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Information technology — JPEG XS low-latency lightweight image coding system —

Part 1: Core coding system

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Partie 1: Système de codage de noyau

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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 third edition cancels and replaces the second edition (ISO/IEC 21122-1:2022), which has been technically revised.

The main changes are as follows:

— coding tools for improving the compression rates for screen content images have been added;

— coding tools that enable lossless coding of images with up to 16 bits per sample have been added.

A list of all parts in the ISO/IEC 21122 series can be found on the ISO 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 and www.iec.ch/national-committees.

Information technology — JPEG XS low-latency lightweight image coding system —

Part 1: Core coding system

1 Scope

This document specifies the syntax and an accompanying decompression process that is capable to represent continuous-tone grey-scale, or continuous-tone colour digital images without visual loss at moderate compression rates. Typical compression rates are between 2:1 and 18:1 but can also be higher depending on the nature of the image. In particular, the syntax and the decoding process specified in this document allow lightweight encoder and decoder implementations that limit the end-to-end latency to a fraction of the frame size. However, the definition of transmission channel buffer models necessary to ensure such latency is beyond the scope of this document.

This document:

— specifies decoding processes for converting compressed image data to reconstructed image data;

— specifies a codestream syntax containing information for interpreting the compressed image data;

— provides guidance on encoding processes for converting source image data to compressed image data.

2 Normative references

There are no normative references in this document.

3 Terms and definitions, abbreviated terms and symbols

3.1 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

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

3.1.1
band
input data to a specific *wavelet filter type* (3.1.54) that contributes to the generation of one of the *components* (3.1.14) of the image

3.1.2
band type
single number collapsing the information on the component, and horizontal and vertical wavelet filter types that are applied in the filter cascade reconstructing spatial image samples from inversely quantized wavelet coefficients

3.1.3
bit
binary choice encoded as either 0 or 1

3.1.4
bitplane
array of bits having all the same significance

3.1.5
bitplane count
number of significant bitplanes of a code group, counting from the LSB up to the most significant, non-empty bitplane

3.1.6
bitplane count subpacket
subset of a packet which decodes to the bitplane counts of all code groups within a packet, followed by padding and optional filler bytes

Note 1 to entry: See subclause C.5.3.

3.1.7
byte
group of 8 bits

3.1.8
colour filter array
CFA
rectangular array of sensor elements yielding a 1-component image where the colour to which a sensor element is sensitive to depends on the position of the sensor element

3.1.9
codestream
compressed image data representation that includes all necessary data to allow a (full or approximate) reconstruction of the sample values of a digital image

3.1.10
code group
group of quantization indices in sign-magnitude representation before inverse quantization

3.1.11
coefficient
input value to the inverse wavelet transformation resulting from inverse quantization

3.1.12
coefficient group
number of horizontally adjacent wavelet coefficients from the same band

3.1.13
column
set of vertically aligned precincts

3.1.14
component
two-dimensional array of samples having the same designation such as red, green or blue in the output or display device

3.1.15
compression
process of reducing the number of bits used to represent source image data

3.1.16
continuous-tone image
image whose components have more than one bit per sample

3.1.17
data subpacket
subset of a packet which consists of the quantization index magnitudes, followed by padding and optional filler bytes

Note 1 to entry: See subclause C.5.4.

3.1.18
deadzone quantizer
quantizer whose zero bucket has a size different from all other buckets

3.1.19
decoder
embodiment of a decoding process

3.1.20
decoding process
process which takes as its input a codestream and outputs a continuous-tone image

3.1.21
decomposition level
number of times a wavelet filter is applied to reconstruct image data from wavelet coefficients

3.1.22
encoder
embodiment of an encoding process

3.1.23
encoding process
process which outputs compressed image data in the form of a codestream

3.1.24
filler bytes
integer number of bytes a decoder will skip over on decoding without interpreting the values of the bytes itself

3.1.25
intra coding
coding process which decodes data independent from data decoded in a previous frame

Note 1 to entry: ISO/IEC 21122-1:2022 only defined intra coding tools.

3.1.26
inverse quantization
inverse procedure to quantization by which the decoder recovers a representation of the coefficients

3.1.27
inverse reversible multiple component transformation
inverse RCT
inverse transform across multiple component sample values located at the same sample grid point that is invertible without loss

Note 1 to entry: See subclauses F.3 and F.4.

3.1.28
LL band
input to a series of wavelet filters where only inverse low-pass filters are applied in horizontal and vertical direction

3.1.29
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)

3.1.30
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

3.1.31
lossy
descriptive term for encoding and decoding processes which are not lossless

3.1.32
packet
segment of the codestream containing entropy coded information on a single precinct, line and a subset of the bands within this precinct and line

3.1.33
padding
bits within the codestream whose only purpose is to align syntax elements to byte boundaries and that carry no information

3.1.34
precinct
collection of quantization indices of all bands contributing to a given spatial region of the image

3.1.35
precision
number of bits allocated to a particular sample, coefficient, or other binary numerical representation

3.1.36
procedure
set of steps which accomplishes one of the tasks which comprise an encoding or decoding process

3.1.37
quantization
method of reducing the precision of the individual coefficients

3.1.38
quantization index
input to the inverse quantization process which reconstructs the quantization index to a wavelet coefficient

3.1.39
quantization index magnitude
absolute value of a quantization index

3.1.40
sample
one element in the two-dimensional image array which comprises a component

3.1.41
sample grid
common coordinate system for all samples of an image, 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

3.1.42
sign subpacket
subset of a packet that consists of the sign information of all non-zero quantization indices within a packet, followed by padding and optional filler bytes

Note 1 to entry: See subclause C.5.5.

3.1.43
significance
attribute of code groups that applies if, depending on the Run Mode flag in the picture header, either at least one of coefficients in the code group is non-zero, or the bitplane count prediction residual of the code group is non-zero

3.1.44
significance group
group of a horizontally adjacent code groups sharing the same significance information in the significance subpacket

3.1.45
significance subpacket
subset of a packet that identifies which significance groups within a packet are insignificant, followed by padding and optional filler bytes

Note 1 to entry: see subclause C.5.2

3.1.46
slice
integral number of precincts whose wavelet coefficients can be entropy-decoded independently

3.1.47
star-tetrix
decorrelation transformation that combines a spatial with an inter-component decorrelation transformation particularly tuned for CFA pattern compression

Note 1 to entry: see subclause F.5

3.1.48
subpacket
substructure of a packet containing information of one or multiple bands of one line of a single precinct

3.1.49
super pixel
2×2 arrangement of sensor elements in a CFA pattern array containing at least one sensor element for each colour filter type

3.1.50
temporal differential coding
TDC
coding process which decodes a differential signal relative to a sample decoded in a previous frame

3.1.51
truncation position
number of least significant bitplanes not included in the quantization index of a wavelet coefficient

3.1.52
uniform quantizer
quantizer whose buckets are all of equal size

3.1.53
upsampling
procedure by which the spatial resolution of a component is increased

3.1.54
wavelet filter type
single number that uniquely identifies each element of the wavelet filter with regard to the number and type of horizontal and vertical decompositions

Note 1 to entry: Unlike the band type, the wavelet filter type does not include component information.

3.2 Abbreviated terms

JPEG XS	informal name of this standard where XS stands for “extra speed”
LSB	least significant bit
MSB	most significant bit

3.3 Symbols

$B[i]$	bit precision of component i
β	wavelet filter type
b	band type
$b_x[\beta,i]$	band existence flag for filter type β in component i. 1 if the filter exists, 0 otherwise.
$b'_x[b]$	band existence flag for band type b. 1 if the filter exists, 0 otherwise.
B_w	nominal overall bit precision of the wavelet coefficients
B_r	number of bits required to encode a bitplane count in raw
C_{pih}	colour transformation type
$c[p,\lambda,b,x]$	wavelet coefficient residual in precinct p, line λ, band b and position x
$c'[p,\lambda,b,x]$	wavelet coefficient in precinct p, line λ, band b and position x
C_s	width of precincts other than the rightmost precinct in sample grid positions
C_t	colour transformation CFA pattern type derived from the component registration
C_f	colour transformation reflection and extension flags
C_w	width of precincts in multiples of 8 LL subsampled band sample grid positions
$D[p,b]$	bitplane count coding mode of band b in precinct p
$D_i[p,b]$	TDC mode of band b in precinct p
$D_r[p,s]$	raw coding mode override flag for packet s in precinct p
DCO	DC offset
$d_x[\beta,i]$	horizontal decomposition level of wavelet filter type β of component i
$d_y[\beta,i]$	vertical decomposition level of wavelet filter type β of component i
$\delta_x[c]$	horizontal position of component c in a CFA super pixel
$\delta_y[c]$	vertical position of component c in a CFA super pixel

E	exponent of the slope of the linear region of the extended non-linearity
e_1	colour transformation exponent of first chroma component
e_2	colour transformation exponent of second chroma component
$f[p,\lambda,b,x]$	contents of the frame buffer at precinct p, line λ, band b and position x
Fs	sign packing flag
$Fslc$	slice coding mode
F_q	number of fractional bits in the representation of wavelet coefficients
$G[b]$	gain of band b
$G_r[b]$	gain of band b under forced refresh
$H_b[\beta,k]$	height of filter type β of component k in wavelet coefficients
$H_c[i]$	height of the component i in sample points
H_f	height of the image in sampling grid points
H_p	height of a precinct in lines
H_{sl}	height of a slice in precincts
I_{sl}	slice TDC flag, set if wavelet coefficients within a slice may use TDC
$I[p,\lambda,b,s]$	line inclusion flag, set if line λ of band b and precinct p is included in packet s, reset otherwise
$k[\delta_x, \delta_y]$	component within CFA super pixel at position δ_x, δ_y
$L_0[p,b]$	first line of band b in precinct p
$L_1[p,b]$	last line + 1 of band b in precinct p
$Lcod$	codestream length in bytes
$L_{cnt}[p,s]$	size of the bitplane count subpacket of precinct p and packet s in bytes
$L_{dat}[p,s]$	size of the data subpacket of precinct p and packet s in bytes
L_h	long header flag in in the picture header, set if long headers are enforced, reset otherwise
$L_{prc}[p]$	length of the entropy coded data in precinct p
$L_{sgn}[p,s]$	size of the sign subpacket of precinct p and packet s in bytes
$L_{sig}[p,s]$	size of the significance subpacket of precinct p and packet s in bytes
$M[p,\lambda,b,g]$	bitplane count of precinct p, line λ, band b and code group g
$M_{top}[p,\lambda,b,g]$	vertical predictor of the bitplane count of precinct p, line λ, band b and code group g
N_c	number of components in an image
$N_{cg}[p,b]$	number of code groups in precinct p and band b
N_β	number of bands per component

N_g	number of coefficients in a code group
$N_i[p,b]$	number of TDC selection groups per line in band b of precinct p
$N_s[p,b]$	number of significance groups per line in band b of precinct p
$N_p[t]$	number of precincts in slice t
N_L	number of bands in the wavelet decomposition of the image (wavelet filter types times components)
$N_{L,x}$	maximal number of horizontal decomposition levels
$N'_{L,x}[i]$	number of horizontal decomposition levels of component i
$N_{L,y}$	maximal number of vertical decomposition levels over all components
$N'_{L,y}[i]$	number of vertical decomposition levels of component i
$N_{p,x}$	number of precincts per sampling grid line
$N_{p,y}$	number of precincts per sampling grid column
$N_{pc}[p]$	number of packets in precinct p
$O[c,x,y]$	unscaled output of the inverse wavelet transformation at coordinates x and y of the component c
$\Omega[c,x,y]$	output of the inverse multiple component transformation at position x,y for component c
$P[b]$	priority of band b
$P_r[b]$	priority of band b under forced refresh
Plev	level a particular codestream complies to
Ppih	profile a particular codestream complies to
Ppoc	progression order in which bands are transmitted in the codestream
$Q[p]$	quantization parameter of precinct p
$Q_f[p]$	quantization parameter to which precinct p will be quantized for storage in the frame buffer
$Q'_f[p]$	quantization parameter of the data stored in the frame buffer corresponding to precinct p
Q_{bi}	quantization adjustment for intra-coded coefficients that are intra-coded due to a rate-decision
Q_{br}	quantization adjustment for intra-coded coefficients that are intra-coded due to refresh, overriding any rate-based TDC decision
Q_{pih}	quantization type of the image
R_l	raw-mode selection per packet flag
Rm	run mode used for significance coding
$R[p]$	refinement of precinct p
$R_f[p]$	refinement parameter of the quantization to which precinct p will be quantized for storage in the frame buffer

$R'_f[p]$	refinement parameter of the quantization of the data stored in the frame buffer corresponding to precinct p
$R[c,x,y]$	reconstructed sample value at position x,y for component c
S_d	number of components for which wavelet decomposition is suppressed
$S_h[b]$	intra refresh hash mask exponent of band b
S_i	size of a TDC selection group in code groups
S_s	size of a significance group in code groups
$s_x[i]$	sampling factor of component i in horizontal direction
$s_y[i]$	sampling factor of component i in vertical direction
$s[p,\lambda,b,x]$	sign of the wavelet coefficient in precinct p, line λ, band b and position x.
$T1$	first threshold of the extended non-linearity
$T2$	second threshold of the extended non-linearity
$T[p,b]$	truncation position of precinct p and band b
$T_{top}[p,b]$	vertical truncation position predictor of precinct p and band b
$T[\beta,x,y]$	temporary wavelet coefficient of filter type β at location x,y.
$v[x,y]$	sample value at the sample grid position x,y
$v[p,\lambda,b,x]$	quantization index magnitude of the wavelet coefficient in precinct p, line λ, band b and position x
$W_b[\beta,k]$	width of filter type β of component k in wavelet coefficients
$W_c[i]$	width of component i in samples
W_f	width of the image in sampling grid points
$W_p[p]$	width of the precinct p in sampling grid points
$W_{pb}[p,b]$	width of band b of precinct p in coefficients
Wt_x	wavelet filter type for horizontal filtering
Wt_y	wavelet filter type for vertical filtering
$X[y]$	one-dimensional temporal array of wavelet coefficients
$Xcrg[c]$	horizontal component registration of component c relative to the sample grid
$Ycrg[c]$	vertical component registration of component c relative to the sample grid
Ysl	slice index enumerating slices contiguously from top to bottom, starting at 0
$Y[p,\lambda,b,k]$	TDC selection flag of precinct p, line λ, band b and TDC selection group k
$Y_h[b]$	intra refresh position hash of band b
$Z[p,\lambda,b,j]$	significance flag of precinct p, line λ, band b and significance group j

4 Conventions

4.1 Conformance language

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 document are similar to those used in the C programming language.

4.2.1 Arithmetic operators

& bitwise AND operation

\+ addition

− subtraction (as a binary operator) or negation (as a unary prefix operator)

× multiplication

/ division without truncation or rounding

<< left shift: $x<<s$ is defined as $x \times 2^s$

>> right shift: $x>>s$ is defined as $\lfloor x/2^s \rfloor$

umod x umod a is the unique value y between 0 and $a-1$ for which $y+Na = x$ with a suitable integer N

4.2.2 Logical operators

|| logical OR

&& logical AND

! logical NOT

4.2.3 Relational operators

> greater than

≥ greater than or equal to

< less than

≤ less than or equal to

== equal to

!= not equal to

4.2.4 Precedence order of operators

NOTE Operators are listed below in descending order of precedence. If several operators appear in the same line, they have equal precedence. When several operators of equal precedence appear at the same level in an expression, evaluation proceeds according to the associativity of the operator either from right to left or from left to right.