PerceptualQualityAssessmentof Joint Rate Allocation in Scalable Stereo Video Coding

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Received: 31.01.2017 Accepted: 24.03.2017

Abstract- Rate-distortion optimized layer selection is crucial for rate adaptation in scalable stereo video coding in order to achieve a higher degree of perceptual quality for a given rate. Quality Layers Optimization (QLO) and Trellis-based Optimization (TBO) are joint rate allocation methods in Scalable Multiview Video Coding (SMVC). But TBO is simpler alternative for real-time applications with one GoP delay. The binocular suppression theory leads the research towards asymmetric stereo video coding for 3D rate scaling. In scalable stereo video coding, it is possible to allocate the total bitrate between the two views symmetrically or asymmetrically through adaptive quality enhancement layer extraction. The contribution of the paper is two-fold: First, we propose asymmetric versions of the TBO algorithm. Second, subjective quality evaluation of TBO (symmetric and asymmetric) and QLO extraction methods are performed by using Single Stimulus Multi Media (SSMM) version of Subjective Evaluation of Stereo VIdeo Quality (SESVIQ). Test results demonstrate that perceptual quality performance of symmetric TBO method is very similar to that of QLO in all cases. Besides, Symmetric TBO rate allocation is preferable for moderate bitrates. However, performance of asymmetric TBO extraction is superior to symmetric TBO extraction for low bitrates.

Keywords 3D video quality assessment, SESVIQ, SMVC.

1. Introduction

For efficient 3DTV transport over the Internet, visual distortion-optimized rate adaptation inevitably requires the use of packet-based fidelity scalability. The concept of Quality Layers Optimization (QLO) is developed within the Scalable Video Coding (SVC) standard to support rate-distortion optimized rate adaptation of a previously encoded video [1]. We have extended QLO to stereo and multi-view scalable video to transport 3D video content efficiently in [2] and [3], respectively. Nonetheless, the QLO method cannot be used in such applications that require real-time encoding, because the whole stereo video sequence must be available for the process of priority determination. An on-line Trellis-based Optimization (TBO) in joint rate adaptation of left and right views is presented in [4] and [5] for scalable stereo video coding with only a delay of one GoP. For each GoP the number of Medium-Grain Fidelity Scalability (MGS) layers to be extracted is determined in rate-distortion optimized way assuming that the encoder/extractor should be aware of changing bandwidth conditions of the best-effort network.

MGS is a normative element of SVC, and provides fragmentation of quality enhancement layer through making groups of the transform coefficients in a frequency-selective manner [6]. After dropping of fragments during adaptation, spreading coefficients into fragments turns out considerable degradation in fidelity. By using peak signal-to-noise ratio (PSNR) metric, test results demonstrate that performance of the TBO on-line method is quite similar to that of QLO which requires the whole stereo sequence for rate-distortion optimization.

Due to the fact that perceptual quality is more realistic than PSNR, the double-stimulus continuous-quality scale (DSCQS) method is generally employed to assess the Human Visual System (HVS) response to stereo video sequences at different resolutions or qualities, which is described in ITU-R Recommendation BT.500-11[7]. However, Single Stimulus Multi Media (SSMM) method is preferred in [8] to prove superiority of Multiview Video Coding (MVC) when compared to the MPEG anchors. The SSMM method is modified from Single Stimulus Impairment Scale (SSIS) of ITU-R Recommendation BT.500-11. Another study using the SSIS method is [9] in which they stated that mixed-quality and symmetric versions of full-resolution gave similar results in terms of perceptual quality at the same bitrates.

On the other hand, presentation of stimuli is consecutive, and rating is performed independently in Absolute Category Rating (ACR) method of ITU-R Recommendation P.910 [10]. Voting non-sequentially is an important factor that enables to design a test in which each subject runs the test with a custom order of presentation. Therefore, it helps to reduce the contextual effect which may occur due to random order of presentation of the two videos in a pair, in which one has poor, the other has good quality. Scores assigned to the pair tends to be lower when the poor one is presented first than the good one presented first. We developed novel software in [11] for interactive multi stimuli method where the distorted video may be compared against the other distorted videos and demonstrated effectiveness of the new Subjective Evaluation of Stereo VIdeo Quality (SESVIQ) method in [12]. In this work SSMM version of SESVIQ is developed in order to assess perceptual quality.

According to binocular suppression theory of stereo view, the HVS can tolerate absence of high frequency information in one of the views; thus, the two views can be represented at unequal resolutions or bitrates. Recently, finding methods for asymmetric stereo video coding and evaluation of the perceptual quality has been a new research area including the works of Meegan, et. al. [13], Ozbek and Tekalp [14], Fehn, et. al. [15], and Saygılı, et. al. [16].To the best of our knowledge, there is no study in the literature searching asymmetry in joint rate allocation of stereo video coding. Therefore, in this work we extend the TBO algorithm to asymmetric versions and evaluate perceptual qualities of all proposed algorithms. Performance evaluation is done by a novel subjective quality assessment method which is SSMM version of SESVIQ. Thepaper is organized as follows: Section 2 gives the proposed methods for joint MGS allocation in detail. Section 3 explains test method and setup used to perform visual quality tests. Section 4 presents test results and their discussion. Conclusions are drawn in Section 5.

2. Joint Rate Allocation

Previously, Ozbek and Tekalp [17] have proposed and implemented SMVC (Scalable Multiview Video Coding) as an extension of the JSVM (Joint Scalable Video Model) JVT-Q202 [18] by sequential interleaving of the View 0 (V0) pictures and View 1 (V1) pictures in each GoP. The prediction structure supports adaptive temporal or disparity compensated prediction. V0, the reference view, is only predicted temporally while each frame in V1 employs temporal or disparity prediction from its own past and future frames and the corresponding frame from V0. In order to make possible random view access at some given temporal resolution, key frames in V1 i.e. the first frame of each GoP use only inter-view prediction. In scalable stereo video coding the number of temporal scalability levels is decreased by one and the effective GoP size is halved compared to the original JSVM, whereas the spatial and fidelity scalability features remain the same. QLO and TBO are proposed to extend SMVC to joint MGS layer allocation of V0 and V1 symmetrically under a given rate constraint.

2.1. Quality Layers Optimization (QLO)

In the Quality Layers method of [1] the encoded stream is organized as virtual layers, and according to the priority values Network Abstraction Layer Units (NALUs) are decided whether if they should be dropped or not for adaptation. The method also presents Quality Layers Optimization (QLO) to extract layers for a given bitrate. Optimization is done as a post-processing such that each frame is decoded as many times as the number of quality increments of that frame. Therefore, the QLO method is not suitable for on-line applications like videoconferencing. The process includes four steps: 1) Rate and distortion values are first calculated for every frame that is encoded using base representation and each quality increments. 2) Then the R-D curve is established by using rate distortion values for all frames. 3) The R-D points on the convex hull are sorted according to slope values. 4) From this slope the priority_id value is calculated at the end.We have previously extended the QLO principle to the case of SMVC for 2 and 8 views in [2] and [3], respectively. The JSVM uses a hierarchical temporal prediction within frames, so dependency constraints may be represented in a hierarchical manner. From the fact that the amount of picture distortion depends on the amount of distortion of the other picture/s from which the picture is predicted, we changed the list of dependants for each frame according to prediction structures, i.e. temporal and inter-view, in SMVC. At the first place, odd numbered frames, namely the last temporal level, have no dependant in single view encoding. However, this is not the case for stereoscopic encoding since they belong to the second view. Secondly, the list of dependants of a V0 frame must have its neighbor (incremented picture number) frame, because of disparity compensated prediction between the two views

2.2. Trellis Based Optimization (TBO)

Trellis-based Optimization (TBO) is a simpler alternative of the QLO method running for each GoP on the extractor software. Nevertheless, it is also easy to adopt the algorithm at the encoder side. Furthermore, the TBO method allows symmetric and asymmetric MGS layer allocation, as well. The principle of the TBO algorithm of Ozbek [5] relies on structuring a trellis with the given constraints to include every possible allocation at each stage. As to nature of dependency hierarchy in SMVC, when the trellis grows, order of temporal layers in the stages increases. Notice that, the base quality is as the initial point, which has V0-MGS=0, and V1-MGS=0. Each stage in the trellis implicitly corresponds to the related temporal level. Under a given rate constraint, for each GoP a trellis is constructed as linking the initial point to the points at the final stage having all possible dependencies within a GoP. Every stage corresponds to a temporal level of which numbers of MGS layers to be determined for the views. Each point is depicted by a pair including total stereo bits of quality increments until the stage, and resultant stereo PSNR for that GoP. In order to build branches, the point satisfying the rate constraint and giving the highest PSNR is selected at the current stage and then linked to the point selected in the previous stage. So, it turns out a resource allocation problem to determine the number of MGS layers should be allocated for each frame in each view, where there are dependencies both in temporal levels and the two views. Thus, we propose to use a trellis-based optimization to solve the problem which states that maximize quality of each GoP given by Eq. (1) in the stereo bitstream,

$$Q_{GoP} = \frac{PSNR_{GoP}^{left} + PSNR_{GoP}^{right}}{2} \qquad (1)$$

$$\text{Subject to} \sum_{TL=0}^{N} R_{TL} \leq R \qquad (2)$$

where Q_{GoP} indicates the average PSNR of left and right views and RTL is total rate of base and enhancements for the temporal level TL and R is the given rate constraint.All rate and PSNR values are calculated over one GoP. We propose three TBO extraction algorithms in Figure 1 such as symmetric, asymmetric and mild asymmetric, respectively. Calculation of RTL and the rate of possible points depend on the extraction algorithm as explained in the following sections.

2.2.1.Symmetric TBO

It is called as symmetric TBO since MGS layers are evenly distributed among the views similar to QLO joint optimization. The algorithm allocates MGS slots symmetrically between V0 and V1 stage by stage. In the symmetric TBO algorithm, a joint trellis is built that links the initial point to the points in the final stage having all possible dependencies within a GoP. The initial point, labeled as b_{-1}, that corresponds to base quality, meaning no MGS layer, video at full temporal resolution. Each point is represented by a pair, such that total stereo bits of all quality increments up to that stage, labeled as b_k, and resultant stereo PSNR for the GoP (Q_{GoP}). The rate of possible points in a stage is given by Eq. (3),

<u>Symmetric TBO Algorithm:</u> start with the initial point for all Trellis stages k for all MGS points l evaluate the rate b_k for all branches l satisfying condition Eq. (2) select the path giving the highest Q_{GoP} move to the next stage k <u>Mild Asymmetric TBO Algorithm:</u> start with the initial point do Algorithm Asymmetric TBO for the first half of Trellis stages do Algorithm Asymmetric TBO for the second half of Trellis stages	<u>Asymmetric TBO Algorithm:</u> start with the initial point for all Trellis stages k of V0 for all MGS points l evaluate the rate b_k for all branches l satisfying condition Eq. (2) select the path giving the highest Q_{GoP} move to the next stage k for all Trellis stages k of V1 for all MGS points l evaluate the rate c_k for all braches satisfying condition Eq. (2) select the path giving the highest Q_{GoP} move to the next stage k

Fig. 1. Symmetric, Asymmetric and Mild Asymmetric TBO layer extraction algorithms

$$\begin{aligned} b_{-1}[0][0] &= R^{left}{}_{Base} + R^{right}{}_{Base} \\ b_k[l][m] &= b_{k-1}[0][0] + R^{left}{}_{Enh}(TL=k, MGS=l) + R^{right}{}_{Enh}(TL=k, MGS=m), \\ & 0 \leq k < N \\ & 1 \leq l, m \leq M \end{aligned} \qquad (3)$$

where N and M show the number of temporal levels and MGS layers, respectively. R_{Base} is the rate of the initial point in the trellis diagram and R_{Enh} is the rate of enhancement quality points on trellis stages showing MGS quality increments for each temporal level.

2.2.2.Asymmetric TBO

However, in the Asymmetric TBO algorithm firstly all possible MGS layers of all temporal levels are allocated to V0 and then the remaining possible MGS layers are allocated to V1. In the asymmetric TBO algorithm, a disjoint trellis is built in which the two trellises are cascaded by first linking the initial point to the points in the final stage having all possible dependencies in the trellis of V0 and then linking the first trellis to the points in the final stage of the trellis of V1. The initial point, labeled as b_{-1}, corresponds to base quality layer video at full temporal resolution. Each point on the first trellis is represented by a pair, such that total stereo bits of all quality increments up to that stage of V0, labeled as b_k, and resultant stereo PSNR for the GoP (Q_{GoP}). Each point on the second trellis is represented by a pair, such that total stereo bits of all quality increments up to that stage of V1, labeled as c_k, and resultant stereo PSNR for the GoP (Q_{GoP}). The rate of possible points in a stage of V0 is given by Eq. (4)

$$\begin{aligned} &b_{-1}[0] = R^{left}{}_{Base} + R^{right}{}_{Base} \\ &b_k[l] = b_{k-1}[0] + R^{left}{}_{Enh}(TL = k, MGS = l), \\ &1 \le l \le M, 1 \le l \le M \end{aligned} \tag{4}$$

The rate of possible points in a stage of V1 is given by Eq. (5),

$$\begin{aligned} &c_{-1}[0] = b_N[M] \\ &c_k[l] = c_{k-1}[0] + R^{right}{}_{Enh}(TL = k, MGS = l), \\ &0 \le k < N, 1 \le l \le M \end{aligned} \tag{5}$$

2.2.3.Mild Symmetric TBO

In the Mild Asymmetric TBO algorithm, a semi-disjoint trellis is built by interleaving a half of V0 stages with the ones of V1. The algorithm firstly allocates MGS slots to the first half of V0 stages then to the first half of V1 stages, secondly the remaining MGS slots are allocated to the second half of V0 stages then to the second half of V1 stages. Namely, the Mild Asymmetric TBO algorithm is a version of the Asymmetric TBO algorithm differs with the interval $0 \le k < N/2$ and $N/2 \le k < N$ in first and second runs, respectively.

3. Perceptual Quality Assessment

We adopted the SSMM method for subjective quality assessment, of which efficiency and reliability has proven in former tests performed by MPEG. Parvez, et. al. [19] also conducted subjective tests using Single Stimulus Continuous Quality Evaluation (SSCQE) method in which a test video sequence is presented alone without being compared to the unimpaired reference. We believed that paired comparison is not suitable for comparison of MVC artifacts since decoded video is very different than the original video in terms of perceptual quality.

3.1. Visual Test Setup

The visual tests were conducted using stereo projection display system in 3DLAB; a screenshot and detailed explanation can be found in [12]. The system includes a silver-covered dielectric screen, a pair of Sharp DLP projectors with polarized filter glasses and a PC driving the two projectors. One of the polarization filters applies linear clockwise direction for right eye and the other one applies counter clockwise direction for left eye. The PC is prepared as to have a 2048x768 virtual desktop so that each projector displays a half of the desktop on the screen on top of each other. The size of silver screen is about 100 inches which is adjusted to the dark room size. Every subject watches from almost 3 meters distance compliant to viewing conditions of ITU-R Recommendation BT.500-11.

3.2. Subjective Testing Procedure

We previously developed an interactive method for perceptual quality evaluation of asymmetrically encoded 3D videos in [11]. In the SESVIQ method, the observer can play and then vote any algorithm in custom order while evaluating the current sequence. Also he can replay and rescore. All algorithms of the current sequence must be scored in order to pass the next sequence. The algorithm access is randomized from one sequence to another in order to avoid the observers scoring similarly according to label of buttons.

In this work, we present SSMM version of SESVIQ test method of which a screenshot is given in Figure 2. The quality evaluation is performed sequence after sequence. We used three stereo test sequences and four algorithms at our test setup. Since the impaired sequences can be directly compared among themselves the SSCQE's misjudgement issue is reduced. Besides, the method is an interactive evaluation approach, and there is no sequential presentation of stimulus as the case in the SSCQE method. Therefore, possible errors due to lack of concentration are reduced and more consistent scores can be achieved. However, each algorithm can be re-played/scored as many times as the assessor wishes but that is highly time-consuming.

Differently, in SSMM version of SESVIQ, the original of the sequence, as hidden or explicit anchor is not included in the evaluation. The SSMM methodology requires comparison among coded versions of media and excludes the reference video. That is why there is no button for the unimpaired reference in Figure 2. To vote the subject moves a slider on the 0 - 10 impairment scale correspondingly to 5 quality items divided linearly such that bad, poor, fair, good, excellent. The subjects are asked for to vote the test stimulus examining naturalness, perceived depth, and sharpness.

Before subjective tests, the following tests below were carried out for all observers: Randot test, far visual acuity, and contrast sensitivity. Anchoring and training session is held in order to make familiar the participants to the test contents, including ranges of quality and evaluation process by means of introducing the SESVIQ program.

Fig. 2. .GUI of SSMM SESVIQ: Soccer2 sequence is under perceptual quality assessment (4 algorithms to be evaluated)

4. Test Results

For our tests, we selected three stereo sequences from the database of Mobile3DTV Project [20]: Flowerpot, Soccer2, and, Balloons, which are at 4SIF (720x480) resolution and 30 fps and 240 frames long. The encoding setup is as one MGS layer upon base layer. MGS layer has three fragments with (3,3,10) scan positions. We examined three different bitrate ranges and selected quantization parameter (QP) values as (28,34) for moderate bitrates, (22,28) for high quality bitrates, and (34,40) for low quality bitrates. In the QP pair, the first value is for the base quality layer and the second value is for the enhancement quality layer, respectively, with fixed quantization in both views for all temporal levels. All extraction points are selected at full temporal resolution, no temporal scaling is selected during layer extraction. Table 1 gives selected test points at moderate bitrates for QLO and TBO (symmetric, asymmetric and mild asymmetric) algorithms. Every test point represents the bitrate of substream extracted from SMVC bitstream (total of left and right views in Kbps) and the stereo PSNR (average of left and right views in dB). Table 2 presents selected test points for QP=(22,28) and QP=(34,40) cases which are higher and lower quality encoding options, respectively. Note that, since it is not possible to truncate a single MGS unit into bytes as in FGS (Fine Granular Scalability) the resultant bitrates cannot be matched after layer extraction for different algorithms when the same rate constraint is given.

Table 1. Stereo bitrate and average PSNR values for the two test points in moderate bitrate case (QP=28/34)

		QLO	Symmetric TBO	Asymmetric TBO	Mild Asymmetric TBO
Flower.	Rate-P1	1264	1289	1292	1293
	Psnr-P1	32.93	32.78	32.90	32.90
	Rate-P2	2436	2412	2405	2409
	Psnr-P2	34.87	34.83	34.39	34.82
Soccer2	Rate-P1	1465	1442	1441	1443
	Psnr-P1	35.56	35.48	35.21	35.24
	Rate-P2	2414	2342	2417	2369
	Psnr-P2	36.69	36.62	36.46	36.65
Balloons	Rate-P1	1752	1756	1768	1768
	Psnr-P1	34.63	34.48	34.51	34.51
	Rate-P2	3682	3578	3639	3628
	Psnr-P2	37.00	36.88	36.87	36.91

Table 2. Stereo bitrate and average PSNR values for test points in high and low quality bitrate cases (QP=22/28 and QP=34/40)

		QLO	Symmetric TBO	Asymmetric TBO	Mild Asymmetric TBO
Flower.	Rate-high	8292	7857	8259	8260
	Psnr-high	39.14	39.06	39.09	39.13
	Rate-low	1189	1145	1185	1188
	Psnr-low	31.26	31.19	31.05	31.24
Soccer2	Rate-high	4618	4618	4608	4605
	Psnr-high	39.24	39.30	38.91	39.27
	Rate-low	870	842	861	865
	Psnr-low	32.88	32.77	32.82	32.82
Balloons	Rate-high	6826	6513	6724	6685
	Psnr-high	40.29	40.37	40.21	40.47
	Rate-low	1582	1486	1562	1562
	Psnr-low	32.78	32.61	32.60	32.73

4.1. Comparison of Symmetric TBO and QLO Methods

Figure 3 shows objective R-D performance comparison of Symmetric TBO and QLO methods for 4SIF videos. It is obvious from the figure that when TBO extraction is used the R-D curve has natural shape and it is still concave, and the most important the TBO curves are quite close to the QLO curves. As we previously reported for QSIF videos, the TBO method provides a finer granularity in rate extraction points and reconstructed points at higher quality because of the GoP-based extraction is done in a rate-distortion optimized way. However, we have never examined before the comparison of perceived quality.

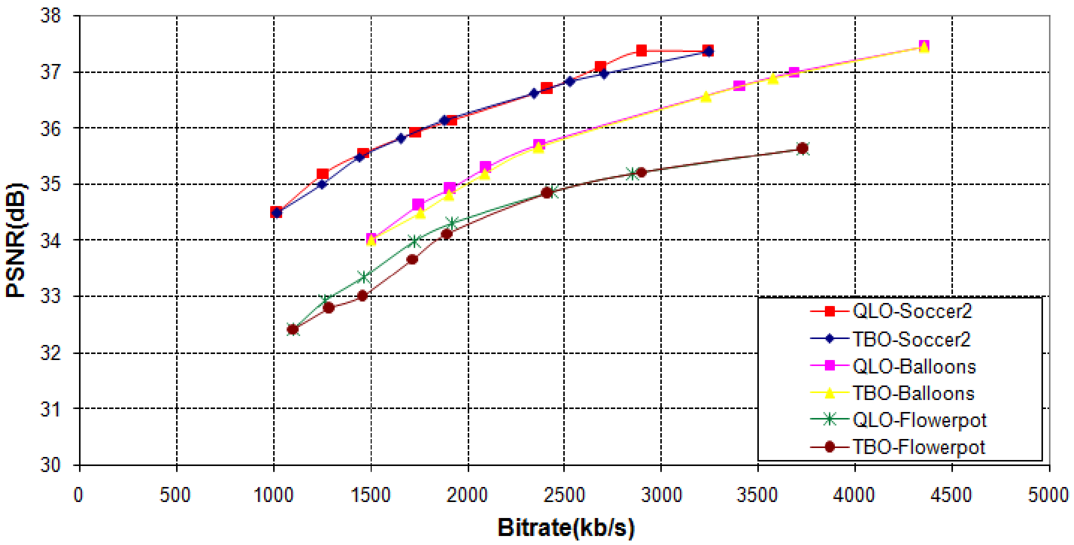


Fig. 3. Objective coding results for Flowerpot, Soccer2, and Balloons sequences in moderate bitrate case (QP=28/34)

Table 3 and Figure 4 show MOS values with 95% confidence interval (CI) of mean for subjective test results, totally 12 selected test points of three videos and four qualities under testing (Table 1). 10 male and 6 female non-expert assessors participated in visual tests at 3DLAB. The results clearly present that perceptual quality of the TBO algorithm is similar to that of the

QLO algorithm. ANOVA (ANalysis Of VAriance) results in Figure 5 support that QLO-P1/P2 and TBO-P1/P2 groups have no significantly different means for Flowerpot and Balloons. In case of Soccer2 sequence, the result is not obvious because of selected test points cannot be discriminated as lower or higher perceptual quality.

Table 3. The MOS values with 95% CI of mean of Symmetric TBO vs. QLO comparison

	Flowerpot	Soccer2	Balloons
QLO-P1	6.3± 0.4	6.3± 0.2	6.1± 0.3
Symmetric TBO-P1	6.4± 0.2	6.5± 0.2	5.7± 0.4
QLO-P2	7.8± 0.3	6.6± 0.3	7.3± 0.5
Symmetric TBO-P2	7.5± 0.5	7.0± 0.2	6.9± 0.4

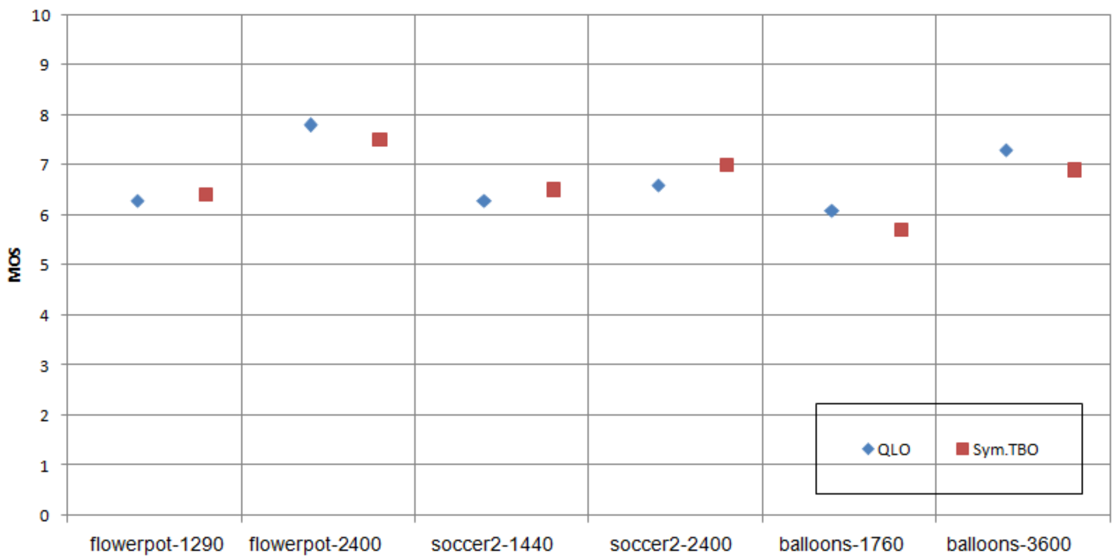
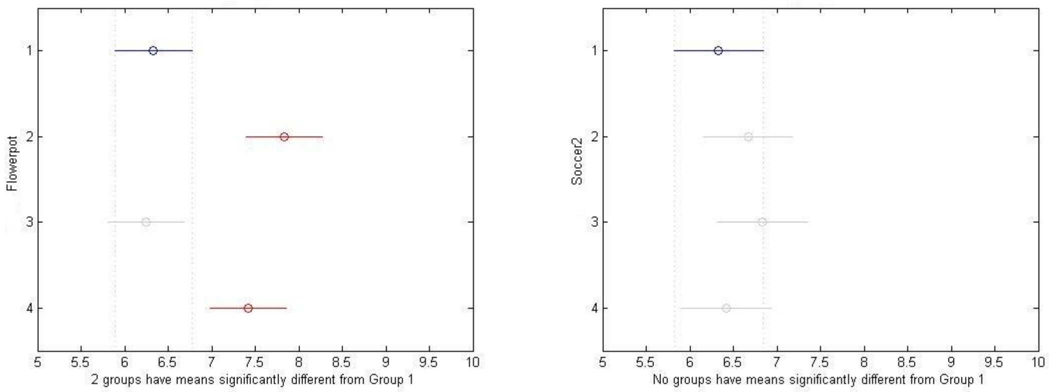


Fig. 4. Subjective test results of Symmetric TBO vs. QLO comparison



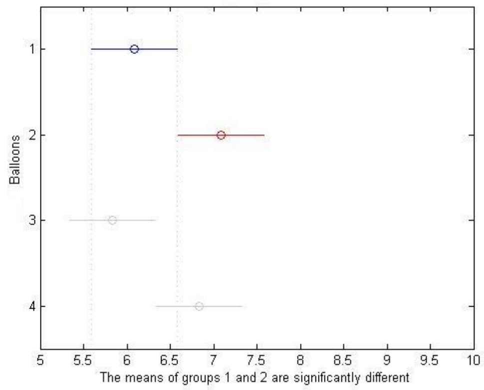


Fig. 5.ANOVA results of Flowerpot, Soccer2 and Balloons sequences (1-QLO P1, 2-QLO P2, 3-symmetric TBO P1, 4-symmetric TBO P2)

4.2. Comparison of Symmetric and Asymmetric TBO Methods

Table 4 gives single view PSNR values of V0 and V1 for the selected bitrates of the proposed TBO algorithms in QP=(28,34) case while single view PSNR values for QP=(22,28) and QP=(34,40) cases are given in Table 5. PSNR values of V0 have an increase trend from Symmetric TBO to Mild Asymmetric TBO and from Mild Asymmetric TBO to Asymmetric TBO whereas it is vice versa for PSNR values of V1.The QL and three proposed TBO extraction methods were subjectively rated by the 3 experts working in the project via the SESVIQ test program.

CASE #1: We observed for moderate bitrates that perceptual quality is from best to worst as follows: 1) Symmetric TBO ≈ QL, 2) Mild Asymmetric TBO, 3) Asymmetric TBO.

CASE #2: We observed for low bitrates that perceptual quality is from best to worst as follows:

1. Asymmetric TBO for Flowerpot and Soccer2, while Mild Asymmetric TBO for Balloons
2. Mild Asymmetric TBO for Flowerpot and Soccer2, while Asymmetric TBO for Balloons
3. Symmetric TBO ≈ QL.

CASE #3: We observed that perceptual quality is similar for high bitrates:

Asymmetric TBO ≈ Mild Asymmetric TBO ≈ Symmetric TBO ≈ QL

Table 4.V0/V1 PSNR values for Symmetric vs. Asymmetric TBO test points in QP=28/34

		Symmetric TBO	Asym. TBO	Mild Asym. TBO
Flower.	V0 Psnr-P1	33.41	33.83	33.83
	V1 Psnr-P1	32.14	31.96	31.97
	V0 Psnr-P2	35.31	35.81	35.36
	V1 Psnr-P2	34.35	32.96	34.28
Soccer2	V0 Psnr-P1	35.53	36.00	35.97
	V1 Psnr-P1	35.43	34.41	34.51
	V0 Psnr-P2	36.52	37.22	36.87
	V1 Psnr-P2	36.72	35.69	36.43
Balloons	V0 Psnr-P1	34.90	35.33	35.32
	V1 Psnr-P1	34.06	33.69	33.70
	V0 Psnr-P2	37.35	37.86	37.65
	V1 Psnr-P2	36.40	35.87	36.17

Table 5.V0/V1 PSNR values for high and low quality bitrate cases (QP=22/28, QP=34/40)

		QLO	Symmetric TBO	Asym. TBO	Mild Asym. TBO
Flowerpot	V0 Psnr-high	39.92	39.30	39.92	39.89
	V1 Psnr-high	38.35	38.82	38.25	38.37
	V0 Psnr-low	31.92	31.71	32.02	31.82
	V1 Psnr-low	30.60	30.67	30.08	30.66
Soccer2	V0 Psnr-high	39.33	38.94	39.78	39.16
	V1 Psnr-high	39.15	39.66	38.03	39.38
	V0 Psnr-low	33.50	33.13	33.58	33.23
	V1 Psnr-low	32.26	32.40	32.05	32.41
Balloons	V0 Psnr-high	40.62	40.76	42.18	41.23
	V1 Psnr-high	39.96	39.97	38.23	39.71
	V0 Psnr-low	33.34	32.94	33.40	33.30
	V1 Psnr-low	32.21	32.27	31.79	32.15

Acknowledgements

3DLAB was prepared with the support of project 109E145 by The Scientific and Technological Council of Turkey (TUBITAK). The author thanks to Gizem Ertan and Oktay Karakuş for their help in Symmetric TBO vs. QLO comparison tests.

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