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Multifractal Analysis of Multiview 3D Video with Different Quantization Parameters Applying Histogram Method

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Abstract: n this paper, multifractal properties of multiview 3D video are determined. Multifractal spectra are determined by using the histogram method. For the analysis of multiview video, long video traces are used, for multiview video with two views. Differences between multifractal properties of different views of multiview video and different types of frames are highlighted. Additional analysis was performed for the left view of multiview 3D videos for different quantization parameters of the frames.

Keywords: 3D video, Multifractals, Multiview coding, Quantization parameters.

1 Introduction

3D video is the video that creates impression of depth [1]. Number of possible applications for this kind of video is in constant increase, so technologies and standards should follow. Since 3D video usually contains several video sequences, quantity of data for this video format is large, and highly efficient video coding is necessary. Some works devoted to the problem of encoding 3D video are presented in [2 – 5]. Large amounts of data led to restrictions in storage and transfer of 3D video. Previous analyses of transport of 3D video were dedicated to network and transport protocols [6], while other analyses of 3D video transport were dedicated to adaptation of the 3D video to the viewer needs and conditions in the network [7].

Since compressed video sequences expose fractal properties [8 – 10], for detailed analysis of 3D video fractal analysis is required. Our analysis includes determining multifractal spectrum by histogram. Analysis is dedicated to multiview 3D video format, being a standard for 3D video coding developed by MPEG/VCEG, which is included as an amendment to H.264/MPEG-4 AVC video compression standard [5]. Results of multifractal analysis can be used for traffic modeling.

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Results presented in the paper are obtained using publicly available video traces [11]. In particular, traces for multiview 3D video are used. Multifractal properties of multiview 3D video are determined taking into account different views in multiview 3D video, different types of frames as well as different values of quantization parameters in one of the views of multiview 3D video.

The paper is organized as follows: Section 2 gives a review of multiview 3D video, as well as explanation of examined multiview 3D video traces, while Section 3 is dedicated to principles of multifractal analysis. Simulation results are presented in Section 4. Some concluding remarks are given in Section 5.

2 Multiview Video

There are several representation formats for 3D video, such as: frame sequential and side by side format, multiview 3D video, and 3D depth based video [1 – 5]. In each of these cases, an observer watching this kind of video has an impression of depth. This is why this kind of video is called three-dimensional (3D) video.

Multiview 3D video has more then one video sequence, that was captured directly using more then one camera, or indirectly during the postproduction [3]. Every video sequence in multiview video is one view on the same scene. This means that if classic type of coding is used for this kind of video (such as H.264/AVC), quantity of information is as many times higher in multiview video then in classical 2D video as there are views in the multiview 3D video. Quantity of data is very important for transmission and storage, and very efficient coding for multiview 3D video is necessary. Efficiency of coding for multiview coding is improved by using redundancy between different views. This means that in multiview coding in addition to time reference pictures, inter-view reference pictures exist. Principles of multiview coding are illustrated in Fig. 1 [2]. This type of coding is included as an amendment to H.264/AVC standard for support of multiview coding [5].

Stereoscopic 3D video is multiview 3D video with two views: the left view and the right view. During the coding of stereoscopic 3D video one view (usually the left one) is used as a reference, while the other view (the right view) is coded relatively to the first one. In this organization, the left view has I (intra-coded), P (predictive), and B (bidirectional), type of frames, while the right view has only P and B frames [5].

In this paper, multiview 3D video with two views is examined. As an example of a multiview 3D video, movie *Alice in Wonderland* by Tim Burton is selected. Video traces for this multiview 3D video are obtained from http://trace.eas.asu.edu [11]. More information about the video traces can be found in [12].

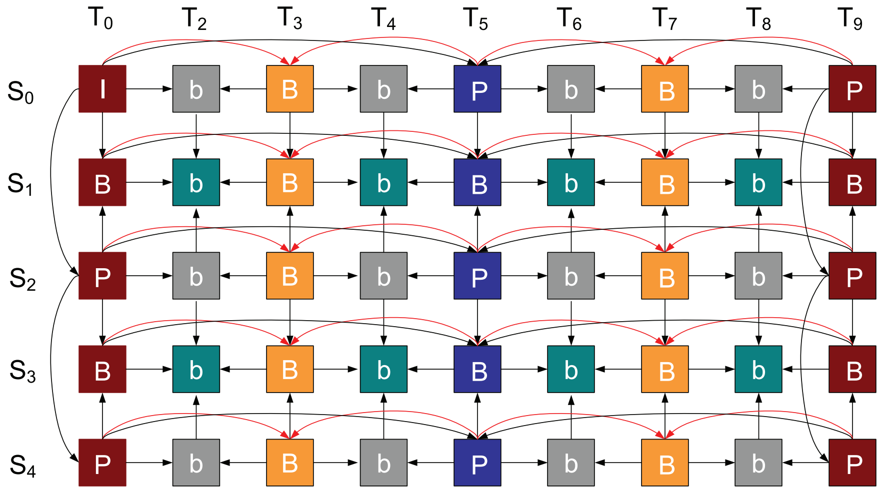

Fig. 1 – *Typical structure of multiview coding.*

Examined video traces contain data about the frame number, time of the frame, type of the frame, size of the frame, peak signal-to-noise ratio, and data about view of multiview video that the frame belongs to. During the analysis, data about the number of the frame, the type of the frame, the size of the frame and the data about the view of the multiview video the frame belongs to were used. Analysis was conducted for each view in multiview 3D video, where both views had around 51200 frames, and for the combined view where frames of the left and the right view appear alternately.

Group of Pictures (GoP) for examined multiview 3D video was G16B1, which means that one GoP for the left view was IBPBPBPBPBPBPBPBI..., while one GoP for the right view was PBPBPBPBPBPBPBPBP... Values for quantization parameters of examined video were, for all frame types 24, 28, or 32. Examined video was in full HD (High Definition) resolution and had frame rate 24 frames/s for each view.

3 Multifractal Analysis

Fractal objects can have property of self-similarity, which means that in complex shape or dynamic behavior of a system, shapes at one scale being similar to shapes at another scale can be found [13, 14].

Natural objects and phenomena can have statistic self-similarity. For example, natural fractal objects such as relief or clouds have property of self-similarity, but shape of the structure is not exactly self-similar, it is statistically self-similar, instead. Such objects are multifractals [14].

Properties of fractal signals and objects are [14]:

- fractal structures do not have associated length that describes them,
- property of self-similarity,
- fractional (non-integer) dimension.

Main analytical parameter for describing structures that have scaling symmetry is the fractal dimension. Term scalable symmetry implies self-similarity of observed objects in variable scale. First introduction of measures that allow possibility of fractional dimension gave mathematician Hausdorff. Besides the Hausdorff definition given in [14], the fractal dimension can be calculated in other ways. Furthermore, for structures obtained by applying strictly defined rules, self-similarity dimension can be determined [14]. However, for fractal structures that are not acquired using strictly defined rules, fractal dimension can not be defined as a dimension of self-similarity. In that case, other methods might be used, among which the best known is the box-counting method, or the method of overlays, being used to determine dimension of an overlay.

For complete characterization of multifractals, dimension as a single number is not enough, so some kind of distribution function is necessary. To characterize multifractals, a value called coarse Hölder exponent, is introduced as

$$\alpha = \frac{\log \mu(box)}{\log \varepsilon}, \tag{1}$$

where $\mu(box)$ is the box measure, and ε is the dimension of the box. For a wide class of self-similar measures, α takes a value within the interval $[\alpha_{\min}, \alpha_{\max}]$, where $0 < \alpha_{\min} < \alpha_{\max} < \infty$. Values of α are close to the corresponding fractal dimension of observed structures.

Within the observed structure, many points can be characterized by the same value of α. It is possible to observe distribution of the exponent α as another parameter to characterize multifractal structures. For each value of α we can count boxes sized ε, having the coarse Hölder exponent equal to α. If this number is, $N_\varepsilon(\alpha)$, is determined, the Hausdorff dimension of the distribution of α is defined as

$$f_\varepsilon(\alpha) = -\frac{\log N_\varepsilon(\alpha)}{\log \varepsilon}. \tag{2}$$

When $\varepsilon \to 0$ the function defined by (2) approaches to the limiting value $f(\alpha)$ which is known as a multifractal spectrum. Note that direct determination of (2) is not possible, since the logarithm of zero is infinite. This value can be estimated from the slope in the log-log plot for several values of ε. The value of $f(\alpha)$ could be interpreted as a fractal dimension of subsets of boxes of size ε with the coarse Hölder exponent equal to α.

There are several algorithms for calculation of $f(\alpha)$, for instance the method based on statistical moments, then on the basis of geometric parameters and the probability theory [11]. According to the classification given in [11], there are three types of spectra of $f(\alpha)$: Hausdorff singularity spectrum, $f_h(\alpha)$, Large deviations spectrum $f_g(\alpha)$, and Legendre multifractal spectrum, $f_l(\alpha)$.

For obtaining an estimate for $f(\alpha)$ for our data, we used histogram method [10, 13, 14]. This method for given measure μ involves the following steps:

1. covering the measure with boxes of size ε and determining number of boxes $N_\varepsilon(\alpha)$,
2. compute the coarse Hölder exponent α_i, where μ_i is the measure of box i,
3. making a histogram for α,
4. repeat steps 1 – 3 for different values of ε,
5. plot $-\log N_\varepsilon(\alpha)/\log\varepsilon$ versus α for different values of ε,
6. estimate $f(\alpha)$ from the slope of plots in 5. for several values of ε.

4 Simulation Results

As compressed video sequences show multifractal behavior for detailed analysis of multiview 3D video multifractal analysis is required. In our analysis, we have determined parameters of multifractal spectra α and $f(\alpha)$ by the histogram method. Analysis was performed on the multiview 3D video with the structure described in Section 2.

In Section 3, different methods for calculation of multifractal spectra were mentioned: Legendre spectrum, large deviations spectrum, and the histogram method of determination of Hausdorff singularities. In our analysis, we have chosen the histogram method, as a method that requires the lowest amount of approximation [13, 14].

To calculate multifractal spectra by the histogram method, we developed appropriate Matlab code. Since information about frame sizes were processed, the computer storage capacity had not been critical issue. Details on principles of the histogram method and the ways of practical realization with data are available in literature, [10, 14].

Examined multiview 3D video, as described in Section 2, had two views (the left view and the right view). In the left view, frame sizes of frame types I, P and B are present, while in the right view P and B frame types exist. We have determined multifractal spectra of different views of multiview 3D video, as well as multifractal spectra of frame sizes of different types of frames.

Results for multifractal spectra by the histogram method for all of the frames of the combined view, the left view, and the right view of multiview 3D video, for quantization parameters of all types of frames equal to 28, are shown in Fig. 2. In this figure, the combined view is labeled as CView, the left view as LView, and the right view as RView.

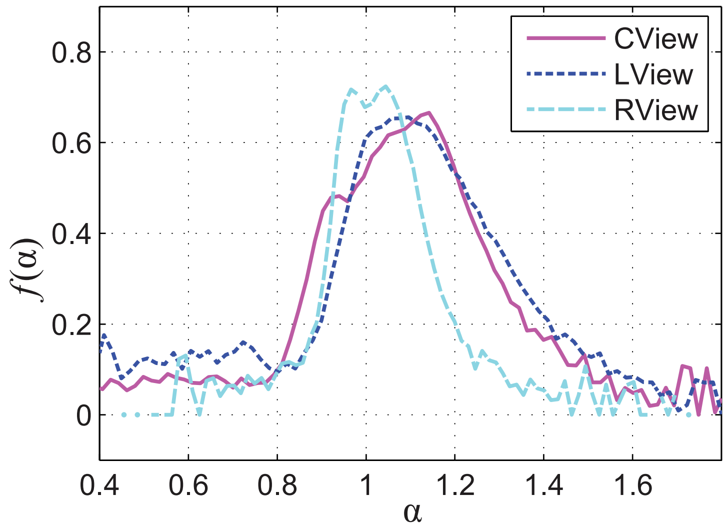

Fig. 2 – *Multifractal spectra by the histogram method for all of the frames, of the combined view, the left view and the right view of the multiview* 3D *video.*

Maximum of the multifractal spectrum (globally frequent cases in the signal) is the highest in the case of the right view, as can be seen from Fig. 2. Spectra of the frame sizes for the left view and the combined have lower maxima, one close to another. Multifractal spectra of the combined view of multiview 3D video have the lowest regularity, which is a consequence of the fact that combined view is a combination of the left and the right view. Width of the multifractal spectrum is the lowest in the case of the right view of the multiview video, while width of the spectra in cases of the left and the combined view are higher. Multifractal spectra of the combined view are in width usually close to the width of multifractal spectra of the left view, but usually narrower.

Multifractal analysis of multiview 3D video contained computation of the multifractal spectra for different views of multiview 3D video (the combined view, the left view, and the right view) for all frames, but also for isolated different types of frames (I, P, and B frames). All types of frames had the same values of quantization parameters, 28. Multifractal spectra for different views (the combined view, the left view and the right view) and different types of frames (I, P, and B frames) for multiview 3D video are shown in Fig. 3a. For detailed analysis, multifractal spectra of the left and the right view and P and B types of frames are isolated in Fig. 3b. Multifractal spectrum for I frames is not present in this figure, since only the left view has I frames, while the right view does not have I frames.

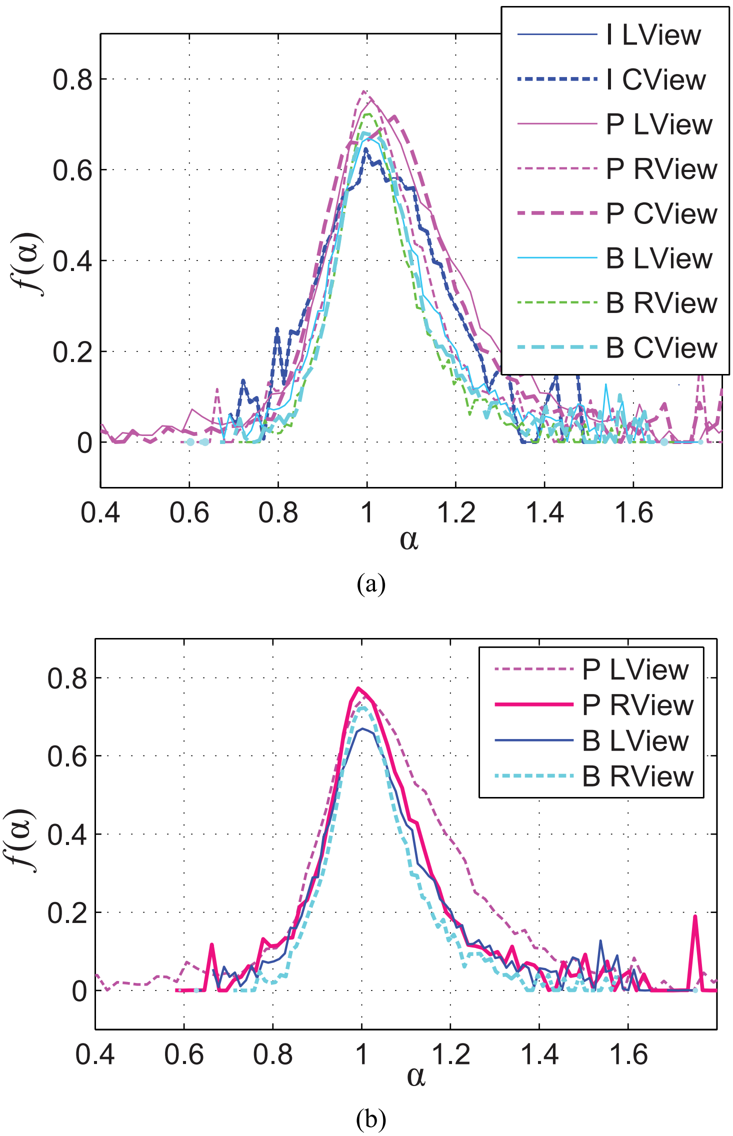

Fig. 3 – *Multifractal spectra by the histogram method for the multiview 3D video* (a) *all of the views and all of the frame types* (b) *comparison of the left and the right view.*

Multifractal spectra presented in Fig. 3 allow comparison of multifractal properties of different types of frames in views of multiview 3D video. From Fig. 3 it can be concluded that I type of frames has multifractal spectrum with the lowest maximum, P type of frames has the highest maximum, and maximum of multifractal spectra for B type of frames lies in between. This conclusion is true regardless the view of multiview 3D video. Width of the multifractal spectrum for one view is different depending on the type of the frame. Multifractal spectra of I type of frames are usually narrower in comparison to all other frame types for small values of spectra (small $f(\alpha)$), but for higher values of $f(\alpha)$ this spectrum lies between the spectra of P and B types of frames. The narrowest multifractal spectrum is in the case of B frames, and the widest for P frames.

From multifractal spectra presented in Fig. 3b, it can be concluded that the left view has wider multifractal spectrum then the right view, regardless of the type of frames.

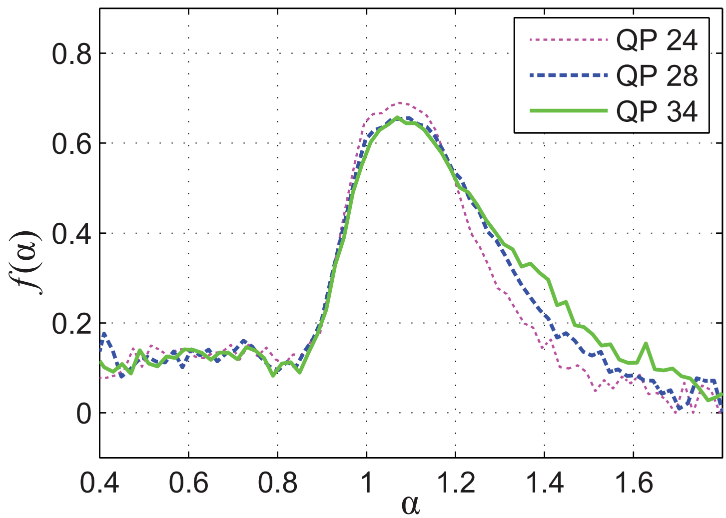

Fig. 4 – *Multifractal spectra by histogram method for the left view of multiview* 3D *video and different values of quantization parameters.*

In addition to our results presented in [15, 16], analysis of the influence of quantization parameters is conducted. Quantization parameters for all types of frames (I, P and B) were (24, 24, 24), (28, 28, 28), and (34, 34, 34). The results for the multifractal spectrum by the histogram method for the left view of the multiview 3D video for different values of quantization parameters are presented in Fig. 4. From these results it can be concluded that increase in the value of quantization parameter leads to expansion of the spectrum, that is, to increase the range of values for α. This increase is pronounced on the right hand side of the spectrum, which is not a precedent, since often multifractal spectra tend to tilt to one side [14]. As it can be seen from Fig. 4, increasing the value of the quantization parameter leads to a reduction in the maximum of the multifractal spectrum.

5 Conclusion

In this paper, results obtained by multifractal analysis of multiview 3D video are presented. Among representation formats of 3D video, multiview 3D video compression format is selected, a format included as an amendment to H.264/MPEG-4 AVC video compression standard to support multiview coding.

Motivation for the analysis of multiview 3D video is in the fact that presence of video content in traffic constantly increases. In the case of multiview 3D video, where every view is a video sequence in full HD resolution, the amount of data is higher in comparison to other compression formats.

For the analysis of multiview 3D compression format, publicly available long frame-size traces are used, [10]. Analyzed video had two views, the left view and the right view. It was shown that the left view has wider multifractal spectrum then the right view, for all of the frames in frame trace. This is a consequence of applied multiview coding method. Also, additional testing was performed for the left view of the video, and different quantization parameters presenting the influence of these parameters on the multifractal spectra.

6 References

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