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| **Title:** | **[NNR] CE2: Report on Codebook Quantization with bounded PDF initialization** |
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# Introduction

This contribution reports InterDigital’s results to the Core Experiment 2, with an updated cluster initialization for codebook-based quantization at the encoder. The test conditions for this CE are detailed in [1]. The proposed method, detailed in [2], relies on cluster-based quantization. The clusters are initialized using a bounded Probability-Density Function (PDF). bounded PDF initialization gives good granularity of the cluster centers around high-probability values while assigning enough cluster centers around the values happening with lower probability. Note that the following results reflect the performance of the quantization without requiring access to annotated data, i.e. without the gradient-based clustering described in [2]. Section 2 describes the proposed modification compared to the original method related to the bounded PDF, and section 3 explains the test results.

# Bounded-PDF initialization

In the original method described in [2], we used only a lower bound for the probability distribution function. After more experiments, we found out that having an upper bound can be useful in cases where some clusters become over-crowded. Please note that this change only improves the efficiency of the quantization on the encoding side and has no effect on the format and bitstream of the compressed network.

In the implementation used for the following tests, we use a “pdfFactor” parameter that defines how PDF based initialization is applied to the K-Means quantization. “pdfFactor” is a number between 0.0 and 1.0 and defines how much we want to apply the PDF-based feature. If it is zero, it means we do not want to use PDF based initialization at all. In this case the K-Means algorithm is initialized uniformly. A value of 1.0 means we want to use PDF feature with its maximum effect. The bounded PDF function used for the initialization of K-Means is calculated as follows:

BoundedPDF = Clip(PDF, LowerBound, UpperBound)

Where:

LowerBound = (1.0-pdfFactor)\*Avg(PDF)

UpperBound = (1.0+pdfFactor)\*Avg(PDF)

# Results

The following results are based on the following pipelines:

* Input Network 🡪 Uniform Quantization 🡪 Baseline Entropy Coding (DeepCABAC)
* Input Network 🡪 Codebook Quantization 🡪 Baseline Entropy Coding (DeepCABAC)

**Input networks:**

* Original Networks
* CE1 outputs: baseline Low Rank method [3] for the 4 working points detailed in [1]

**Use cases:**

* VGG-16
* ResNet-50
* MobileNetV2
* DCase (Audio Classification)
* UC12B (Image Compression)

We used NCTM [4] to do quantization, baseline entropy coding [5], and evaluation of the results. Here is a sample for ReseNet-50 use case using CE1 Working point 4 as input. For complete results please refer to the attached spreadsheets.



# Test frameworks and platform

The presented results were obtained under the following test conditions:

* **Operating System:** Ubuntu 18.04 LTS
* **Programming Language:** Python 3.6, Tensorflow 1.14.0
* **Additional Libraries:** Cuda V10.0.130 and CUDNN 7.6
* **The hardware configuration:**
	+ Intel i9-7920x CPU@2.9 Ghz
	+ NVIDIA TITAN Xp
	+ 128 GB DDR4 RAM

# Patent rights declaration(s)

**InterDigital Communications, Inc. may have current or pending patent rights relating to the technology described in this contribution and, conditioned on reciprocity, is prepared to grant licenses under reasonable and non-discriminatory terms as necessary for implementation of the resulting ITU-T Recommendation | ISO/IEC International Standard (per box 2 of the ITU-T/ITU-R/ISO/IEC patent statement and licensing declaration form).**

# References

1. “Description of Core Experiments on compression of neural networks for multimedia content description and analysis”, ISO/IEC JTC1/SC29/WG11 N18574, July 2019.
2. Shahab Hamidi-Rad, Swayambhoo Jain, Fabien Racapé “Gradient-Based K-Means for Quantization of Deep Neural Network parameters” ISO/IEC JTC1/SC29/WG11 m49260, July 2019.
3. Swayambhoo Jain, Shahab Hamidi-Rad, Fabien Racapé, “Low Displacement Rank decomposition for compressing convolutional layers” ISO/IEC JTC1/SC29/WG11 N18574, July 2019
4. “Test model 3 of Compression of neural networks for multimedia content description and analysis”, ISO/IEC JTC 1/SC 29/WG11 N18993
5. Simon Wiedemann et. Al. “Response to the Call for Proposals on Neural Network Compression: End-to-end processing pipeline for highly compressible neural networks”, ISO/IEC JTC1/SC29/WG11 m47698, March 2019.