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**ISO/IEC JTC 1/SC 29/WG 7 MPEG Coding for 3D Graphics and haptics**

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# Introduction

In May 2021, MPEG issued a call for proposals for the specification of a new coding format for haptic data [1]. Following this call, a baseline reference design and associated software implementation were defined for the representation and coding of haptic data in a so-called phase 1 [3].

This report introduces the performances of this first phase of the MPEG haptics coding standard computed during the development of the standard. The final version of the standard may have slightly different results due to the changes and improvements done during the standardization phase. However, it is not expected to be drastically different.

# Methodology

The MPEG CfP methodology [2], test streams test platforms and protocols defined to assess the quality of the proposed coding scheme with both objective metrics (PSNR) and subjective tests (MUSHRA), have been used for this evaluation.

The two platforms designed for the CfP for vibrotactile and kinesthetic signals have been used. The objective of those platforms was to evaluate the potential perceived distortions induced by the signal encoding. Test subjects at three independent laboratories were asked to assess the subjective quality for three different bit-rates representative of the available range from moderate to high compression. The following compressed target bitrates were used: 64 kb/s, 16 kb/s, 8kb/s, 2 kb/s.

The version CRM3 of the public MPEG reference software [4](<https://github.com/MPEGGroup/HapticReferenceSoftware>) was used with the default parameter set: cutoff frequency of 72.5Hz and an automatic bit budget computed based on the target bitrate for wavelet bands.

The three sets of test streams from the MPEG CfP have been used: Two sets for vibrotactile signals (short effects and long effects) and one set for kinesthetic signals (including force signals, acceleration, or movement). A total of 29 tests streams were used. These test streams include both parametric and PCM input test files with duration ranging from 8ms to 10s.

# Objective Performances

To assess the quality of the encoding and also to evaluate the required bit-rate for encoding high quality haptics, different evaluations were done.

First, bitrates were plotted for descriptive/parametric signals (.ivs and .ahap), as shown in Figure 1. As depicted, the bit-rate ranges from a few kbps to roughly 60 kbps. Of course, for descriptive encoding, the bit-rate depends on the number of encoded effects. But for the set of tests streams used, corresponding to typical use cases, the distribution of bit-rates shown in Figure 1 demonstrates that most content can be encoded with a bit-rate lower than 8kbps.

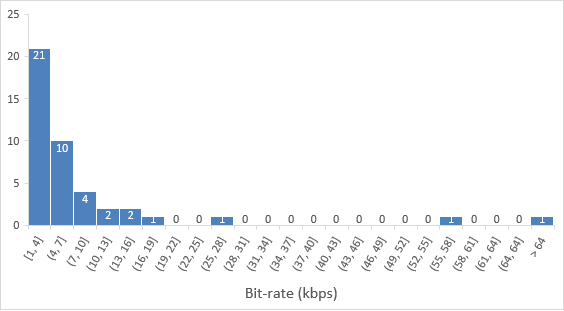
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Figure - Bit-rate distribution of encoded parametric synthetic signals.

Second, for PCM tests streams (.wav), the PSNR of the decoded wave files was computed, using three configurations of the encoder:

C2V: 1 band encoding using vectorial parameters

C2W: 1 band encoding using wavelet decomposition

C2VWR: 2 bands encoding, the low-frequency (LF) band using vectorial and the high-frequency (HF) band using wavelet decomposition and residual coding.

Figure 2 depicts the resulting values for the full test streams. The wavelet encoding provides a more accurate reconstruction of the signal than parametric representation and

interpolation, especially at high bit-rates. This is because arbitrary signals can be represented accurately using this method, when enough bits are spent for encoding. On the other hand, vectorial coding allows very low bit-rates with reasonable quality and reduced computational overhead. The residual coding provides a compromise between the advantages of both solutions, since errors in the low-frequency coding are compensated by the wavelet coding when the target bit-rate provides room for higher reconstruction fidelity. Additionally, one could also just decode the LF band to get a low frequency approximation of the signal.

A graph with different colored lines and numbers

Description automatically generated

Figure – PSNR values for PCM encoded signals.

# Subjective Performances

35 subjects (25 participants aged [18-30], 7 aged [31-40] and 4 aged [41-50]) participated in the evaluation in three independent labs using the MUSHRA methodology. Each individual user test session lasted about 30 minutes for vibrotactile and 1 hour for kinesthetic. In each trial, the user experienced several versions of each test item (the tests streams), processed by a different system under test (vibrotactile and kinesthetic setup). Users were asked to judge the “Basic Haptic Quality” of the versions of the test item in each trial as compared to the open reference, with a linear ranking between 0 (bad) to 100 (excellent). Any perceived difference from the open reference was required to be rated down. One of the systems under test was always the hidden reference that was expected be given a rating of 100.

The results are provided in Figure 3 considering the 97.5% confidence interval. From the overall results (considering all bit-rates, streams and users), the wavelet encoding (C2W)

exhibits lower results than both vectorial (C2V) and combined coding (C2WR) (i.e. 2 bands vectorial + wavelet residual coding) at low bit-rates. At higher bit-rates vectorial is performing lower than the other methods. The combined C2VWR coding generally provides the best tradeoff with good results at all bit-rates. It benefits from the best of each method.

**A diagram of a graph

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Figure - Average subjective performances of the different encoder configurations for all PCM input files & for three bit-rates, with the 2.5% confidence interval (HR: Hidden Reference, V: Vectorial (C2V), W: Wavelet (C2W), VWR: Vectorial + Wavelet + Residual (C2VWR))..

# Conclusion

The results reported in this document clearly show that the MPEG codec is flexible and generic to fulfill current and future applications and services. For instance, vectorial encoding can be used to encode haptic effects for very low bit-rate applications and simple synthetic effects, while a higher quality encoding can be achieved using an additional wavelet encoding band (or even using only wavelet encoding), for higher bit-rates and real signal recordings.

From the evaluations performed during the development process, the following bit-rate ranges per channel can be recommended depending on the expected quality level:

• 2-4 kbps: perceptible distortion

• 8-16 kbps: some distortions, but not annoying

• 32-64 kbps: no perceptible distortion

• ≥ 64 kbps: perceptually lossless.

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