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| **Joint Collaborative Team on Video Coding (JCT-VC)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11**  29th Meeting: Macao, CN, 19–25 Oct. 2017 | Document: JCTVC-AC0026 |

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| *Title:* | **BD-Rate/BD-PSNR Excel extensions** | | |
| *Status:* | Input document to JCT-VC | | |
| *Purpose:* | Information | | |
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# Abstract

This contribution provides some extensions to the JCT-VC/JVET Excel template for the computation of BD-rate and BD-PSNR numbers. In particular, the new formulation enables computation of BD-rate and BD-PSNR numbers for larger than 4-point data sets, can report “coverage” percentages between two data sets, and can also provide the ability to dynamically extrapolate the curves so as to guarantee their overlap. The ability to also compute “region of interest” measurements is also provided.

# Introduction

The video standardization community has used BD-rate and BD-PSNR [1][2] measurements for several years as a method for evaluating the performance of new codecs and video coding tools. With BD-rate in particular one can measure the average rate difference between two rate-distortion curves (Figure 1), where PSNR is commonly used as the distortion metric. Similarly, BD-PSNR measures the average PSNR difference between those same curves.



Figure 1. Two Rate Distortion Curves for BD-rate/BD-PSNR computation

The computation of BD-rate and BD-PSNR first requires that rate is first converted into logarithmic units (Figure 2). Then the overlapping area between the two lograte-distortion curves in terms of PSNR for BD-rate (Figure 3) or bitrate for BD-PSNR (Figure 4) is computed using an integration process. In the original contributions [1][2] a 3rd order polynomial interpolation was used to fit the two curves. An excel formulation for this computation was also provided in [3]. However, it was noted [4] that the polynomial interpolation method might not always provide reliable results. It was suggested to replace it with a piecewise cubic interpolation scheme instead. A new excel document that supports this new formulation was provided in [5].



Figure 2. The two Rate Distortion Curves from Figure 1 using a log-rate scale



Figure 3. Area used for the computation of BD-rate. Only the overlapping PSNR intervals are considered.



Figure 4. Area used for the computation of BD-PSNR. Only the overlapping rate intervals are considered.

Unfortunately, the new computation still has some limitations. In particular, the formula provided in Excel can only support 4 rate-distortion points, whereas an overlap between the two curves is a requirement so as to compute meaningful results. Otherwise, the resulting BD-rate or BD-PSNR number will be set to 0 even if the two curves are radically different. This can present a problem for some tests. In this contribution an extension of the excel template provided in [5] is presented that tries to address these issues.

# Extended BD-rate/BD-PSNR functions

As stated in the previous section, the original BD-rate/BD-PSNR functions provided in [5] could only support data sets with 4 rate distortion points. Furthermore, an overlap between the two tested curves was necessary for the computation of meaningful results.

We first addressed the first issue by detecting the length of the range that one wishes to perform the computation for, as well as by using dynamic memory allocation for any arrays used for the computation process. These are relatively easy using the *Range.Count* property and *ReDim* Statement in VBA respectively. However, we also realized that under some circumstances the considered range may contain empty cells, duplicates, and/or be unsorted. These could confuse the computation. Therefore, we also added an analysis and preprocessing step on the data that removes empty or duplicate cells. A sorting process on the data is also performed. The sorting process depends on whether we are measuring BD-rate or BD-PSNR. After trimming and sorting the data the integration process is performed using the piece-wise cubic interpolation method. The interpolation is performed across all points in the provided range. It should be noted that the data still need to maintain a monotonic behavior.

For the second issue we decided to use an extrapolation method. In particular, linear extrapolation in the log-rate domain is used to extend the curves so as to guarantee an overlap and thus be able to perform the integration process. We have selected the linear extrapolation method since we found that the piece-wise cubic interpolation method can be a bit unreliable when extrapolating data, unlike when it is interpolating. Nevertheless, only the edge point is extrapolated using linear extrapolation. All intermediate points still use the piece-wise cubic interpolation method.

The syntax of the new functions is as follows:

bdRateExtend(rateA As Range, distA As Range, rateB As Range, distB As Range, Optional bMode As String = "None", Optional bRange As Boolean = False)

bdPSNRExtend(rateA As Range, distA As Range, rateB As Range, distB As Range, Optional bMode As String = "None", Optional bRange As Boolean = False)

The last two options, bMode and bRange, are optional and permit us to use these two new functions using exactly the same syntax as the original bdrate and bdpsnr functions.

Our new functions, given the newly introduced extrapolation functionality, now support seven (7) different modes using the optional parameter bMode. These modes, for the BD-rate case, are as follows:

1. “None”. Default. No extrapolation is considered. However, if no overlap exists, the function reports either -100% or 100% bdrate change depending on the location relationship of the two curves.
2. “Low”. Adaptive extrapolation is performed only and only if there is no overlap, and only for the “higher” performance curve towards the low PSNR end. Extrapolation is performed using a linear extrapolation in the log bitrate domain.
3. “High”. Adaptive extrapolation is performed only and only if there is no overlap, and only for the “lower” performance curve towards the higher PSNR end. Extrapolation is performed using a linear extrapolation in the log bitrate domain.
4. “Both”. Adaptive extrapolation is performed only and only if there is no overlap, and for both curves achieving maximal coverage. Extrapolation is performed using a linear extrapolation in the log bitrate domain.
5. “LowAlways”. Extrapolation is always performed for the “higher” performance curve towards the low PSNR end. Extrapolation is performed using a linear extrapolation in the log bitrate domain.
6. “HighAlways”. Extrapolation is always performed for the “lower” performance curve towards the higher PSNR end. Extrapolation is performed using a linear extrapolation in the log bitrate domain.
7. “BothAlways”. Extrapolation is performed for both curves achieving maximal coverage. Extrapolation is performed using a linear extrapolation in the log bitrate domain.

It might be desirable, for example, to use one of the adaptive options, i.e. Low, High, or Both, for experiments where the two curves vary significantly and there is a possibility that the two curves might not overlap. Even though it could be argued that an extrapolation method will not result in very accurate results, at least these new options could provide some indication of performance, which could then be investigated further.

The option bRange computes, if set to TRUE, the overlap range between the two curves. This number can then be considered as a confidence criterion, if desired for the actual BD-rate or BD-PSNR measurements [6].

Some possible usage examples for bdRateExtend are as follows:

 =bdRateExtend($K8:$K12,O8:O12,$AA8:$AA12,AD8:AD12)

 =bdRateExtend($K8:$K12,O8:O12,$AA8:$AA12,AD8:AD12,"Both")

 =bdRateExtend($K8:$K12,O8:O12,$AA8:$AA12,AD8:AD12,"Low",FALSE)

 =bdRateExtend($K8:$K12,O8:O12,$AA8:$AA12,AD8:AD12,”None”,TRUE)

Given the above functionality, we also created two additional functions, named bdRateROI and bdPSNRROI, which permit the computation of BD-rate and BD-PSNR for specific rate or PSNR intervals. The syntax of these functions is as follows:

bdRateROI(rateA As Range, distA As Range, rateB As Range, distB As Range, minValue As Double, maxValue As Double, Optional bMode As Boolean = False)

bdPSNRROI(rateA As Range, distA As Range, rateB As Range, distB As Range, minValue As Double, maxValue As Double, Optional bMode As Boolean = False)

The bdRateROI function could be used, for example, as follows in either PSNR or Bitrate range mode:

% PSNR range mode

  =bdRateROI($K8:$K12,O8:O12,$AA8:$AA12,AD8:AD12,40,45)

% Bitrate range mode (range 5000 to 10000 kbps)

  =bdRateROI($K8:$K12,O8:O12,$AA8:$AA12,AD8:AD12, 5000, 10000, TRUE)

Similarly, the bdPSNRROI function could be used as follows in either Bitrate or PSNR range mode:

% Bitrate range mode (range 5000 to 10000 kbps)

  =bdRateROI($K8:$K12,O8:O12,$AA8:$AA12,AD8:AD12,5000,10000)

% PSNR range mode

  =bdRateROI($K8:$K12,O8:O12,$AA8:$AA12,AD8:AD12, 40, 45, TRUE)

It should be noted that all of these functions utilize the same core subroutines, making it potentially easier to maintain and extend them. For example, currently sorting of the data is performed using the bubble sort method, but another more efficient method could be used in the future instead.

# Conclusion

In this contribution we have introduced extensions to the BD-rate and BD-PSNR VBA scripts that are available in the JCT-VC/JVET Excel template. These new extensions permit computation of such measurements for any number of test points and allow also more meaningful performance estimates when the two compared curves do not overlap. ROI extensions are also provided.

# References

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# Patent rights declaration(s)

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