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Information technology — JPEG AI learning-based image coding system —

Part 1: Core coding system

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This document was prepared by ITU-T (as ITU-T T.840.1) and drafted in accordance with its editorial rules, in collaboration with Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 29, *Coding of audio, picture, multimedia and hypermedia information*.

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INTERNATIONAL STANDARD ISO/IEC 6048-1
RECOMMENDATION ITU-T T.840.1

Information technology – JPEG AI learning-based image coding system: Core coding system

Summary

Recommendation ITU-T T.840.1 | ISO/IEC 6048-1 specifies an image coding technology known as *JPEG AI learning-based image coding (JPEG AI)* and it has been designed with multi-task goal. It facilitates the compression and processing of images for both human and machine vision. This Recommendation | International Standard describes the JPEG AI learning-based standard for the creation of an image from the parsed single-stream, which contains the compact compressed domain representation, targeting both human visualization, with significant compression efficiency improvement over image coding standards in common use at equivalent subjective quality, and effective performance for image processing and computer vision tasks.

Core coding system describes the JPEG AI standard for the human vision reconstruction task and thus specifies the parsing of the coded stream and the image reconstruction process.

The trainable model parameters, which are an integral part of this Recommendation | International Standard, are not contained in the Specification due to their size. Instead, the trained model parameters are available at: https://standards.iso.org/iso-iec/6048/-1/ed-1/en/ and https://www.itu.int/myworkspace/#/t-signals/vectors?val=40 (see subclause 18.2).

This Recommendation | International Standard was developed collaboratively with ISO/IEC JTC 1/SC 29, and corresponds with ISO/IEC 6048-1 as common text.

History *

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Coding, compression, decoding, human vision, image, machine vision, neural network.

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Introduction

Purpose

This Recommendation | International Standard specifies an image coding technology known as *JPEG AI learning-based image coding (JPEG AI)*, and it has been designed with multi-task goal. It allows the compression and processing of images for both human and machine vision. The scope of JPEG AI is the creation of a learning-based image coding standard offering a single-stream, compact compressed domain representation, targeting both human visualization, with significant compression efficiency improvement over image coding standards in common use at equivalent subjective quality, and with effective performance for image processing and computer vision tasks.

Core coding system describes the JPEG AI standard for the human vision reconstruction task and thus specifies the parsing of the coded stream and the image reconstruction process.

Profiles and levels

This Recommendation | International Standard is designed to cover a wide range of applications, bit rates, resolutions, qualities and services. Applications include, but are not limited to, image coding for digital storage media, image sharing through messengers or social media, visual surveillance, screen sharing applications and real-time communication. In the course of creating this Recommendation | International Standard, several requirements from typical applications have been considered, necessary algorithmic elements have been developed, and these have been integrated into a single syntax. Hence, this Recommendation | International Standard is designed to facilitate image data interchange among different applications.

Considering the practicality of implementing the full syntax of this Recommendation | International Standard, however, a limited number of subsets of the syntax are also stipulated by means of "stream profiles", "decoder profiles" and "levels". These and other related terms are formally defined in clause 3.

A stream profile is a subset of the entire bitstream syntax that is specified in this Recommendation | International Standard while a decoder profile defines the capabilities of the decoder, i.e. a subset of tools that allow the obtention of the decoded image. Different decoded qualities can be achieved for different decoder profiles using the same stream compliant with a specific stream profile. This means that interoperability may not be broken between decoders that use the same stream profile but use different decoder profiles. Within the bounds imposed by the syntax of a given stream and decoder profile, it is still possible to obtain a very large variation in the performance of encoders and decoders depending on the values taken by syntax elements in the bitstream.

A level is a specified set of constraints imposed on values of the syntax elements in the bitstream. Some of these constraints are expressed as simple limits on values, while others take the form of constraints on arithmetic combinations of values. A lower level specified is more constrained than a higher level.

Coded picture content conforming to this Recommendation | International Standard uses a common syntax. In order to achieve a subset of the complete syntax, flags, parameters and other syntax elements are included in the bitstream that signal the presence or absence of syntactic elements that occur later in the bitstream.

Encoding process, decoding process and use of optional codestream segments

Any encoding process that produces bitstream data that conforms to the specified bitstream syntax format requirements of this Recommendation | International Standard is considered to be in conformance with the requirements of this Recommendation | International Standard. The decoding process is specified such that all decoders that conform to a specified combination of capabilities known as the profile and level will produce cropped decoded output pictures that are allowed to be different within a margin or closer to the source than is produced by the described decoding process. Any decoding process that produces cropped decoded output pictures within such a specified margin to those produced by the process described herein (with the correct output order or output timing, as specified) is considered to be in conformance with the requirements of this Recommendation | International Standard.

Some design elements (such as post-filters and rendering parameters) are optional. Information related to those design elements is signalled in optional code stream segments and does not affect conformance. These optional design elements and parameters may be used together with this Recommendation | International Standard.

Versions of this Recommendation | International Standard

This is the first version of this Recommendation | International Standard.

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Overview of the design characteristics

The coded representation specified in the syntax is designed to enable high compression for a desired image quality. The algorithm is not mathematically lossless, as the exact source sample values are not preserved through the encoding and decoding processes. A learnable coding solution was trained to minimize distortion between source and reconstructed sample values. A reduced set of conventional techniques are specified to enable content adaptation. Encoding algorithms are not specified within the scope of this Recommendation | International Standard, but two informative encoder specifications producing code streams conformant with the standard are included. An encoder converts the image to the tensor representation (latent tensor) and hyper tensor. The latent tensor is differentially coded using a prediction, which is generated from hyper tensor and earlier reconstructed elements of the latent tensor. The residual is the difference between latent tensor and its precision and is entropy coded with probability distribution parameters derived from the hyper tensor. On the decoder side, the reconstructed latent tensor is processed by one of several synthesis transforms, producing a reconstructed image. The reconstructed image can be optionally processed by filters for further quality improvement.

This Recommendation | International Standard supports several functionalities such as region of interest decoding and progressive decoding, and operates with images in 4:4:4, 4:2:2 or 4:2:0 colour sampling representation. The bit-depth of the image can be 8, 10, 12, 14 or 16 bits.

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INTERNATIONAL STANDARD
ITU-T RECOMMENDATION

Information technology – JPEG AI learning-based image coding system: Core coding system

1 Scope

This Recommendation | International Standard specifies an image coding technology known as *JPEG AI learning-based image coding (JPEG AI)* comprising an image coding technology that facilitates the compression and processing of images for both human and machine vision. The scope of the JPEG AI Recommendation | International Standard is the creation of a learning-based image coding standard offering a single-stream, compact compressed domain representation, targeting both human visualization, with significant compression efficiency improvement over image coding standards in common use at equivalent subjective quality, and effective performance for image processing and computer vision tasks.

The core coding system describes JPEG AI standard for the human vision reconstruction task and thus specifies the JPEG AI specifies the parsing coded stream and the image reconstruction process. Only the syntax format, semantics, and associated decoding process requirements are specified, while other matters such as pre-processing, the encoding process, system signalling and multiplexing, data loss recovery, post-processing, and video display are considered to be outside the scope of this Recommendation | International Standard.

This Recommendation | International Standard is designed to be generic in the sense that it serves a wide range of applications, bit rates, resolutions, qualities and services. In the course of creating this Recommendation | International Standard, several requirements from typical applications have been considered, necessary algorithmic elements have been developed, and these have been integrated into a single syntax. Hence, this Recommendation | International Standard is designed to facilitate image data interchange among different applications and services.

2 Normative references

The following Recommendations and International Standards contain provisions which, through reference in this text, constitute provisions of this Recommendation | International Standard. At the time of publication, the editions indicated were valid. All Recommendations and Standards are subject to revision, and parties to agreements based on this Recommendation | International Standard are encouraged to investigate the possibility of applying the most recent edition of the Recommendations and Standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards. The Telecommunication Standardization Bureau of the ITU maintains a list of currently valid ITU-T Recommendations.

2.1 Identical Recommendations | International Standards

– None.

2.2 Paired Recommendations | International Standards equivalent in technical content

– None.

2.3 Additional references

– Rec. ITU-T H.265 | ISO/IEC 23008-2, *Information technology – High efficiency coding and media delivery in heterogeneous environments – High efficiency video coding.*

– Rec. ITU-T H.273 | ISO/IEC 23091-2, *Information technology – Coding-independent code points – Video.*

3 Definitions

For the purposes of this Recommendation | International Standard, the following definitions apply:

3.1 **analysis transform**: Process that produces a latent tensor from an image component.

3.2 **bit**: Binary digit (0 or 1).

3.3 **bitstream**: Sequence of bytes.

3.4 **byte**: Sequence of 8 bits, within which, when written or read as a sequence of bit values, the left-most and right-most bits represent the most and least significant bits, respectively.

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3.5 **byte-aligned**: Position in a *bitstream* is byte-aligned when the position is an integer multiple of 8 bits from the position of the first bit in the *bitstream*, and a bit or *byte* or *syntax element* is said to be byte-aligned when the position at which it appears in a *bitstream* is byte-aligned.

3.6 **chroma**: Sample array or single sample representing one of the two colour difference signals related to the primary colours, represented by the symbols Cb and Cr.

NOTE – The term chroma is used rather than the term chrominance in order to avoid the implication of the use of linear light transfer characteristics that are often associated with the term chrominance.

3.7 **codestream**: Bitstream plus associated markers.

3.8 **codestream segment**: Part of a codestream where the start and end of the codestream segment is derived from a syntax element..

3.9 **component**: Array or a single sample from a *luma* or *chroma* colour plane, or of one of the colour planes in RGB representation.

3.10 **decoder**: Embodiment of a *decoding process*.

3.11 **decoding process**: Process specified in this Specification that reads a *bitstream* and derives a *reconstructed image* from it.

3.12 **encoder**: Embodiment of an *encoding process*.

3.13 **encoding process**: Process not specified in this Specification that produces a *bitstream* conforming to this Specification.

3.14 **entropy encoder**: Embodiment of an entropy encoding procedure.

3.15 **entropy encoding**: Lossless procedure which converts a sequence of input tensor elements into a sequence of bits such that the average number of bits per symbol approaches the entropy of the input symbols.

3.16 **entropy decoder**: Embodiment of an entropy decoding procedure.

3.17 **flag**: Variable or single-bit *syntax element* that can take one of the two possible values 0 or 1.

3.18 **forward gain tensor**: Tensor with scaling coefficients for the residual latent tensor elements.

3.19 **inverse gain tensor**: Tensor with inverse scaling coefficients for the residual latent tensor elements.

3.20 **latent domain prediction**: Process of generation tensor predicting latent tensor elements.

3.21 **latent tensor**: Coded representation of the image after analysis transform in the encoding or after latent domain prediction in the decoding processes.

3.22 **latent tensor element**: Value of the latent tensor element.

3.23 **level**: Defined set of constraints on the values that may be taken by the *syntax elements* and variables of this Specification.

NOTE – One same set of levels is defined for all profiles, with most aspects of the definition of each level being in common across different profiles. Individual implementations could, within the specified constraints, support a different level for each supported profile.

3.24 **log scale standard deviation**: Tensor of unsigned integers, used for entropy coding, denoted as I_σ, which consists of standard deviations in logarithmic scale for residual tensor elements.

3.25 **luma**: Sample array or single sample representing the monochrome signal related to the primary colours, represented by the symbol or subscript Y.

NOTE – The term luma is used rather than the term luminance in order to avoid implying the use of linear light transfer characteristics that are often associated with the term luminance.

3.26 **marker**: A two-byte code in which the 12 most significant bits (MSBs) have the default value of 0xff in this version of the Specification.

3.27 **marker segment**: Part of the codestream that starts with marker.

3.28 **me-tANS coder**: A specific implementation of the entropy coder called memory efficient tabulated Asymmetrical Numeral Systems.

3.29 **neural network layer**: Part of a neural network that has trainable parameters and performs an operation on the received input tensor to create an output tensor.

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3.30 **neural network model**: A sequence of neural network modules (also called architecture) and model parameters (weights and biases).

3.31 **neural network module**: A set of neural network layers.

3.32 **picture header (PH)**: *Syntax structure* containing *syntax elements* that apply to the whole coded image.

3.33 **primary component**: Array of *luma* in image coding format.

3.34 **stream profile**: Specified subset of the syntax defined in this Specification.

3.35 **decoder profile**: Subset of the full JPEG AI tool set defined in this Specification that allows for the obtention of the decoded image.

3.36 **pixel**: Vector that consists of samples and has a dimension equal to the number of colour channels.

3.37 **raster scan**: Mapping of a rectangular two-dimensional pattern to a one-dimensional pattern such that the first entries in the one-dimensional pattern are from the first top row of the two-dimensional pattern scanned from left to right, followed similarly by the second, third, etc., rows of the pattern (going down), each scanned from left to right.

3.38 **rate control parameter (β)**: Parameter that defines the quantization step for the residual latent tensor elements.

3.39 **secondary component**: Tensor that consists of two *chroma* components in image coding format.

3.40 **standard deviation tensor**: Tensor used for entropy coding with the standard deviations of the residual tensor elements, denoted as σ.

3.41 **synthesis transform**: Process that produces a reconstructed image component from a reconstructed latent tensor.

3.42 **reconstructed image**: *Image* produced by applying the *decoding process*.

3.43 **residual latent tensor**: Difference between the latent tensor elements and the latent prediction tensor elements.

3.44 **sample**: One element in the two-dimensional array that comprises a component.

4 Abbreviations

For the purposes of this Recommendation | International Standard, the following abbreviations apply:

AI	Artificial Intelligence
CAB	Convolution-based Attention Block
CDF	Cumulative Distribution Function
CSV	Comma-Separated Values
DWT	Discrete Wavelet Transform
EFE	Enhancement Filter Extensions
ICCI	Inter Channel Correlation Information
LEF	Luma Edge Filter
LRB	Lightweight Residual Block
LSB	Least Significant Bit
LSBS	Latent Scale Before Synthesis
MCM	Multistage Context Modelling
MSB	Most Significant Bit
ONNX	Open Neural Network Exchange
PDF	Probability Distribution Function
RB	Residual Block
RVS	Residual and Variance Scaling
TAB	Transformer-based Attention Block
TAM	Transformer-based Attention Module

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