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Information technology — Scalable compression and coding of continuous-tone still images —

Part 7: HDR Floating-Point Coding

Technologies de l'information — Compression échelonnable et codage d'images plates en ton continu —

Partie 7: Codage de la virgule flottante en HDR

Reference number
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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 18477-7:2016), of which it constitutes a minor revision. The changes compared to the previous edition are as follows:

— a definition has been added for the term "horizontal subsampling factor" as 3.1.31;

— notes to entry have been added to terms throughout Clause 3;

— text in F.3 and F.4.2 has been modified;

— minor editorial changes.

A list of all the parts in the ISO/IEC 18477 series can be found on the ISO website.

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Introduction

This document specifies a coded codestream format for storage of continuous-tone high and low dynamic range photographic content. JPEG XT part 7 is a scalable image coding system supporting multiple component images consisting of floating-point samples. It is by itself an extension of the coding tools defined in ISO/IEC 18477-1 and the box-based format defined in ISO/IEC 18477-3; the codestream is composed in such a way that legacy applications conforming to Rec. ITU-T T.81 | ISO/IEC 10918-1 are able to reconstruct a lower quality, low dynamic range, eight bits per sample version of the image. This standard low dynamic range image is typically constructed at the encoder side by tone mapping from the high dynamic image; while the LDR image is always present, this document does not define a process that generates this image.

Today, the most widely used digital photography format, a minimal implementation of JPEG (specified in Rec. ITU-T T.81 | ISO/IEC 10918-1), uses a bit depth of 8; each of the three channels that together compose an image pixel is represented by eight bits, providing 256 representable values per channel. If the dynamic range of the input scene is too large, however, an integer sample representation is no longer applicable and sample values need to be specified in floating-point. These values typically are, or are proportional to physical radiance values of three primaries. These primaries may be device specific physical colours, or may be the basis of the CIE XYZ colourspace.

JPEG XT is primarily designed to provide coded data containing high dynamic range and wide colour gamut content while simultaneously providing eight bits per pixel low dynamic range images using tools defined in ISO/IEC 18477-1. The goal is to provide a backwards compatible coding specification that allows legacy applications and existing tool chains to continue to operate on codestreams conforming to this document.

JPEG XT has been designed to be backwards compatible to legacy applications while at the same time having a small coding complexity; JPEG XT uses, whenever possible, functional blocks of Rec. ITU-T T.81 | ISO/IEC 10918-1 to extend the functionality of the legacy JPEG Coding System. It is optimized for storage and transmission of high dynamic range and wide colour gamut floating-point images while also enabling low-complexity encoder and decoder implementations.

This document is an extension of ISO/IEC 18477-1, a compression system for continuous- tone digital still images which is backwards compatible with Rec. ITU-T T.81 | ISO/IEC 10918-1. That is, legacy applications conforming to Rec. ITU-T T.81 | ISO/IEC 10918-1 will be able to reconstruct streams generated by an encoder conforming to this document, though will possibly not be able to reconstruct such streams in full dynamic range, full quality or other features defined in this document.

This document is itself based on ISO/IEC 18477-3, which defines a box-based file format similar to other JPEG standards. The aim of this document is to provide a migration path for legacy applications to support, potentially in a limited way, lossless coding and coding of high dynamic range images consisting of samples represented in floating-point. Existing tools depending on the existing standards will continue to work, but will only be able to reconstruct a lossy and/or a low dynamic range version of the image contained in the codestream. This document specifies a coded file format, referred to as JPEG XT, which is designed primarily for storage and interchange of continuous-tone photographic content

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Information technology — Scalable compression and coding of continuous-tone still images —

Part 7:
HDR Floating-Point Coding

1 Scope

This document specifies a coding format, referred to as JPEG XT, which is designed primarily for continuous-tone photographic content.

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 18477-1:2015, *Information technology — Scalable compression and coding of continuous-tone still images — Part 1: Scalable compression and coding of continuous-tone still images*

ISO/IEC 18477-2, *Information technology — Scalable compression and coding of continuous-tone still images — Part 2: Coding of high dynamic range images*

ISO/IEC 18477-3:2015, *Information technology — Scalable compression and coding of continuous-tone still images — Part 3: Box file format*

ISO/IEC 18477-6:2016, *Information technology — Scalable compression and coding of continuous-tone still images — Part 6: IDR Integer Coding*

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

Rec. ITU-T T.81 | ISO/IEC 10918–1:1994, *Information technology — Digital compression and coding of continuous-tone still images — Requirements and guidelines*

Rec. ITU-T BT.601, *Studio encoding parameters of digital television for standard 4:3 and wide screen 16:9 aspect ratios*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

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

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

— IEC Electropedia: available at http://www.electropedia.org/

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

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3.1.1
ASCII encoding
encoding of text characters and text strings according to ISO/IEC 10646

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.2
base decoding path
process of decoding legacy codestream and refinement data to the base image, jointly with all further steps until residual data is added to the values obtained from the residual codestream

Note 1 to entry: See ISO/IEC 18477-6.

3.1.3
base image
collection of sample values obtained by entropy decoding the DCT coefficients of the legacy codestream and the refinement codestream, and inversely DCT transforming them jointly

Note 1 to entry: See ISO/IEC 18477-6.

3.1.4
binary decision
choice between two alternatives

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.5
bitstream
partially encoded or decoded sequence of bits comprising an entropy-coded segment

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.6
block
8 × 8 array of samples or an 8 × 8 array of DCT coefficient values of one component

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.7
box
structured collection of data describing the image or the image decoding process embedded into one or multiple APP_{11} marker segments

Note 1 to entry: See ISO/IEC 18477-3:2015, Annex B.

3.1.8
byte
group of 8 bits

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.9
coder
embodiment of a coding process

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.10
coding
encoding or decoding

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

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3.1.11
coding model
procedure used to convert input data into symbols to be coded

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.12
(coding) process
general term for referring to an encoding process, a decoding process, or both

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.13
compression
reduction in the number of bits used to represent source image data

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.14
component
two-dimensional array of samples having the same designation in the output or display device

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

Note 2 to entry: An image typically consists of several components, e.g. red, green and blue.

3.1.15
continuous-tone image
image whose components have more than one bit per sample

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.16
data unit
8 × 8 block of samples of one component in DCT-based processes; a sample in lossless processes

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.17
decoder
embodiment of a decoding process

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.18
decoding process
process which takes as its input compressed image data and outputs a continuous-tone image

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.19
dequantization
inverse procedure to quantization by which the decoder recovers a representation of the DCT coefficients

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.20
discrete cosine transform
DCT
either the forward discrete cosine transform or the inverse discrete cosine transform

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

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3.1.21
downsampling
procedure by which the spatial resolution of a component is reduced

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.22
encoder
embodiment of an encoding process

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.23
encoding process
process which takes as its input a continuous-tone image and outputs compressed image data

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.24
entropy-coded (data) segment
independently decodable sequence of entropy encoded bytes of compressed image data

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.25
entropy decoder
embodiment of an entropy decoding procedure

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.26
entropy decoding
lossless procedure which recovers the sequence of symbols from the sequence of bits produced by the entropy encoder

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.27
entropy encoder
embodiment of an entropy encoding procedure

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.28
entropy encoding
lossless procedure which converts a sequence of input symbols into a sequence of bits such that the average number of bits per symbol approaches the entropy of the input symbols

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.29
grayscale image
continuous-tone image that has only one component

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.30
high dynamic range
image or image data comprised of samples using a floating-point representation

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3.1.31
horizontal subsampling factor
relative number of vertical data units of a particular component with respect to the number of horizontal data units in the other components in the frame

Note 1 to entry: See ISO/IEC 18477-1.

3.1.32
Huffman decoder
embodiment of a Huffman decoding procedure

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.33
Huffman decoding
entropy decoding procedure which recovers the symbol from each variable length code produced by the Huffman encoder

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.34
Huffman encoder
embodiment of a Huffman encoding procedure

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.35
Huffman encoding
entropy encoding procedure which assigns a variable length code to each input symbol

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.36
joint photographic experts group
JPEG
informal name of the committee which created this document

Note 1 to entry: The "joint" comes from the ITU-T and ISO/IEC collaboration.

3.1.37
legacy codestream
collection of markers and syntax elements defined by Rec. ITU-T T.81 | ISO/IEC 10918-1 bare any syntax elements defined by the family ISO/IEC 18477 standards

EXAMPLE The legacy codestream consists of the collection of all markers except those APP_{11} markers that describe JPEG XT boxes by the syntax defined in ISO/IEC 18477-3, Annex A.

Note 1 to entry: See ISO/IEC 18477-6.

3.1.38
legacy decoder
embodiment of a decoding process conforming to Rec. ITU-T T.81 | ISO/IEC 10918-1, confined to the lossy DCT process and the baseline, sequential or progressive modes, decoding at most four components to eight bits per component

Note 1 to entry: See ISO/IEC 18477-6.

3.1.39
lossless
descriptive term for encoding and decoding processes and procedures in which the output of the decoding procedure(s) is identical to the input to the encoding procedure(s)

Note 1 to entry: See ISO/IEC 18477-8.

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3.1.40
lossless coding
mode of operation which refers to any one of the coding processes defined in this document in which all of the procedures are lossless

Note 1 to entry: See ISO/IEC 18477-8.

3.1.41
lossy
descriptive term for encoding and decoding processes which are not lossless

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.42
low dynamic range
image or image data comprised of data with no more than eight bits per sample

Note 1 to entry: See ISO/IEC 18477-6.

3.1.43
marker
two-byte code in which the first byte is hexadecimal FF and the second byte is a value between 1 and hexadecimal FE

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.44
marker segment
marker together with its associated set of parameters

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.45
pixel
collection of sample values in the spatial image domain having all the same sample coordinates

Note 1 to entry: A pixel may consist of three samples describing its red, green and blue value.

Note 2 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.46
precision
number of bits allocated to a particular sample or DCT coefficient

3.1.47
procedure
set of steps which accomplishes one of the tasks which comprise an encoding or decoding process

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.48
quantization value
integer value used in the quantization procedure

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.49
quantize
act of performing the quantization procedure for a DCT coefficient

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

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3.1.50
residual decoding path
collection of operations applied to the entropy coded data contained in the residual data box and residual refinement scan boxes up to the point where this data is merged with the base image to form the final output image

Note 1 to entry: See ISO/IEC 18477-6.

3.1.51
residual image
sample values as reconstructed by inverse quantization and inverse DCT transformation applied to the entropy-decoded coefficients described by the residual scan and residual refinement scans

Note 1 to entry: See ISO/IEC 18477-6.

3.1.52
residual scan
additional pass over the image data invisible to legacy decoders which provides additive and/or multiplicative correction data of the legacy scans to allow reproduction of high dynamic range or wide colour gamut data

Note 1 to entry: See ISO/IEC 18477-6.

3.1.53
refinement scan
additional pass over the image data invisible to legacy decoders which provides additional least significant bits to extend the precision of the DCT transformed coefficients

Note 1 to entry: See ISO/IEC 18477-6.

3.1.54
sample
one element in the two-dimensional image array which comprises a component

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.55
sample grid
common coordinate system for all samples of an image

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

Note 2 to entry: The samples at the top left edge of the image have the coordinates (0,0), the first coordinate increases towards the right, the second towards the bottom.

3.1.56
scan
single pass through the data for one or more of the components in an image

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.57
scan header
marker segment that contains a start-of-scan marker and associated scan parameters that are coded at the beginning of a scan

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

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3.1.58
table specification data
coded representation from which the tables used in the encoder and decoder are generated and their destinations specified

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.59
(uniform) quantization
procedure by which DCT coefficients are linearly scaled in order to achieve compression

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.60
upsampling
procedure by which the spatial resolution of a component is increased

Note 1 to entry: See ISO/IEC 18477-1.

3.1.61
vertical subsampling factor
relative number of vertical data units of a particular component with respect to the number of vertical data units in the other components in the frame

Note 1 to entry: See ISO/IEC 18477-1.

3.1.62
zero byte
0×00 byte

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.1.63
zig-zag sequence
specific sequential ordering of the DCT coefficients from (approximately) lowest spatial frequency to highest

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

3.2 Symbols

X width of the sample grid in positions

Y height of the sample grid in positions

Nf number of components in an image

$s_{i,x}$ subsampling factor of component i in horizontal direction

$s_{i,y}$ subsampling factor of component i in vertical direction

H_i subsampling indicator of component i in the frame header

V_i subsampling indicator of component i in the frame header

$v_{x,y}$ sample value at the sample grid position x,y

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R_h additional number of DCT coefficient bits represented by refinement scans in the legacy decoding path, $8 + R_h$ is the number of non-fractional bits (i.e. bits in front of the "binary dot") of the output of the inverse DCT process in the legacy decoding path

R_r additional number of DCT coefficient bits represented by refinement scans in the residual decoding path. $p + R_r$ is the number of non-fractional bits of the output of the inverse DCT process in the residual decoding path, where p is the frame-precision of the residual image as recorded in the frame header of the residual codestream

R_b additional bits in the HDR image. $8 + R_b$ is the sample precision of the reconstructed HDR image

3.3 Abbreviated terms

ASCII American Standard Code for Information Interchange

LSB Least Significant Bit

MSB Most Significant Bit

HDR High Dynamic Range

LDR Low Dynamic Range

TMO Tone Mapping Operator

DCT Discrete Cosine Transformation

4 Conventions

4.1 Conformance language

This document consists of normative and informative text.

Normative text is that text which expresses mandatory requirements. The word "shall" is used to express mandatory requirements strictly to be followed in order to conform to this document and from which no deviation is permitted. A conforming implementation is one that fulfils all mandatory requirements.

Informative text is text that is potentially helpful to the user, but not indispensable and can be removed, changed or added editorially without affecting interoperability. All text in this document is normative, with the following exceptions: the Introduction, any parts of the text that are explicitly labelled as "informative", and statements appearing with the preamble "NOTE" and behaviour described using the word "should". The word "should" is used to describe behaviour that is encouraged but is not required for conformance to this document.

The keywords "may" and "need not" indicate a course of action that is permissible in a conforming implementation.

The keyword "reserved" indicates a provision that is not specified at this time, shall not be used, and may be specified in the future. The keyword "forbidden" indicates "reserved" and in addition indicates that the provision will never be specified in the future.

4.2 Operators

NOTE Many of the operators used in this document are similar to those used in the C programming language.

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