INTERNATIONAL STANDARD

ISO/IEC 15444-5

Second edition
2015-10-15

Information technology — JPEG 2000 image coding system: Reference software

Technologies de l'information — Système de codage d'images JPEG 2000: Logiciel de référence

Reference number
ISO/IEC 15444-5:2015(E)

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Published in Switzerland

Foreword

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The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

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.

ISO/IEC 15444-5 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 29, *Coding of audio, picture, multimedia and hypermedia information*, in collaboration with ITU-T. The identical text is published as ITU-T Rec. T.804.

This second edition cancels and replaces the first edition (ISO 15444-5:2003), which has been technically revised. It also incorporates ISO/IEC 15444-5:2003/Amd.1:2003 and ISO/IEC 15444-5:2003/Amd.2:2015.

ISO/IEC 15444 consists of the following parts, under the general title *Information technology — JPEG 2000 image coding system*:

— *Part 1: Core coding system*

— *Part 2: Extensions*

— *Part 3: Motion JPEG 2000*

— *Part 4: Conformance testing*

— *Part 5: Reference software*

— *Part 6: Compound image file format*

— *Part 8: Secure JPEG 2000*

— *Part 9: Interactivity tools, APIs and protocols*

— *Part 10: Extensions for three-dimensional data*

— *Part 11: Wireless*

— *Part 12: ISO base media file format*

— *Part 13: An entry level JPEG 2000 encode*

— *Part 14: XML representation and reference*

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Electronic attachment: JASPER, JJ2000, OPENJPEG reference packages

INTERNATIONAL STANDARD
ITU-T RECOMMENDATION

Information technology – JPEG 2000 image coding system: Reference software

1 Scope

Rec. ITU-T T.800 | ISO/IEC 15444-1[1] defines a set of lossless and lossy compression methods for coding continuous-tone, bi-level, greyscale or colour digital still images. This Recommendation | International Standard provides three independently created software reference implementations of Rec. ITU-T T.800 | ISO/IEC 15444-1, in order to assist implementers of Rec. ITU-T T.800 | ISO/IEC 15444-1 in testing and understanding its content. The packages are JASPER, JJ2000 and OPENJPEG.

The reference software packages are informative only. This Recommendation | International Standard does not define any additional part of the JPEG 2000 image coding system.

Each version of the reference software contains source code, which may be compiled to provide the following functionality:

- transcoding from selected, widely available image formats into a JPEG 2000 codestream;
- transcoding from selected, widely available image formats into the JP2 file format;
- selection of a wide range of JPEG 2000 encoding options (as documented in each reference software);
- decoding from a JPEG 2000 codestream to a range of selected widely available image formats;
- Processing of a JP2 file to extract a JPEG 2000 codestream for decoding and conversion to a range of selected widely available image formats.
- The ability to extract metadata from a JP2 file, including the contents of the Image Header box and the colour space.
- The decoding of JP2 files that use the Three-Component Matrix-Based form of the Restricted ICC method for the specification of colour space and the conversion of the decoded image data to the sRGB colour space for display, including limited upsampling of all decoded components to the same resolution.
- The decoding of JP2 files that use the Monochrome form of the Restricted ICC method for the specification of colour space and the conversion of the decoded image data to the sRGB based greyscale space as defined within the JP2 file format.
- The decoding of JP2 files that use the sYCC colour space and the conversion of the decoded image data to the sRGB colour space for display, including upsampling of all decoded components to the same resolution.
- some additional tools to help with evaluation and testing.

The reference software is intended for use as a testing and validation tool for other implementations of JPEG 2000, and to help in the understanding of Rec. ITU-T T.800 | ISO/IEC 15444-1. Although components of the reference software may find application in software intended for product development, this was not an objective of the development of this software, and prospective implementers are cautioned against making any estimations of performance or resource usage based on the reference software.

2 Normative references

The following Recommendations and International Standards contain provisions which, through reference in this text, constitute provisions of the 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.

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[1] This Specification includes an electronic attachment containing the JASPER, JJ2000 and OPENJPEG reference packages.

2.1 Identical Recommendations | International Standards

– ITU-T Recommendation T.800 (2002) | ISO/IEC 15444-1:2002, *Information technology – JPEG 2000 Image Coding System: Core coding system*.

2.2 Additional references

– ISO/IEC 9899:1999, *Programming languages – C*.

– ISO/IEC 9945-1:1996, *Information technology – Portable Operating System Interface (POSIX) – Part 1: System Application Program Interface (API) (C language)*.

– ISO/IEC 9945-2:1993, *Information technology – Portable Operating System Interface (POSIX) – Part 2: Shell and utilities*.

3 Definitions

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

3.1 **big endian**: The bits of a value representation occur in order from most significant to least significant.

3.2 **bit**: A contraction of the term "binary digit"; a unit of information represented by a zero or a one.

3.3 **bit-plane**: A two-dimensional array of bits. In this Recommendation | International Standard, a bit-plane refers to all the bits of the same magnitude in all coefficients or samples. This could refer to a bit-plane in a component, tile-component, code-block, region of interest, or other.

3.4 **bit stream**: The actual sequence of bits resulting from the coding of a sequence of symbols. It does not include the markers or marker segments in the main and tile-part headers or the EOC marker. It does include any packet headers and in stream markers and marker segments not found within the main or tile-part headers.

3.5 **box**: A portion of the file format defined by a length and unique box type. Boxes of some types may contain other boxes.

3.6 **box contents**: Refers to the data wrapped within the box structure. The contents of a particular box are stored within the DBox field within the Box data structure.

3.7 **byte**: Eight bits.

3.8 **channel**: One logical component of the image. A channel may be a direct representation of one component from the codestream, or may be generated by the application of a palette to a component from the codestream.

3.9 **code-block**: A rectangular grouping of coefficients from the same subband of a tile-component.

3.10 **coder**: An embodiment of either an encoding or decoding process.

3.11 **codestream**: A collection of one or more bit streams and the main header, tile-part headers, and the EOC required for their decoding and expansion into image data. This is the image data in a compressed form with all of the signalling needed to decode.

3.12 **coefficient**: The values that are the result of a transformation.

3.13 **component**: A two-dimensional array of samples. An image typically consists of several components, for instance representing red, green and blue.

3.14 **compressed image data**: Part or all of a bit stream. Can also refer to a collection of bit streams in part or all of a codestream.

3.15 **decoder**: An embodiment of a decoding process, and optionally a colour transformation process.

3.16 **decoding process**: A process which takes as its input all or part of a codestream and outputs all or part of a reconstructed image.

3.17 **discrete wavelet transformation (DWT)**: A transformation that iteratively transforms one signal into two or more filtered and decimated signals corresponding to different frequency bands. This transformation operates on spatially discrete samples.

3.18 **encoder**: An embodiment of an encoding process.

3.19 **encoding process**: A process that takes as its input all or part of a source image data and outputs a codestream.

3.20 **file format**: A codestream and additional support data and information not explicitly required for the decoding of codestream. Examples of such support data include text fields providing titling, security and historical information, data to support placement of multiple codestreams within a given data file, and data to support exchange between platforms or conversion to other file formats.

3.21 **header**: Either a part of the codestream that contains only markers and marker segments (main header and tile-part header) or the signalling part of a packet (packet header).

3.22 **image**: The set of all components.

3.23 **image area**: A rectangular part of the reference grid, registered by offsets from the origin and the extent of the reference grid.

3.24 **image area offset**: The number of reference grid points down and to the right of the reference grid origin where the origin of the image area can be found.

3.25 **image data**: The components and component samples making up an image. Image data can refer to either the source image data or the reconstructed image data.

3.26 **irreversible**: A transformation, progression, system, quantization, or other process that, due to systemic or quantization error, disallows lossless recovery. An irreversible process can only lead to lossy compression.

3.27 **JP2**: The name of the file format defined by Rec. ITU-T T.800 | ISO/IEC 15444-1.

3.28 **JPEG**: Used to refer globally to the encoding and decoding process of the following Recommendations | International Standards:

- Recommendation ITU-T T.81 (1992) | ISO/IEC 10918-1:1994, Information technology – Digital compression and coding of continuous-tone still images: Requirements and guidelines.
- Recommendation ITU-T T.83 (1994) | ISO/IEC 10918-2:1995, Information technology – Digital compression and coding of continuous-tone still images: Compliance testing.
- Recommendation ITU-T T.84 (1996) | ISO/IEC 10918-3:1997, Information technology – Digital compression and coding of continuous-tone still images: Extensions.
- Recommendation ITU-T T.84 (1996)/Amd. 1 (1999), Information technology – Digital compression and coding of continuous-tone still images: Extensions – Amendment 1: Provisions to allow registration of new compression types and versions in the SPIFF header.
- Recommendation ITU-T T.86 (1998) | ISO/IEC 10918-4, Information technology – Digital compression and coding of continuous-tone still images: Registration of JPEG Profiles, SPIFF Profiles, SPIFF Tags, SPIFF colour Spaces, APPn Markers, SPIFF Compression types and Registration authorities (REGAUT).

3.29 **JPEG 2000**: Used to refer globally to the encoding and decoding processes in this Recommendation | International Standard and their embodiment in applications.

3.30 **layer**: A collection of compressed image data from coding passes of one, or more, code-blocks of a tile-component. Layers have an order for encoding and decoding that must be preserved.

3.31 **lossless**: A descriptive term for the effect of the overall encoding and decoding processes in which the output of the decoding process is identical to the input to the encoding process. Distortion free restoration can be assured. All of the coding processes or steps used for encoding and decoding are reversible.

3.32 **lossy**: A descriptive term for the effect of the overall encoding and decoding processes in which the output of the decoding process is not identical to the input to the encoding process. There is distortion (measured mathematically). At least one of the coding processes or steps used for encoding and decoding is irreversible.

3.33 **marker**: A two-byte code in which the first byte is hexadecimal FF (0xFF) and the second byte is a value between 1 (0x01) and hexadecimal FE (0xFE).

3.34 **marker segment**: A marker and associated (not empty) set of parameters.

3.35 **packet**: A part of the bit stream comprising a packet header and the compressed image data from one layer of one precinct of one resolution level of one tile-component.

3.36 **packet header**: Portion of the packet that contains signalling necessary for decoding that packet.

3.37 **precinct**: A one rectangular region of a transformed tile-component, within each resolution level, used for limiting the size of packets.

3.38 **precision**: Number of bits allocated to a particular sample, coefficient, or other binary numerical representation.

3.39 **progression**: The order of a codestream where the decoding of each successive bit contributes to a "better" reconstruction of the image. What metrics make the reconstruction "better" is a function of the application. Some examples of progression are increasing resolution or improved sample fidelity.

3.40 **quantization**: A method of reducing the precision of the individual coefficients to reduce the number of bits used to entropy code them. This is equivalent to division while compressing and multiplying while decompressing. Quantization can be achieved by an explicit operation with a given quantization value or by dropping (truncating) coding passes from the codestream.

3.41 **raster order**: A particular sequential order of data of any type within an array. The raster order starts with the top left data point and moves to the immediate right data point, and so on, to the end of the row. After the end of the row is reached, the next data point in the sequence is the left-most data point immediately below the current row. This order is continued to the end of the array.

3.42 **reconstructed image**: An image that is the output of a decoder.

3.43 **reconstructed sample**: A sample reconstructed by the decoder. This always equals the original sample value in lossless coding but may differ from the original sample value in lossy coding.

3.44 **reference grid**: A regular rectangular array of points used as a reference for other rectangular arrays of data. Examples include components and tiles.

3.45 **reference tile**: A rectangular sub-grid of any size associated with the reference grid.

3.46 **region of interest (ROI)**: A collection of coefficients that are considered of particular relevance by some user defined measure.

3.47 **resolution level**: Equivalent to decomposition level with one exception: the LL subband is also a separate resolution level.

3.48 **reversible**: A transformation, progression, system, or other process that does not suffer systemic or quantization error and, therefore, allows lossless signal recovery.

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

3.50 **source image**: An image used as input to an encoder.

3.51 **subband**: A group of transform coefficients resulting from the same sequence of low-pass and high-pass filtering operations, both vertically and horizontally.

3.52 **subband coefficient**: A transform coefficient within a given subband.

3.53 **tile**: A rectangular array of points on the reference grid, registered with and offset from the reference grid origin and defined by a width and height. The tiles which overlap are used to define tile-components.

3.54 **tile-component**: All the samples of a given component in a tile.

3.55 **tile index**: The index of the current tile ranging from zero to the number of tiles minus one.

3.56 **transformation**: A mathematical mapping from one signal space to another.

4 Abbreviations and symbols

4.1 Abbreviations

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

ICC	International Colour Consortium
ICT	Irreversible Colour transformation
JPEG	Joint Photographic Experts Group – The joint ISO/ITU committee responsible for developing standards for continuous-tone still picture coding. It also refers to the standards produced by this committee: Rec. ITU-T T.81 | ISO/IEC 10918-1, Rec. ITU-T T.83 | ISO/IEC 10918-2, Rec. ITU-T T.84 | ISO/IEC 10918-3 and Rec. ITU-T T.87 | ISO/IEC 14495-1.
JURA	JPEG Utilities Registration Authority
1D-DWT	One-dimensional Discrete Wavelet Transformation
FDWT	Forward Discrete Wavelet Transformation
IDWT	Inverse Discrete Wavelet Transformation

LSB	Least Significant Bit
MSB	Most Significant Bit
PCS	Profile Connection Space
RCT	Reversible Colour Transformation
ROI	Region of Interest
SNR	Signal to Noise Ratio
UCS	Universal Character Set
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
UTF-8	UCS Transformation Format 8
UUID	Universal Unique Identifier
XML	Extensible Markup Language
W3C	World-Wide Web Consortium

4.2 Symbols

For the purposes of this Recommendation | International Standard, the following symbols apply.

0x----	Denotes a hexadecimal number
\nnn	A three-digit number preceded by a backslash indicates the value of a single byte within a character string, where the three digits specify the octal value of that byte
COC	Coding style component marker
COD	Coding style default marker
COM	Comment marker
CRG	Component registration marker
EPH	End of packet header marker
EOC	End of codestream marker
PLM	Packet length, main header marker
PLT	Packet length, tile-part header marker
POC	Progression order change marker
PPM	Packed packet headers, main header marker
PPT	Packed packet headers, tile-part header marker
QCC	Quantization component marker
QCD	Quantization default marker
RGN	Region of interest marker
SIZ	Image and tile size marker
SOC	Start of codestream marker
SOP	Start of packet marker
SOD	Start of data marker
SOT	Start of tile-part marker
TLM	Tile-part lengths marker

5 Conventions

The source files provided are supplied in the form of an individual zip file for each source tree. File locations given in this Recommendation | International Standard are expressed relative to the top level of the corresponding source tree. A Unix style file structure and delimiters are assumed.

Basic instructions are provided within the reference software for the installation and compilation of the sources under a variety of operating systems and platforms. No support can be provided by ISO | ITU-T beyond that offered in this Recommendation | International Standard and through links on the official JPEG web site, http://www.jpeg.org.

6 General description

Three independent and separate software source trees are provided. These are:

– JASPER.ZIP, provided as indicated in the file COPYRIGHT, contained within the zip file. This is written in the C programming language, and should compile and run on any platform with a C language implementation conforming to ISO/IEC 9899:1999, and supporting a subset of the POSIX C API, ISO/IEC 9945-1:1996.

– JJ2000.ZIP, provided as indicated in the file COPYRIGHT, contained within the zip file. This is written in the Java programming language, and executes under versions of the Java Virtual Machine (JVM) from version 1.1.1 onwards.

– OPENJPEG.ZIP, provided as indicated in the file LICENSE, contained within the zip file. This is written in the C programming language, and compiles and runs on any platform with a C language implementation conforming to ISO/IEC 9899:1999 (a.k.a. C99).

The supplied executables are described briefly in clause 8, and in more detail with some information about the supplied source code in Annex A (JasPer), Annex B (JJ2000) and Annex C (OpenJPEG).

These three distributions have been tested as meeting the coding and decoding requirements for codestreams identified in Rec. ITU-T T.800 | ISO/IEC 15444-1. Formal compliance is beyond the scope of this Recommendation | International Standard.

7 Copyright and licensing

These software modules were originally developed by the parties indicated in the file **COPYRIGHT** or **LICENSE** within each package forming a part of this Recommendation | International Standard, in the course of development of Rec. ITU-T T.800 | ISO/IEC 15444-1. These software modules are separate and discrete implementations of Rec. ITU-T T.800 | ISO/IEC 15444-1. ITU-T and ISO/IEC draw the attention of the users of these software modules to the license terms and conditions specified in the file **LICENSE** in each implementation. Those intending to use these software modules in hardware or software products are advised that their use may infringe existing patents. In particular, the original developers of these software modules and their respective companies, the editors and their companies, and ITU and ISO/IEC have disclaimed liability for any proposed use of these software modules or modifications thereof. No licensing is implied for their use in whole or in part in products that fail to conform to Rec. ITU-T T.800 | ISO/IEC 15444-1. The original software authors retain full rights to use the code within this Recommendation | International Standard for their own purposes, to assign or donate the code to a third party and to inhibit third parties from using the code for products that fail to conform to Rec. ITU-T T.800 | ISO/IEC 15444-1.

The three distributions have differing copyright and licensing restrictions, which reflect the different requirements and operating environments of those organizations that have contributed to the development of the software.

8 Platform requirements

The three reference software implementations have been successfully built on a variety of operating platforms and with a selection of compilers. They have been written with portability and comprehensibility in mind. Platforms for which there is specific installation documentation are indicated below.

8.1 JasPer requirements

JasPer has been successfully compiled in the following environments:

– Red Hat Linux 7.0, GNU C 2.96, GNU Make 3.79.1.

– SunOS/SPARC 5.5.1, GNU C 2.7.2.1, SunOS make.

– SunOS/SPARC 5.7, GNU C 2.95, SunOS make.

– Windows 2000 Professional, Microsoft Visual C 6.0.

– Windows 98 Second Edition, Cygwin 1.1.8.2, GNU Bash 2.04, GNU C 2.95, GNU Make 3.79.1.

8.2 JJ2000 requirements

JJ2000 has been tested on versions of the Java™ Virtual Machine from version 1.1.1 and later, on a variety of platforms including Sun Solaris, Microsoft Windows 95/98/NT/2000, Linux, and MacOS, using Sun's Java Development Kit (JDK),

Sun's Java Runtime Environment (JRE) and Microsoft's Java Virtual Machine (JVM). Detailed instructions on how to set up and run the JJ2000 executables are included in the file **README** in the top level of the JJ2000 source tree.

8.3 OpenJPEG requirements

OpenJPEG has been successfully compiled on a variety of platforms, including Windows XP, Windows Vista, Windows 7 and Windows 8, Mac OS X (up to 10.9, 32 and 64 bits) and Linux (Ubuntu and Debian). OpenJPEG uses CMake, a cross-platform build system, to configure, build and test the library and executables on the supported platforms.

9 Reference code structure

The three sets of reference software offer the capability to encode and decode codestreams and JP2 files that conform to the syntax defined in Rec. ITU-T T.800 | ISO/IEC 15444-1.

For transcoding to other image formats or for display, the three sets of reference software allow the user to assume in the absence of additional information that decoded codestream components are in the sRGB colour space or sRGB based greyscale.

The executable files described below are available by compiling the reference software as indicated in the **INSTALL** file held in the top level of each respective source tree. For each reference software, more than 30 optional different command line parameters may be defined, which can demonstrate aspects of the encoding for JPEG 2000 codestreams defined in Rec. ITU-T T.800 | ISO/IEC 15444-1.

9.1 JasPer executables

The JasPer reference software distribution provides three executables:

- **JASPER**, the transcoder which can be used to convert to and from a variety of image file formats including JPEG, Portable BitMap (PNM/PGM/PPM), Windows BMP, and Sun Rasterfile. The transcoder acts as both encoder and decoder for JPEG 2000 files.
- **IMGCMP**, provided as a test utility to measure differences between images and provide various measures of the comparative differences, such as SNR.
- **IMGINFO**, provided as a simple command line utility to analyse JPEG 2000 files.

9.2 JJ2000 executables

The JJ2000 software distributions provide two executables:

- **JJ2KEncoder**, which acts as an encoder from PGM, PPM and PGX to JPEG 2000 (both codestream and JP2 file format).

  NOTE – PGX is a non-standard format, defined in the JJ2000 documentation, that (unlike PGM) supports arbitrary bit-depths and signed sample values.
- **JJ2KDecoder**, which takes a JPEG 2000 codestream or JP2 file and decodes it to PGM, PPM, or PGX format. It can also take a number of optional parameters that emulate some of the partial decoding features that might be anticipated in a client server environment with restricted bandwidth communications. It is also capable of rendering the image to a screen display if no output file specification is provided, offering simple viewing capabilities for JPEG 2000 codestreams and JP2 files.

9.3 OpenJPEG executables

The OpenJPEG reference software distribution provides three main executables:

- opj_compress: converts from a pnm/pbm/pgm/ppm/pam/pgx/png/bmp/tif/raw/tga file to a j2k/jp2 file.
- opj_decompress: converts from a j2k/jp2 file to a pnm/pbm/pgm/ppm/pam/pgx/png/bmp/tif/raw/tga file.
- opj_dump: dumps information about the j2k/jp2 input file.

NOTE – In addition to these three executables, other executables are available. These executables provide additional features related to other parts of the JPEG 2000 standard, but they are beyond the scope of this Recommendation.

10 Intellectual Property

There is the possibility that, for some of the processes specified in Rec. ITU-T T.800 | ISO/IEC 15444-1 or Rec. ITU-T T.804 | ISO/IEC 15444-5 conformance or compliance may require use of an invention covered by patent