INTERNATIONAL STANDARD

ISO/IEC 15444-5

Third edition
2021-10

Information technology — JPEG 2000 image coding system —

Part 5: Reference software

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

Partie 5: Logiciel de référence

Reference number
ISO/IEC 15444-5:2021(E)

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Published in Switzerland

Foreword

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This document was prepared by ITU-T (as ITU-T REC. T.803) 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*.

This third edition cancels and replaces the second edition (ISO/IEC 15444-5:2015), which has been technically revised.

The main changes are as follows:

— addition of a software reference implementation of a High Throughput (HT) block coding algorithm specified in Rec. ITU-T T.814 | ISO/IEC 15444-15; and

— addition of a software reference implementation of a JPH file format specified in Rec. ITU-T T.814 | ISO/IEC 15444-15.

A list of all parts in the ISO/IEC 15444 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.

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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.

This Recommendation | International Standard also provides an independently created software reference implementation of Rec. ITU-T T.814 | ISO/IEC 15444-15, which specifies a high-throughput (HT) block coding algorithm that can be used in place of the block coding algorithm of Rec. ITU-T T.800 | ISO/IEC 15444-1, in order to assist implementers of Rec. ITU-T T.814 | ISO/IEC 15444-15 in testing and understanding its content. The package is TT.

This Recommendation | International Standard additionally provides an independently created software reference implementation for parsing of a JP2 file format specified in Rec. ITU-T T.800 | ISO/IEC 15444-1 and a JPH file format specified in Rec. ITU-T T.814 | ISO/IEC 15444-15, The package is Codestream-parser.

This Recommendation | International Standard does not define any additional part of the JPEG 2000 image coding system.

Each version of the J2K reference software contains source code, which can 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 TT-HTJ2K reference software contains source code, which can be compiled to provide the following functionality:

- Decoding from a HTJ2K codestream to a range of selected widely available image formats.

The codestream-parser reference software contains source code, which can provide the following functionality:

- Parsing of JP2 file format;
- Parsing of JPH file format.

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 and Rec. ITU-T T.814 | ISO/IEC 15444-15.

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[1] This Specification includes an electronic attachment containing the JASPER, JJ2000, OPENJPEG, TT, Codestream-parser reference packages.

2 Normative references

The following Recommendations and International Standards contain provisions which, through reference in this text, constitute provisions of this Recommendation | International Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. At the time of publication, the editions indicated in dated references 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

- Recommendation ITU-T T.800 | ISO/IEC 15444-1, *Information technology – JPEG 2000 Image Coding System: Core coding system*.
- Recommendation ITU-T T.814 | ISO/IEC 15444-15, *Information technology – JPEG 2000 image coding system – Part 15: High Throughput JPEG 2000*.

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*.
- ISO/IEC 14882:2011, *Programming languages – C++*.

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 is required to 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.

3.57 **J2K**: Used to refer to the encoding and decoding processes in Rec. ITU-T T.800 | ISO/IEC 15444-1.

3.58 **HTJ2K**: Used to refer to the encoding and decoding processes in Rec. ITU-T T.814 | ISO/IEC 15444-15.

3.59 **JPH**: The name of the file format defined by Rec. ITU-T T.814 | ISO/IEC 15444-15.

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
CAP	Extended capabilities marker
CPF	Corresponding Profile Marker
COC	Coding style component marker
COD	Coding style default marker
COM	Comment marker
CRG	Component registration marker
EOC	End of codestream marker
EPH	End of packet header 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.

6 General description

Five 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™[2] 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 (also known as C99).
- TT.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 14882:2011 (also known as C++11).
- Codestream-parser.ZIP, provided as indicated in the file LICENSE, contained within the zip file. This is written in the Python programming language, and executes on platforms that support Python version 2.7.

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), Annex C (OpenJPEG), Annex D (TT) and Annex E (Codestream-parser).

The Jasper, JJ2000, OpenJPEG and TT distributions have been tested as meeting the coding and decoding requirements for codestreams identified in Rec. ITU-T T.800 | ISO/IEC 15444-1. The TT distribution has been tested as meeting the decoding requirements for codestreams identified in Rec. ITU-T T.814 | ISO/IEC 15444-15. The codestream-parser distribution has been tested as meeting the coding and decoding requirements for file formats identified in Rec. ITU-T T.800 | ISO/IEC 15444-1 and Rec. ITU-T T.814 | ISO/IEC 15444-15. 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.

[2] This trademark is given for the convenience of users of this document and does not constitute an endorsement by ISO | ITU of the product named. Equivalent products may be used if they can be shown to lead to the same results.

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. 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 JasPer, JJ2000, OpenJPEG and TT reference software implementations have been successfully built on a variety of operating platforms and with a selection of compilers. The codestream-parser reference software implementation has been successfully executed on a variety of operating platforms. They have been written with portability and comprehensibility in mind.

9 Reference code structure

The JasPer, JJ2000 and OpenJPEG reference software each 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.The TT reference software offers the capability to encode codetreams that conform to the syntax defined in Rec. ITU-T T.800 | ISO/IEC 15444-1, and decode codetreams that conform to the syntax defined in Rec. ITU-T T.800 | ISO/IEC 15444-1 and Rec. ITU-T T.814 | ISO/IEC 15444-15. The Codestream-parser software offers the capability to parse file formats that conform to the syntax defined in Rec. ITU-T T.800 | ISO/IEC 15444-1 and Rec. ITU-T T.814 | ISO/IEC 15444-15.

For transcoding to other image formats or for display, each reference software allows 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 jpg/pnm/pgm/ppm/bmp/ras. 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.

9.4 TT executable

The TT reference software distribution provides a single main executable 'TT', which:

- converts from a j2k/jphc file to a pgm/ppm/bmp/raw file.
- converts from a pgm/ppm/bmp/tif file to a j2k/jphc file.

9.5 Codestream-parser executable

The Codestream-parser reference software distribution provides a single main executable:

- jp2file.py: parses both JP2 and JPH file format and show the extracted information.

10 Software availability and updates

The reference software sources released with this Recommendation | International Standard are the latest tested versions available at the date on which the text was released for final approval. Later versions of the software and implementation or fault reports and fixes may be made available after the publication of this Recommendation | International Standard.

Annex A

JASPER – C reference software – software description

(This annex does not form an integral part of this Recommendation | International Standard.)

A.1 Introduction

JasPer is a collection of software (i.e., a library and application programs) for the coding and manipulation of images. This software is written in the C programming language. Of particular relevance to this standard, the JasPer software provides an implementation of the image codec specified in Rec. ITU-T T.800 | ISO/IEC 15444-1. Support for several other popular image codecs are also included in order to facilitate the transcoding of image data to and from JPEG 2000 codestreams and the JP2 file format. The JasPer software was developed with the objective of providing a license and royalty fee free JPEG 2000 implementation to anyone wishing to use the JPEG 2000 standard, although no warranty is provided as to any potential infringement of intellectual property (see the document **LICENSE** included with the software). Users of the software are advised to satisfy themselves as to the validity of any claims made for intellectual property which are made against Rec. ITU-T T.800 | ISO/IEC 15444-1 before using this software.

In addition to this annex, readers interested in the JasPer software should also read the JasPer Software Reference Manual, which is included in the JasPer software distribution archive. This manual contains detailed information about the JasPer software, and includes release-specific details that have been deliberately omitted from this annex.

A.2 Software updates

The JasPer software release accompanying this Recommendation | International Standard represents the most recent version available at the time this Recommendation | International Standard was published. The development of the JasPer software is expected to continue. As new features and functionality are added, new releases of the software may become available.

A.3 Version numbering

As the JasPer software is expected to evolve over time, it is important to be able to identify particular releases of the software. Each release of the JasPer software has a version identifier. For the purposes of this annex, a version identifier is comprised of three integers separated by dots. In order, the three integers correspond to the major, minor, and micro version numbers for the software. For example, the version identifier "1.500.0" corresponds to a major version of 1, a minor version of 500, and a micro version of 0. In instances where the micro version is zero, the version identifier may be truncated after the minor version number. For example, the version identifier "1.500" is completely valid and an abbreviation for "1.500.0".

Given two different releases of the JasPer software, the most recent can be identified by comparing the version identifiers, as follows:

1) if the major version numbers differ, the release with the higher major version number is newer;
2) if the major version numbers are equal and the minor version numbers differ, the release with the higher minor version number is newer; or
3) if the major version numbers are equal and the minor version numbers are equal, the release with the higher micro version is newer.

A.4 Software overview

The JasPer software consists of a library, and several demonstration application programs that utilize this library. The code is written in the C programming language in conformance with ISO/IEC 9899:1999. This language was chosen due to the availability of C development environments for most of today's computing platforms. In total, the software consists of about 30K lines of code.

In the clauses that follow, a brief overview of the JasPer software is provided. No mention is made of details that are likely to change between software releases. These are described within documents included in the relevant software distribution, to avoid introducing inconsistencies between this Recommendation | International Standard and the documentation accompanying the relevant JasPer software release.

A.5 JasPer library

At the core of the JasPer software is the JasPer library, named libjasper. The library consists of two distinct categories of code:

1) base/core code; and
2) codec drivers.

The base code provides generic routines for manipulating images and provides a framework for constructing codec drivers. The codec drivers provide a means for encoding/decoding images in specific formats. The library has been designed to be extensible, so that adding support for new image formats should be straightforward.

Currently, codec drivers are provided for the following image formats:

1) JPEG 2000 JP2 file (JP2);
2) JPEG 2000 code stream (JPC);
3) JPEG JFIF (JPG);
4) Portable Bitmap (PNM);
5) Windows™[3] BMP (BMP); and
6) Sun Rasterfile (RAS).

In addition, support is also provided for a number of non-standard formats, which offer features that are not available through any of the above formats (for example unusual image geometries). These formats are documented in the JasPer Software Reference Manual. The JPG codec driver requires that the IJG JPEG library be available on the system used to compile the software. The IJG JPEG library is free software and can be obtained from the Internet via the URL:

http://www.ijg.org

For licensing reasons, the IJG JPEG library is not distributed with the JasPer software.

The JP2 and JPC codecs provided are the main element of relevance to this Recommendation | International Standard. The JPG codec within JasPer provides support for the original JPEG format, and can be used to convert JPEG-formatted data into JPEG 2000.

The JasPer library provides the following key classes:

1) An image class – This class is used to represent an image, and also provides access to codec drivers for encoding/decoding image data in various formats.
2) A sequence/matrix class – This class provides matrix and two-dimensional sequence classes.
3) A I/O stream class – This class provides I/O streams similar to that of the standard C library, but with additional functionality required by other code in JasPer.
4) A fixed-point number class – This (templated) class is used for performing fixed-point arithmetic.
5) A tag-value parser class – This class facilitates the parsing of tag-value pairs. A tag-value pair is a string of the form "tag=value". Such pairs are used by some interfaces within JasPer in order to pass parameters.
6) A command line option class – This class allows the parsing of command lines. This code is similar to the getopt function available on most UNIX systems.

A.6 JasPer demo application programs

Three demonstration application programs are included that utilize the JasPer library. These application programs are:

1) **jasper** – This is a simple transcoder application. It converts image data from one format to another.
2) **imgcmp** – This is an image comparison utility. It can be used to quantify the difference between two images (using various distortion metrics).
3) **imginfo** – This program outputs basic information about the type and geometry of an image.

The **jasper** program is the main reference software provided and can be used as a JPEG 2000 encoder and/or decoder. The **imgcmp** utility is useful for analysing image coding performance.

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[3] This trademark is given for the convenience of users of this document and does not constitute an endorsement by ISO | ITU of the product named. Equivalent products may be used if they can be shown to lead to the same results.

A.7 Software requirements

The JasPer code is intended to compile on any platform with a C language implementation conforming to ISO/IEC 9899:1999 and supporting a subset of ISO/IEC 9945-1:1996 (i.e., the POSIX C API). Only limited POSIX support is required (i.e., the open, close, read, write, and lseek functions are required to be supported).

The GNU C compiler is suggested for building the JasPer software as this compiler is compliant for the purposes of this reference software with ISO/IEC 9899:1999, and produces good quality code. This compiler is available for systems based on POSIX/UNIX and Microsoft Windows, amongst others. More information about the GNU C compiler can be found on the Internet at:

http://www.gnu.org

Portability was a major consideration during the design of the JasPer software. For this reason, the software makes minimal assumptions about the runtime environment. The code uses very little floating-point arithmetic, most of which can be attributed to floating-point conversions in printf's. This minimal use of floating-point arithmetic should make the code easier to port to platforms lacking hardware support for floating-point arithmetic.

A.8 Building the software

The JasPer software can be built using one of two different methods. The first method is based on a configure script (produced using the well-known autoconf tool). This method should work in most mainstream UNIX- or POSIX-like environments (e.g., Linux, Solaris, and the Cygwin environment under Microsoft Windows). This is the preferred and recommended method for building JasPer. The second method is specifically tailored to the needs of Microsoft Visual C ™[4] users. Detailed instructions for each of these two build methods can be found in the JasPer Software Reference Manual. (See the section titled "Building the Software".)

A.9 Using the software

As described earlier, the JasPer software consists of a library and several application programs. All of the application programs have a similar UNIX-style command line interface. The specifics of the command line interface for each application program are given in the JasPer Software Reference Manual. (See the section titled "Using the Software".) It is also possible to use the JasPer library to build new application programs (or even other libraries). Information on how to do this can also be found in the same section in the JasPer Software Reference Manual.

[4] This trademark is given for the convenience of users of this document and does not constitute an endorsement by ISO | ITU of the product named. Equivalent products may be used if they can be shown to lead to the same results.

Annex B

JJ2000 – Java reference software – software description

(This annex does not form an integral part of this Recommendation | International Standard.)

B.1 Introduction

JJ2000 is a Java implementation of JPEG 2000 as defined in Rec. ITU-T T.800 | ISO/IEC 15444-1. The software consists of an encoder and a decoder. The encoder compresses image files from a number of image formats to a JPEG 2000 Codestream or a JP2 file (see 9.2). The encoder provides an implementation of the image encoder specified in Rec. ITU-T T.800 | ISO/IEC 15444-1 and supports a number of additional features such as parallelization and running the encoder as a Java applet. The decoder provides decompression of a JPEG 2000 codestream into a number of image formats, and support for the JP2 file 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.

How to install and use the encoder and the decoder is described in the **INSTALL** document provided in the software distribution.

B.2 Software updates

The latest version of the JJ2000 software, as of the time this Recommendation | International Standard was published, can be found as an electronic attachment to this Recommendation | International standard, and also at https://standards.iso.org/iso-iec/15444/-5/ed-3/en.

B.3 Software architecture

The JJ2000 software consists of several Java hierarchical packages, each one corresponding to a specific module of the JJ2000 encoder-decoder. Each of these packages correspond to a directory with the same name within the zip-file containing the software distribution accompanying this Recommendation | International Standard.

jj2000	
jj2000.disp	Display of decoded images
jj2000.j2k	JPEG 2000 modules
jj2000.j2k.io	Writing to/Reading from files
jj2000.j2k.roi	Region of Interest support
jj2000.j2k.util	Useful tools for JJ2000 implementation
jj2000.j2k.codestream	
jj2000.j2k.codestream.writer	Writing of the code-stream
jj2000.j2k.codestream.reader	Reading of the code-stream
jj2000.j2k.decoder	Decoder module
jj2000.j2k.encoder	Encoder module
jj2000.j2k.entropy	Arithmetic encoding/decoding
jj2000.j2k.entropy.decoder	MQ and entropy decoders
jj2000.j2k.entropy.encoder	MQ, entropy encoder, EBCOT
jj2000.j2k.wavelet	Filters and filtering
jj2000.j2k.wavelet.analysis	Forward wavelet decomposition
jj2000.j2k.wavelet.synthesis	Inverse wavelet decomposition
jj2000.j2k.image	Spatial domain operations
jj2000.j2k.image.forwcompTransf	Forward Component transformation

jj2000.j2k.image.invcomptransf	Inverse Component transformation
jj2000.j2k.image.output	Writing of PGM/PPM/PGX files
jj2000.j2k.image.input	Reading of PGM/PPM/PGX files
jj2000.j2k.quantization	
jj2000.j2k.quantization.quantizer	Dead-zone Scalar quantizer
jj2000.j2k.quamtization.dequantizer	Dead-zone Scalar Dequantizer

A more thorough description of the design and classes of JJ2000 can be found in the **README** file provided in the software distribution. For more information about encoder/decoder, please refer to the embedded command-line help and the source-code documentation.

B.4 Installing and running the software

JJ2000 is written in Java and to run the software a Java compiler and a Java Virtual Machine is needed. Instructions of how to compile and run the software on different platforms is given in the **INSTALL** document provided in the software distribution. The same document also describes how to generate documentation from the source code and how to use some of the additional features of the encoder.

Annex C

OpenJPEG – C reference software - software description

(This annex does not form an integral part of this Recommendation | International Standard.)

C.1 Introduction

OpenJPEG is a software suite (libraries and application programs), written in C language, and dedicated to the implementation of JPEG standards. Among other parts, OpenJPEG provides the OpenJP2 library, an implementation of Rec. ITU-T T.800 | ISO/IEC 15444-1. OpenJPEG software has been released under 2-clauses BSD license. This software may be subject to other third party and contributor rights, including patent rights, and no such rights are granted under this license.

C.2 Getting and updating the software

The subset of the OpenJPEG software suite accompanying this Recommendation | International Standard is made of the *openjp2* library (rev2908), together with the *opj_compress*, *opj_decompress* and *opj_dump* executables. It represents the most recent version of this subset available at the time this Recommendation | International Standard was published.

C.3 Building and using the software

The only maintained building method for the OpenJPEG software suite is through the use of CMake. This allows compiling OpenJPEG on a variety of different platforms without having to maintain several project files or makefiles.

Configuration of CMake files (through command-line, ccmake or cmake-gui) allows the user to decide which libraries and executables to build, and if required, third-party libraries (libpng, libtiff, libz, liblcms2) will be compiled or searched on the local machine. These third-party libraries are solely used by the executables to enable PNG and TIF support, and colour profile management. Once configuration is done, CMake generates makefiles or project files and the software can be built. The OpenJP2 library itself does not have any external dependencies (except the math library on Unix platform).

Once built, command-line executables can be used to convert images. Available parameters and options are described in the documentation and with the "-h" option of the executables.

C.4 Testing the software

The software accompanying this Recommendation | International Standard has been successfully tested against all conformance test files, following the procedures described in Rec. ITU-T T.803 | ISO/IEC 15444-4 for Rec. ITU-T T.800 | ISO/IEC 15444-1.