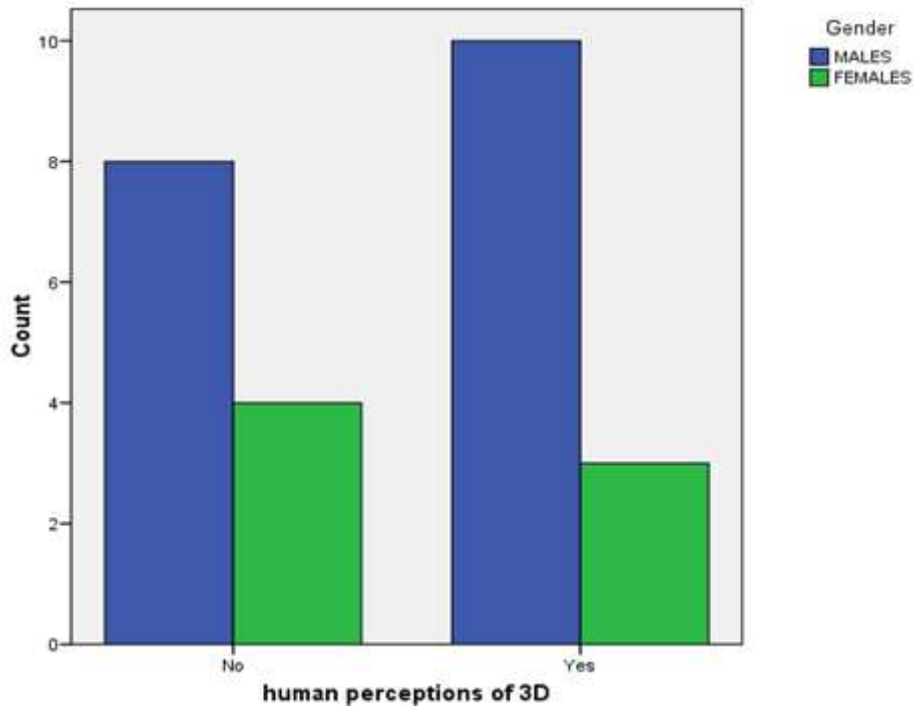


Figure 3: Human perception of 3D video

Table 3: Frequency distribution showing level of satisfaction

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	30	1	4.0	4.0	4.0
	40	2	8.0	8.0	12.0
	45	1	4.0	4.0	16.0
	50	2	8.0	8.0	24.0
	55	3	12.0	12.0	36.0
	60	3	12.0	12.0	48.0
	65	1	4.0	4.0	52.0
	70	4	16.0	16.0	68.0
	80	6	24.0	24.0	92.0
	85	2	8.0	8.0	100.0
Total		25	100.0	100.0	

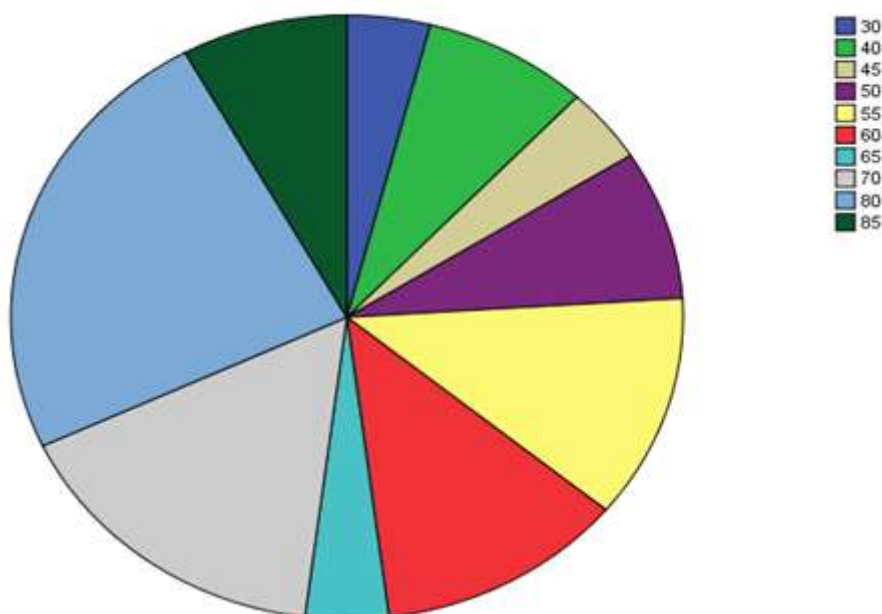


Figure 4: Pie chart showing level of satisfaction

In statistical analysis, a box plot is a graph that can be a valuable source of easy-to-interpret information about a sample of study. It gives information about our sample range, median, normality and skew of our distribution. In fig. 5 below, the box plot shows a box encased by two outer lines known as whiskers. The box represents the middle 50% of our sample, the remaining 50% of the sample is contained within the areas between the box and the whiskers with some exceptions called outliers. The bottom 25% of our MOS is represented by the space between the lower whiskers and the box, the middle 50% is within the box, and the remaining 25% contain between the box and the upper whisker. The location of the box within the whiskers gives us insight on the normality of the MOS of our distribution. The MOS may be positively or negatively skewed. For both male and

female participants, in our survey the results show that the box is shifted significantly to the high end, it is negatively skewed.

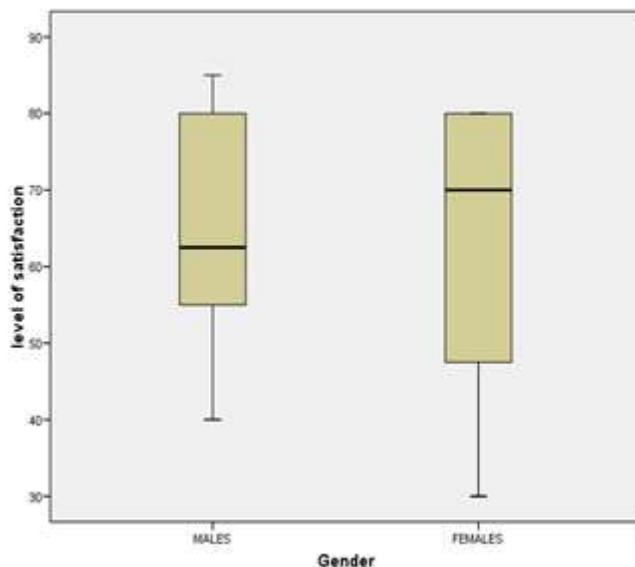


Figure 5: MOS values and 95% confidence interval obtained using Boxplot

The normal Q-Q plot graphically, compares the distribution of the expected MOS and observed MOS to the normal distribution. The straight line represents what our data would look like if it were perfectly normally distributed. Our actual observed data is represented by the dots circle plotted along this line. The closer the dot circles are to the line, the more normally distributed our data looks. Here in fig. 6 and 7, most of our points fall almost perfectly along the line. This is a good indicator that our MOS from both male and female participants is normally distributed.

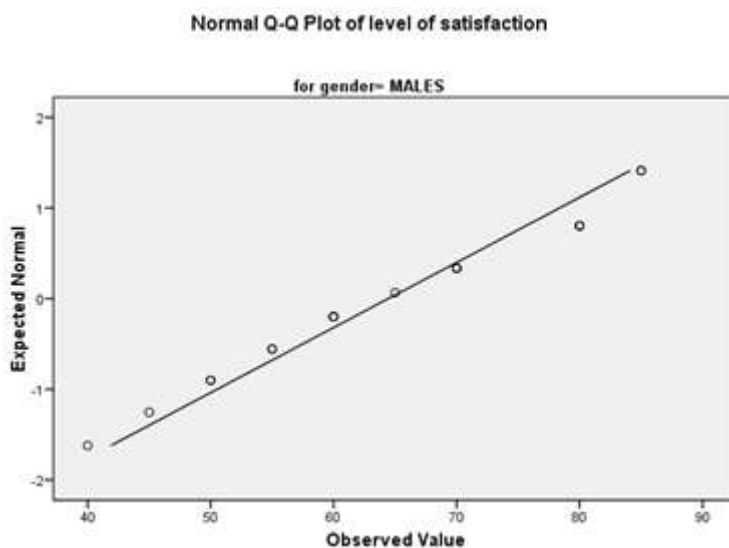


Figure 6: MOS values and 95% confidence interval obtained

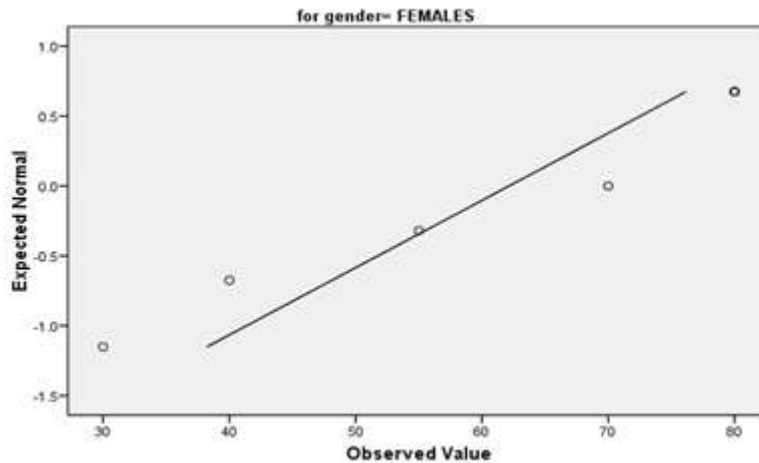


Figure 7: MOS values and 95% confidence interval obtained

6. CONCLUSION

We proposed a subjective quality assessment model to evaluate human perception and quality of experience (QoE) for 3D videos. We evaluated the proposed approach on publicly available datasets for 3D quality. The statistical features seem to perform well in terms of correlation with human perception across contents. The histogram, mean, median and standard deviation of the scores correlate well with the mean opinion scores (MOS) across these videos. It is clear that the proposed approach performs well in terms of correlation with subjective human perception of 3D videos.

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REFERENCES

- [1] Hewage, C.T. et al., "Quality Evaluation of Color Plus Depth Map-Based Stereoscopic Video", IEEE Journal of Selected Topics in Signal Processing, vol. 3, issue 2, pp. 304-318. April 2009.
- [2] Video Quality Expert Group (VQEG), "Final Report From the Video Quality Expert Group on the Validation of Objective Models of Video Quality Assessment, Phase II", 2003 [online]. Available: <http://www.vqeg.org>.
- [3] S. Khalil, Yonis, "Objective Video Quality Assessment using the 3D Dual-Tree Complex Wavelet Transform", Msc Thesis, department of Systems and Computer Engineering, Carleton University, 2009.
- [4] F. Okuyama, "Evaluation of stereoscopic display with visual function and interview", In proceedings of the SPIE 3639, pp. 28-35, 1999.
- [5] P. Seuntjens, "Visual experience of 3D TV", PhD. Thesis, Eindhoven University, Eindhoven, The Netherland, 2006.
- [6] H. Kalva, L. Christodoulou, and B. Furht, "Evaluation of 3D TV service using asymmetric view coding based on MPEG-2", in Proceedings of 3DTV-Conference, Kos Island, , pp. 1-4, Greece, May 2007.
- [7] A. P. Mapp, H. Ono, and R. Berbeito, "What does dominant eye dominate? A brief and somewhat contentious review", Perception and Psychophysics, vol. 65, no. 2, pp. 310-317, 2003.
- [8] E. Shneur and S. Hoshstein, "Effects of eye dominance in visual perception", in Proceedings of the Vision International Congress, vol. 1282 of International Congress Series, pp. 719-723, London, UK, April 2005.
- [9] N. Holliman, B. Froner, and S. Liversedge, "An application driven comparison of depth perception on desktop 3D displays", in Stereoscopic Displays and Virtual Reality Systems XIV, vol. 6490 of proceedings of SPIE, pp. 1-22, San Jose, Calif, USA, January 2007.
- [10] A. Berthold, "The influence of blur on the perceived quality and sensation of depth of 2D and stereo images", Tech. rep. ATR Human Information Processing Research Laboratories", 1997.
- [11] P. Seuntjens, L. Meesters, and W. IJsselsteijn, "Perceived quality of compressed stereoscopic images: Effects of symmetric and asymmetric JPEG coding and camera separation", ACM Trans. Appl. Perception (TAP), vol. 3, pp. 95-109, 2006.

- [12] H. A. Karim, A. H. Sadka, and A. M. Kondo, “Reduced Resolution Depth Compression for 3D video over wireless networks”, In Proc. IEE 2nd Int. Workshop Signal Process. Wireless Comm, London, UK, pp. 96-99, June 2004.
- [13] H. R. Sheikh, Z. Wang, L. Cormack, and A. C. Bovik, “Live image quality assessment database release 2”, Available online at: <http://live.ece.utexas.edu/research/quality/subjective.htm> .
- [14] F. D. Simone, M. Naccari, M. Tagliasacchi, F. Dufaux, S. Tubaro, and T. Ebrahimi, “Subjective assessment of H.264/AVC video sequences transmitted over a noisy channel”, in First International Workshop on Quality of Multimedia Experience, San Diego, CA, USA, July 2009.
- [15] A. Mittal, K. Moorthy, J. Ghosh and A. Bovik, “Algorithmic Assessment of 3D Quality of Experience for Images and Videos”, Proceedings of the 14th IEEE Digital Signal Processing & Signal Processing Education Workshop, Enchantment Resort, Sedona, Arizona, USA. Jan 4-7, 2011.
- [16] S. Jumisko, M. Weitzel, D. Strohmeier, “Designing for User Experience: What to Expect from Mobile 3D TV and Video?”, Proceeding of the 1st international conference on Designing interactive user experiences for TV and video, New York, NY, USA ©2008.
- [17] Wiegand, T. & Sullivan, G.J., 2007. The H.264/AVC Video Coding Standard. IEEE Signal Processing Magazine, (August 1999), 148-153.
- [18] C.L. Zitnick, S.B. Kang, M. Uyttendaele, S. Winder, and R. Szeliski, “High-quality video view interpolation using a layered representation,” ACM SIGGRAPH and ACM Trans. on Graphics, Los Angeles, CA, Aug. 2004, pp. 600-608.
- [19] F. D. Simone, M. Tagliasacchi, M. Naccir, S. Tubaro, T. Ebrahim, “A H.264/AVC Video Database for the Evaluation of Quality Metrics”, 35th International Conference on Acoustics, Speech, and Signal Processing (ICASSP 2010), Dallas, Texas, U.S.A, March 14–19, 2010.