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Information technology — JPEG 2000 image coding system —

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 part of ISO/IEC 15444 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 15444-4 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, but is not published as common text at this time.

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 7: Guideline of minimum support function of ISO/IEC 15444-1*

Annexes B and C form a normative part of this part of ISO/IEC 15444. Annexes A, D, E, F and G are for information only.

Introduction

ITU-T T.800 | ISO/IEC 15444-1 is a specification that describes an image compression system that allows great flexibility, not only for the compression of images but also for access into the codestream. The codestream provides a number of mechanisms for locating and extracting portions of the compressed image data for the purpose of retransmission, storage, display, or editing. This access allows storage and retrieval of compressed image data appropriate for a given application without decoding.

This Recommendation | International Standard provides the framework, concepts, and methodology for testing and the criteria to be achieved to claim compliance to ITU-T T.800 | ISO/IEC 15444-1 standard. The objective of standardization in this field is to promote interoperability between JPEG 2000 encoders and decoders and to test these systems for compliance to this specification. Compliance testing is the testing of a candidate product for the existence of specific characteristics required by a standard. It involves testing the capabilities of an implementation against both the compliance requirements in the relevant standard and the statement of the implementation's capability.

The purpose of this Recommendation | International Standard is to define a common test methodology, to provide a framework for specifying abstract test suites (ATS), and to define the procedures to be followed during compliance testing.

Any organization contemplating the use of test methods defined in this Recommendation | International Standard should carefully consider the constraints on their applicability. Compliance testing does not include robustness testing, acceptance testing, and performance testing.

INFORMATION TECHNOLOGY –

JPEG 2000 IMAGE CODING SYSTEM —

PART 4: CONFORMANCE TESTING

1 Scope

This Recommendation | International Standard specifies the framework, concepts, methodology for testing, and criteria to be achieved to claim compliance to ITU-T Recommendation T.800 | ISO/IEC 15444-1. It provides a framework for specifying abstract test suites and for defining the procedures to be followed during compliance testing.

This Recommendation | International Standard

- specifies compliance testing procedures for encoding and decoding using JPEG 2000 Part 1 (ITU-T Recommendation T.800 | ISO/IEC 15444-1);
- specifies codestreams, decoded images, and error metrics to be used with the testing procedures;
- specifies abstract test suites;
- provides guidance for creating an encoder compliance test.

This Recommendation | International Standard does not include the following tests:

Acceptance testing: the process of determining whether an implementation satisfies acceptance criteria and enables the user to determine whether or not to accept the implementation. This includes the planning and execution of several kinds of tests (e.g., functionality, quality, and speed performance testing) that demonstrate that the implementation satisfies the user requirements.

Performance testing: measures the performance characteristics of an Implementation Under Test (IUT) such as its throughput, responsiveness, etc., under various conditions.

Robustness testing: the process of determining how well an implementation processes data which contains errors.

2 References

The following references document the technical details and legal codestream syntax that serve as a basis for this Recommendation | International Standard. At the time of publication, the editions indicated were valid. All Recommendations and Standards are subject to revision, and parties to agreements based on this Recommendation | International Standard are encouraged to investigate the possibility of applying the most recent edition of the Recommendations and Standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards. The Telecommunication Standardization Bureau of the ITU maintains a list of currently valid ITU-T Recommendations.

- ITU-T Recommendation T.800 | ISO/IEC 15444-1, Information technology — JPEG 2000 Image Coding System.
- ITU-T Recommendation T.800 | ISO/IEC 15444-1 Amendment 1, Information technology — JPEG 2000 Image Coding System, Amendment 1.
- ITU-T Recommendation T.800 | ISO/IEC 15444-1 Amendment 2, Information technology — JPEG 2000 Image Coding System, Amendment 2.

— ITU-T Recommendation T.800 | ISO/IEC 15444-1 Corrigendum 1, Information technology — JPEG 2000 Image Coding System.

— ITU-T Recommendation T.800 | ISO/IEC 15444-1 Corrigendum 2, Information technology — JPEG 2000 Image Coding System.

— ITU-T Recommendation T.800 | ISO/IEC 15444-1 Corrigendum 3, Information technology — JPEG 2000 Image Coding System.

3 Definitions

For the purposes of this Recommendation | International Standard, the following definitions apply. The definitions from ITU-T T.800 | ISO/IEC 15444-1 clause 3 also apply to this Recommendation | International Standard.

3.1 **abstract test suite:** Generic compliance testing concepts and procedures for a given requirement.

3.2 **arithmetic coder:** An entropy coder that converts variable length strings to variable length codes (encoding) and vice versa (decoding).

3.3 **big endian:** An order of bytes with the most significant byte first.

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

3.5 **bit-depth:** The number of bits required to represent an original component of an image.

3.6 **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.

3.7 **bitstream:** 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.

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

3.9 **byte:** Eight bits.

3.10 **Cclass:** Defines a level of performance for a decoder. Also provides guidance for encoders to produce codestreams that are easily decodable by compliant decoders.

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

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

3.13 **codestream:** A collection of one or more bitstreams 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. This does not include the file format.

3.14 **coding pass:** A procedure accessing coefficients in a code-block where the context and bit are determined. Typically there are 3 different coding passes for each bitplane, each coefficient will be represented in exactly one of the three passes. For an encoder a coding pass examines coefficinets and agments a bitstream. For a decoder a coding pass reads a bitstream and updates coefficients.

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

3.16 **component:** A two-dimensional array of samples. An image typically consists of several components (e.g., red, green, and blue).

3.17 **compressed image data:** Part or all of a codestream. Can also refer to a collection of bitstreams in part or all of a codestream.

3.18 **compliance:** Fulfillment of the specified requirements, as defined in this specification, for a given Profile and Cclass.

3.19 compliance test procedure: The process of assessing compliance.

3.20 context: Function of coefficients previously decoded and used to condition the decoding of the present coefficient.

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

3.22 decoding process: A process that takes as its input all or part of a codestream and outputs all or part of a reconstructed image.

3.23 decomposition level: A collection of wavelet subbands where each coefficient has the same spatial impact or span with respect to the source component samples. These include all subbands of the same two-dimensional subband decomposition. For the last decomposition level, the LL subband is also included.

3.24 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.

3.25 encoder: An embodiment of an encoding process, and optionally a colour transformation process.

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

3.27 executable test suite: Set of executable test cases that support the abstract test cases.

3.28 file format: A codestream and additional support data and information not explicitly required for the decoding of the 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.

3.29 fully decode: Applying ITU-T T.800 | ISO/IEC 15444-1 to produce an image from a codestream where all coded data in the codestream has been used to produce the image.

3.30 guard bits: Additional most significant bits that have been added to sample data.

3.31 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).

3.32 image: The set of all components.

3.33 image data: The component samples making up an image. Image data can refer to either the source image data or the reconstructed image data.

3.34 implementation: A realization of a specification.

3.35 Implementation Compliance Statement (ICS): Statement of specification options and the extent to which they have been implemented by a implementation under test.

3.36 Implementation Under Test (IUT): An implementation that is being evaluated for compliance.

3.37 irreversible: A transformation, progression, system, quantization, or other process that, due to systemic or quantization error, prevents lossless recovery.

3.38 JP2 file: The name of a file in the file format described in this specification. Structurally, a JP2 file is a contiguous sequence of boxes.

3.39 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: ITU-T.81 | ISO/IEC 10918-1, ITU-T T.83 | ISO/IEC 10918-2, ITU-T T.84 | ISO/IEC 10918-2 and ITU-T T.87 | ISO/IEC 14495.

3.40 LL subband: The subband obtained by forward horizontal low-pass filtering and vertical low-pass filtering. This subband contributes to reconstruction with inverse vertical low-pass filtering and horizontal low-pass filtering.

3.41 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.

3.42 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.

3.43 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.

3.44 main header: A group of markers and marker segments at the beginning of the codestream that describe the image parameters and coding parameters that can apply to every tile and tile-component.

3.45 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).

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

3.47 packet: A part of the codestream comprising a packet header and the compressed image data from one layer of one precinct of one resolution level of one tile-component.

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

3.49 parser: Reads and identifies components of the codestream down to the code-block level.

3.50 partial decoding: Producing an image from a subset of an entire codestream.

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

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

3.53 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.

3.54 profile: A subset of technology, from ITU-T T.800 | ISO/IEC 15444-1 Amendment 1, that meets the needs of a given application with limits on parameters within a selected technology. This is a codestream limitation.

3.55 quantization: A method of reducing the precision of the individual coefficients to reduce the number of bits used to represent 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 (scalar quantization) or by dropping (truncating) coding passes from the codestream.

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

3.57 reference grid: A regular rectangular array of points used to define other rectangular arrays of data. The reference grid is used to determine the number of samples in tile-components for example.

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

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

3.60 reversible filter: A particular filter pair used in the wavelet transformation which allows lossless compression.

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

3.62 selective arithmetic coding bypass: A coding style where some of the code-block passes are not coded by the arithmetic coder. Instead, the bits to be coded are appended directly to the bitstream without coding.

3.63 shift: Multiplication or division of a number by powers of two. Division of an integer via shift implies truncation toward minus infinity of the non-integer portion.

3.64 sign bit: A bit that indicates whether a number is positive (zero value) or negative (one value).

3.65 sign-magnitude notation: A binary representation of an integer where the distance from the origin is expressed with a positive number and the direction from the origin (positive or negative) is expressed with a separate single sign bit.

3.66 source image: An image used as input to an encoder.

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

3.68 testing: The process of evaluating compliance.

3.69 tile: A rectangular array of points on the reference grid, registered with an offset from the reference grid origin and defined by a width and height.

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

3.71 tile-part: A portion of the codestream with compressed image data for some, or all, of a tile. The tile-part may include one or more packets that make up the coded tile.

3.72 tile-part header: A group of markers and marker segments at the beginning of each tile-part in the codestream that describe the tile-part coding parameters.

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

3.74 transform coefficient: A value that is the result of a transformation.

4 Abbreviations

For the purposes of this Recommendation | International Standard, the following abbreviations apply. The abbreviations defined in ITU-T T.800 | ISO/IEC 15444-1 subclause 4.1 also apply to this Recommendation | International Standard.

ATS: Abstract Test Suite

CCITT: International Telegraph and Telephone Consultative Committee, now ITU-T

ETS: Executable Test Suite

ICC: International Color Consortium

ICT: Irreversible Colour Transformation

ICS: Implementation Compliance Statement

IEC: International Electrotechnical Commission

ISO: International Organization for Standardization

ITU: International Telecommunication Union

ITU-T: International Telecommunication Union – Telecommunication Standardization Sector (formerly the CCITT)

IUT: Implementation Under Test

JPEG: Joint Photographic Experts Group

MSE: Mean Squared Error

RCT: Reversible Colour Transformation

ROI: Region Of Interest

TCS: Test Codestream

5 Symbols

For the purposes of this Recommendation | International Standard, the following symbols apply. The symbols defined in ITU-T T.800 | ISO/IEC 15444-1 subclause 4.2 also apply to this Recommendation | International Standard.

0x----: Denotes a hexadecimal number

B: Bitdepth accuracy for reversible 5-3

C: Components guarenteed to be decoded

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

H: Image height guarantee

L: Layer guarantees

$\mathbf{L_{body}}$**:** Code data buffering guarantee

M: Decoded bitplane guarantee

$\mathbf{N_{cb}}$**:** Code-block parsing guarantee

$\mathbf{N_{comp}}$**:** Component parsing guarantee

P: Irreversible 9-7 precision guarantee

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

$\mathbf{T_L}$**:** Transform level guarantees

TLM: Tile-part lengths marker

W: Image width guarantee

6 General description

Perhaps the most distinctive feature of JPEG 2000 is its emphasis on and support for scalability. An existing codestream may be accessed at a reduced resolution, at a reduced quality (higher compression), at a reduced number of components, and even over a reduced spatial region. Moreover, the Recommendation | International Standard supports a rich family of information progression sequences whereby the information may be reordered without introducing additional distortion. This enables a single compressed codestream to serve the needs of a diverse range of applications.

JPEG 2000 encoders may employ only a fraction of the features supported by ITU-T T.800 | ISO/IEC 15444-1. Likewise, some decoders will not support all the features supported by the Recommendation | International Standard. It is impossible to provide test cases for all possible combinations of tools that an encoder or decoder may choose to implement. This Recommendation | International Standard provides abstract test procedures for JPEG 2000 encoders and decoders. A developer may designate the features that have been implemented and determine a set of test cases that applies to those features. For the greatest level of interoperability, there are explicit decoder test procedures. These tests are run for a particular Profile (defined in ITU-T T.800 | ISO/IEC 15444-1 Amendment 1) and a particular compliance class defined herein. Passing the explicit tests allows a decoder to be labeled “Profile-x Cclass-y Compliant.”

Even with the explicit decoder tests, it is expected that some decoders may not decode all of the information that was originally incorporated into the codestream by an encoder. This is the only way to truly exploit the scalability of ITU-T T.800 | ISO/IEC 15444-1. It is desirable to allow decoders to ignore information that is not of interest to their target application. While this flexibility is one of the strengths of JPEG 2000, it also renders inappropriate some of the conventional compliance testing methodologies that have been applied to non-scalable or less scalable compression standards.

Many approaches to compliance could be taken. At one extreme, decoder implementations might be allowed to decode any portion of the codestream that is of interest to them. At the other extreme, they might be required to correctly decode the entire codestream. The first approach offers content providers and consumers no guarantee concerning the quality of the resulting imagery. The other approach is also inappropriate because it offers the implementor no guarantee concerning the resources that may be required for decoding, and in many cases the codestream may contain information that is of no interest to the application.

This document describes compliance for JPEG 2000 decoders in terms of a system of guarantees. These guarantees serve to discourage encoders from producing codestreams that will be exceedingly difficult or impossible for a decoder to process, to encourage decoders to provide quality images from any reasonable codestream, and to encourage use of the flexibility and scalability of JPEG 2000 codestreams.

Profiles define a subset of technology, from ITU-T T.800 | ISO/IEC 15444-1: JPEG 2000, that meets the needs of a given application with limits on parameters within a selected technology. Profiles limit bitstreams. Decoders define capabilities for all bitstreams within a profile. Encoders achieve quality guarentees for particular decoders by encoding bitstreams which meet a particular profile definition. *Compliance classes* (Cclass) define guarantees of a given level of image quality for a decoder and guidance for encoders to produce codestreams that are easily decodable by compliant decoders.

Essentially, if a JPEG 2000 encoder produces a codestream with certain properties, then a decoder of a certain Cclass will be capable of producing an image with some defined level of quality. The compliance class of a decoder is based solely on passing certain tests. The tests in this document are designed to require a compliant decoder to be capable of decoding all codestreams with a set of defined properties.

6.1 Profiles and compliance classes

Two profiles are defined in ITU-T T.800 | ISO/IEC 15444-1 Amendment 1, labeled Profile 0 and Profile 1. The two profiles describe bitstream constraints for an ITU-T T.800 | ISO/IEC 15444-1 encoder. Profile 0 is a subset of Profile 1. Hence, any implementation capable of decoding Profile 1 test streams shall be capable of passing the compliance tests for Profile 0 of the same Cclass.