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Information technology — Multimedia content description interface — —

Part 17: Compression of neural networks for multimedia content description and analysis

Technologies de l'information — Interface de description du contenu multimédia — Partie 17: Compression des réseaux neuronaux pour la description et l'analyse du contenu multimédia

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC~~ ~~1, *Information technology*, Subcommittee SC~~ ~~29, *Coding of audio, picture, multimedia and hypermedia information*.

This second edition cancels and replaces the first edition (ISO/IEC 15938-17:2022), which has been technically revised.

The main changes are as follows:

— Support for incremental compression of updates of neural networks respective to a base model,

— Additional sparsification tools, and

— Additional quantization tools, including representation as residuals of updates.

— Additional high-level syntax, covering the new coding tools as well as more metadata (e.g. performance metrics).

A list of all parts in the ISO/IEC 15938 series can be found on the ISO ~~website~~ and IEC websites.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at ~~www.iso.org/members.html~~www.iso.org/members.html and www.iec.ch/national-committees.

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Introduction

Artificial neural networks have been adopted for a broad range of tasks in multimedia analysis and processing, media coding, data analytics and many other fields. Their recent success is based on the feasibility of processing much larger and complex neural networks (deep neural networks, DNNs) than in the past, and the availability of large-scale training data sets. As a consequence, trained neural networks contain a large number of parameters and weights, resulting in a quite large size (e.g. several hundred MBs). Many applications require the deployment of a particular trained network instance, potentially to a larger number of devices, which may have limitations in terms of processing power and memory (e.g. mobile devices or smart cameras), and also in terms of communication bandwidth. Any use case, in which a trained neural network (or its updates) needs to be deployed to a number of devices thus benefits from a standard for the compressed representation of neural networks.

Considering the fact that compression of neural networks is likely to have a hardware dependent and hardware independent component, this document is designed as a toolbox of compression technologies. Some of these technologies require specific representations in an exchange format (i.e. sparse representations, adaptive quantization), and thus a normative specification for representing outputs of these technologies is defined. Others do not at all materialize in a serialized representation (e.g. pruning), however, also for the latter ones required metadata is specified. This document is independent of a particular neural network exchange format, and interoperability with common formats is described in the annexes.

This document thus defines a high-level syntax that specifies required metadata elements and related semantics. In cases where the structure of binary data is to be specified (e.g. decomposed matrices) this document also specifies the actual bitstream syntax of the respective block. Annexes to the document specify the requirements and constraints of compressed neural network representations; as defined in this document; and how they are applied.

— ~~Annex A~~Annex A specifies the implementation of this document with the Neural Network Exchange Format (NNEF[1]), defining the use of NNEF to represent network topologies in a compressed neural network bitstream.

— ~~Annex B~~Annex B provides recommendations for the implementation of this document with the Open Neural Network Exchange Format (ONNX®)[2], defining the use of ONNX to represent network topologies in a compressed neural network bitstream.

— ~~Annex C~~Annex C provides recommendations for the implementation of this document with the PyTorch®[3] format, defining the reference to PyTorch elements in the network topology description of a compressed neural network bitstream.

— ~~Annex D~~Annex D provides recommendations for the implementation of this document with the Tensorflow®[4] format, defining the reference to Tensorflow elements in the network topology description of a compressed neural network bitstream.

— ~~Annex E~~Annex E provides recommendations for the carriage of tensors compressed according to this document in third party container formats.

[1] NNEF is the trademark of a product owned by The Khronos® Group. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO/IEC of the product named.
[2] ONNX is the trademark of a product owned by LF PROJECTS, LLC. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO/IEC of the product named.
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[4] TensorFlow is the trademark of a product supplied by Google LLC. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO/IEC of the product named.

— ~~Annex F~~Annex F provides recommendations for the naming of common performance metrics to specify the metric that was used for validation.

— ~~Annex G~~Annex G provides recommendations for implementing the encoding side of some of the compression tools.

The compression tools described in this document have been selected and evaluated for neural networks used in applications for multimedia description, analysis and processing. However, they may be useful for the compression of neural networks used in other applications and applied to other types of data.

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Information technology — Multimedia content description interface — Part 17: Compression of neural networks for multimedia content description and analysis

1 Scope

This document specifies Neural Network Coding (NNC) as a compressed representation of the parameters/weights of a trained neural network and a decoding process for the compressed representation, complementing the description of the network topology in existing (exchange) formats for neural networks. It establishes a toolbox of compression methods, specifying (where applicable) the resulting elements of the compressed bitstream. Most of these tools can be applied to the compression of entire neural networks, and some of them can also be applied to the compression of differential updates of neural networks with respect to a base network. Such differential updates are for example useful when models are redistributed after fine-tuning or transfer learning, or when providing versions of a neural network with different compression ratios.

This document does not specify a complete protocol for the transmission of neural networks, but focuses on compression of network parameters. Only the syntax format, semantics, associated decoding process requirements, parameter sparsification, parameter transformation methods, parameter quantization, entropy coding method and integration/signalling within existing exchange formats are specified, while other matters such as pre-processing, system signalling and multiplexing, data loss recovery and post-processing are considered to be outside the scope of this document. Additionally, the internal processing steps performed within a decoder are also considered to be outside the scope of this document; only the externally observable output behaviour is required to conform to the specifications of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 10646, *Information technology — Universal coded character set (UCS)*

ISO/IEC 60559, *Information technology — Microprocessor Systems — Floating-Point arithmetic*

IETF RFC 1950, *ZLIB Compressed Data Format Specification version 3.3, 1996*

NNEF-v1.0.3, Neural Network Exchange Format, The Khronos NNEF Working Group, Version 1.0.3, 2020-06-12 (https://www.khronos.org/registry/NNEF/specs/1.0/nnef-1.0.3.pdf)

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~~*FIPS PUB 180-4, Secure Hash Standard (SHS), 2015.*~~

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at ~~https://www.iso.org/obp~~https://www.iso.org/obp

— IEC Electropedia: available at ~~https://www.electropedia.org/~~https://www.electropedia.org/

3.1
aggregate NNR unit
NNR unit which carries multiple NNR units in its payload

3.2
base neural network
neural network serving as reference for a differential update

3.3
compressed neural network representation
NNR
representation of a neural network with model parameters encoded using compression tools

3.4
decomposition
transformation to express a tensor as product of two tensors

3.5
hyperparameter
parameter whose value is used to control the learning process

3.6
layer
collection of nodes operating together at a specific depth within a neural network

3.7
model parameter
coefficients of the neural network model such as weights and biases

3.8
NNR unit
data structure for carrying (compressed or uncompressed) neural network data and related metadata

3.9
parameter identifier
value that uniquely identifies a parameter throughout different incremental updates

Note 1 to ~~Entry:~~ entry: Parameters having the same parameter identifier are at the same position in the same tensor in different incremental updates. This means they are co-located.

3.10
pruning
reduction of parameters in (a part of) the neural network

3.11
sparsification
increase of the number of zero-valued entries of a tensor

3.12
tensor
multidimensional structure grouping related model parameters

3.13
updated neural network
neural network resulting from modifying the base neural network

