

Digital Imaging and Communications in Medicine (DICOM)

Supplement 105: JPEG 2000 Part 2 Multi-component Transfer Syntaxes

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Foreword

This Supplement adds support for multi component extensions of JPEG 2000 Transfer Syntaxes, to support more efficient compression of 3D volumes.

Scope and Field of Application

INTRODUCTION

Additional DICOM Transfer Syntaxes are introduced to add support for the Multi-component Transformations in Part 2 of the JPEG 2000 Standard. Both lossy and lossless multi-component transforms are supported.

Part 2 of JPEG 2000 (ISO/IEC 15444-2), entitled Extensions, includes extensions to many of the technologies in Part 1 of the JPEG 2000 Standard (ISO/IEC 15444-1). The multi-component transformation extensions allow for the use of wavelet transformations and array based transformations in the component direction, for multi-component or multi-frame imagery.

Supplement 61 introduced new Transfer Syntaxes for JPEG 2000 Part 1 lossless and lossy compression. Part 1 of the JPEG 2000 does not allow for any multi-component transformation besides the simple RGB to YUV transformations for 3 channel color images. For multi-spectral and 3D volumetric data it has been shown that the JPEG 2000 Part 2 Multi-component Transformation extensions can improve compression efficiency, for both lossless and lossy compression. For lossless compression, the improvement has been shown to be about 5-25%, depending on the type of images. More significant improvements have been observed for lossy compression. For details, see the report from Aware, Inc, which can be found here: http://medical.nema.org/Dicom/minutes/WG-04/2004/2004-02-18/3D_compression_RSNA_2003_ver2.pdf

The introduction of these Part 2 JPEG 2000 transfer syntaxes is in no way intended to imply that the compression schemes already incorporated in the standard, some of which are widely used, are in some way "inferior". Likewise, the introduction of JPEG 2000 Part 2 does not imply endorsement of the scheme for any particular clinical or diagnostic application. The standard simply makes the scheme available; it is the responsibility of individual users, vendors, regulatory agencies and professional societies to ascertain the safety and efficacy of the use of any tool for a particular clinical application.

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DESIGN DECISIONS

The approach proposed is to encapsulate JPEG 2000 Part 2 bit streams in exactly the same manner as is currently used for JPEG (10918-1), JPEG-LS and RLE and JPEG 2000 Part 1. This implies that:

- The optional JPX file format headers defined in ISO/IEC 15444-2 is not included, only the actual compressed JPEG 2000 Part 2 bit stream (this is the same as for JPEG 2000 Part 1 which does not include a JP2 header in the DICOM encapsulation).
- Separate transfer syntaxes are defined for reversible multi-component transformations and either reversible or irreversible transformations (at the sender's discretion), in order to be able to negotiate reversible transfers.

FORM OF THIS SUPPLEMENT

This supplement adds new Transfer Syntaxes to support JPEG 2000 Part 2 Multi-component transformation extensions.

Since this document proposes changes to existing Parts of DICOM, the reader should have a working understanding of the Standard. This proposed Supplement includes a number of Addenda to existing Parts of DICOM:

- PS 3.5 Addendum: Data Structures and Encoding
- PS 3.6 Addendum: Data Dictionary

**Changes to
NEMA Standards Publication PS3.5-2004**

*Digital Imaging and Communications in Medicine (DICOM)
Part 5: Data Structures and Encoding*

Add JPEG 2000 Part 2 to Section 2:

Section 2 Normative references

ISO/IEC 15444-2 JPEG 2000 Image Coding System: Extensions

Add JPEG 2000 Part 2 to Section 8:

Section 8 Encoding of Pixel, Overlay and Waveform Data

8.2.4 JPEG 2000 IMAGE COMPRESSION

DICOM provides a mechanism for supporting the use of JPEG 2000 Image Compression through the Encapsulated Format (see PS 3.3). Annex A defines a number of Transfer Syntaxes which reference the JPEG 2000 Standard and provide lossless (bit preserving) and lossy compression schemes.

Note: The context where the usage of lossy compression of medical images is clinically acceptable is beyond the scope of the DICOM Standard. The policies associated with the selection of appropriate compression parameters (e.g. compression ratio) for JPEG 2000 lossy compression are also beyond the scope of this standard.

The use of the DICOM Encapsulated Format to support JPEG 2000 Compressed Pixel Data requires that the Data Elements which are related to the Pixel Data encoding (e.g. Photometric Interpretation, Samples per Pixel, Planar Configuration, Bits Allocated, Bits Stored, High Bit, Pixel Representation, Rows, Columns, etc.) shall contain values which are consistent with the characteristics of the compressed data stream. The Pixel Data characteristics included in the JPEG 2000 bit stream shall be used to decode the compressed data stream.

Note: These requirements are specified in terms of consistency with what is encapsulated, rather than in terms of the uncompressed pixel data from which the compressed data stream may have been derived.

When decompressing, should the characteristics explicitly specified in the compressed data stream be inconsistent with those specified in the DICOM Data Elements, those explicitly specified in the compressed data stream should be used to control the decompression. The DICOM data elements, if inconsistent, can be regarded as suggestions as to the form in which an uncompressed data set might be encoded.

The JPEG 2000 bit stream specifies whether or not a reversible or irreversible multi-component (color) transformation, if any, has been applied. If no multi-component transformation has been applied, then the components shall correspond to those specified by the DICOM Attribute Photometric Interpretation (0028,0004) . If the JPEG 2000 **Part 1** reversible multi-component transformation has been applied then the DICOM Attribute Photometric Interpretation (0028,0004) shall be YBR_RCT. If the JPEG 2000 **Part 1** irreversible multi-component transformation has been applied then the DICOM Attribute Photometric Interpretation (0028,0004) shall be YBR_ICT.

Notes:

1. For example, single component may be present, and the Photometric Interpretation (0028,0004) may be MONOCHROME2.
2. Though it would be unusual, would not take advantage of correlation between the red, green and blue components, and would not achieve effective compression, a Photometric Interpretation of RGB could be specified as long as no multi-component transformation was specified by the JPEG 2000 bit stream.
3. Despite the application of a multi-component color transformation and its reflection in the Photometric Interpretation attribute, the "color space" remains undefined. There is currently no means of conveying "standard color spaces" either by fixed values (such as sRGB) or by ICC profiles. Note in particular that the JP2 file header is not sent in the JPEG 2000 bitstream that is encapsulated in DICOM.

The JPEG 2000 bitstream is capable of encoding both signed and unsigned pixel values, hence the value of Pixel Representation (0028,0103) may be either 0 or 1 depending on what has been encoded (as specified in the SIZ marker segment in the precision and sign of component parameter).

The value of Planar Configuration (0028,0006) is irrelevant since the manner of encoding components is specified in the JPEG 2000 standard, hence it shall be set to 0.

Add JPEG 2000 Part 2 to Section 10:

Section 10 Transfer Syntax

10.6 TRANSFER SYNTAX FOR JPEG 2000 COMPRESSION

One Transfer Syntax is specified for JPEG 2000 Image Compression (Lossless Only), and one Transfer Syntax is specified for JPEG 2000 Image Compression. Either of these may be negotiated separately and there is no default or baseline specified (other than described in section 10.1).

Notes:

1. All JPEG 2000 codecs are required by ISO/IEC 15444-1 to support both reversible and irreversible wavelet and multi-component transformations. The reason for specifying two separate Transfer Syntaxes in DICOM is to allow an application to request the transfer of images in a lossless manner when possible. The JPEG 2000 Image Compression Transfer Syntax allows for either lossless or lossy compression to be used at the sender's discretion.
2. No baseline using other compression schemes is required.
3. When the pixel data has been received in the JPEG 2000 Image Compression Transfer Syntax, since it may have been lossy compressed, the waiver of the requirement in Section 10.1 to support the DICOM default Transfer Syntax still applies.

In addition, one Transfer Syntax is specified for JPEG 2000 Multi-component Image Compression (Lossless Only) with Multi-Component Transformation Extensions, and one Transfer Syntax is specified for JPEG 2000 Multi-component Image Compression with Multi-Component Transformation Extensions. Either of these may be negotiated separately and there is no default or baseline specified (other than described in section 10.1).

Note: JPEG 2000 codecs that support the Part 2 JPEG 2000 Multi-Component Transformation Extensions are required to support all the multi-component extensions as described in Annex J of ISO/IEC 15444-2. This includes both array based transformations and the 9-7 and 5-3 wavelet transformations that are also used in Part 1 of JPEG 2000. This also includes component reordering, component collections and application of more than one multi-component transformation in succession.

Add JPEG 2000 Part 2 to Annex A:

Annex A (Normative) Transfer Syntax Specifications

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A.4.4 JPEG 2000 IMAGE COMPRESSION

The International Standards Organization ISO/IEC JTC1 has developed an International Standard, ISO/IEC 15444-1 (JPEG 2000 Part 1), for digital compression and coding of continuous-tone still images. (See Annex F for further details.) A DICOM Transfer Syntax for JPEG 2000 Image Compression shall be identified by a UID value, appropriate to the choice of JPEG 2000 coding process.

Two Transfer Syntaxes are specified for JPEG 2000 **Part 1**:

1. A Transfer Syntax with a UID of 1.2.840.10008.1.2.4.90, which specifies the use of the lossless (reversible) mode of JPEG 2000 Part 1 (ISO/~~IECS~~ 15444-1) (i.e. the use of a reversible wavelet transformation and a reversible color component transformation, if applicable, and no quantization).
2. A Transfer Syntax with a UID of 1.2.840.10008.1.2.4.91, which specifies the use of either:
 - a. the lossless (reversible) mode of JPEG 2000 Part 1 (ISO/~~IECS~~ 15444-1) (i.e. the use of a reversible wavelet transformation and a reversible color component transformation, if applicable, and no quantization **or codestream truncation**), or
 - b. the lossy (irreversible) mode of JPEG 2000 Part 1 (ISO/~~IECS~~ 15444-1) (i.e. the use of an irreversible wavelet transformation and an irreversible color component transformation, if applicable, and optionally quantization, **or the use of a reversible wavelet transformation and a reversible color component transformation, if applicable, followed by codestream truncation**).

The choice of **reversible versus irreversible** is at the discretion of the sender (SCU or FSC/FSU).

Note: When using the **irreversible wavelet transformation and an irreversible color component transformation, if applicable**~~lossy (irreversible) mode~~, even if no quantization is performed, some loss will always occur due to the finite precision of the calculation of the wavelet and multi-component transformations.

Only the features defined in JPEG 2000 Part 1 (ISO/IEC 15444-1) are permitted for these two Transfer Syntaxes. Additional features and extensions that may be defined in other parts of JPEG 2000 shall not be included in the compressed bitstream unless they can be decoded or ignored without loss of fidelity by all Part 1 compliant implementations.

If the object allows multi-frame images in the pixel data field, then, **for these JPEG 2000 Part 1 Transfer Syntaxes**, Each frame shall be encoded separately. Each fragment shall contain encoded data from a single frame.

Note: That is, the processes defined in ISO/IEC 15444-1 shall be applied on a per-frame basis. The proposal for encapsulation of multiple frames in a non-DICOM manner in so-called "Motion-JPEG" or "M-JPEG" defined in 15444-3 is not used.

For all images, including all frames of a multi-frame image, the JPEG 2000 bitstream specified in ISO/IEC 15444-1 shall be used. The optional JP2 file format header shall NOT be included.

Note: The role of the JP2 file format header is fulfilled by the non-pixel data attributes in the DICOM data set.

The International Standards Organization ISO/IEC JTC1 has also developed JPEG 2000 Part 2 (ISO/IEC 15444-2), which includes Extensions to the compression techniques described in Part 1 of the JPEG 200 Standard. Annex J of JPEG 2000 Part 2 describes extensions to the ICT and RCT multiple component transformations allowed in Part 1. Two types of multiple component transformations are defined in Annex J of Part 2 of JPEG 2000:

1. **Array based multiple component transforms which form linear combinations of components to reduce the correlation between components. Array based transforms include prediction based transformations such as DPCM as well as more complicated transformations such as the KLT. These array based transformations can be implemented reversibly or irreversibly.**
2. **Wavelet based multiple component transformations using the same two wavelet filters as used in Part 1 of JPEG 2000 (5-3 reversible wavelet and 9-7 irreversible wavelet).**

Annex J of JPEG 2000 Part 2 also describes a flexible mechanism to allow these techniques to be applied in sequence. Furthermore, it provides mechanisms which allow components to be re-ordered and grouped into component collections. Different multiple component transformation can then be applied to each component collection.

Two additional Transfer Syntaxes are specified for Part 2 JPEG 2000:

1. **A Transfer Syntax with a UID of 1.2.840.10008.1.2.4.92, which specifies the use of the lossless (reversible) mode of JPEG 2000 Part 2 (ISO/IEC 15444-2) multiple component transformation extensions, as defined in Annex J of JPEG 2000 Part 2 (i.e. the use of a reversible wavelet transformation and a reversible multiple component transformation, and no quantization or codestream truncation).**
2. **A Transfer Syntax with a UID of 1.2.840.10008.1.2.4.93, which specifies the use of either:**
 - a. **the lossless (reversible) mode of JPEG 2000 Part 2 (ISO/IEC 15444-2) multiple component transformation extensions, as defined in Annex J of JPEG 2000 Part 2 (i.e. the use of a reversible wavelet transformation and a reversible multiple component transformation, and no quantization), or**
 - b. **the lossy (irreversible) mode of JPEG 2000 Part 2 (ISO/IEC 15444-2) multiple component transformation extensions, as defined in Annex J of JPEG 2000 Part 2 (i.e. the use of an irreversible wavelet transformation and an irreversible multiple component transformation, and optionally quantization, or the use of an reversible wavelet transformation and a reversible multiple component transformation, followed by codestream truncation).**

Only the multiple component transformation extensions defined in Annex J of JPEG 2000 Part 2 (ISO/IEC 15444-2) are permitted for these two Transfer Syntaxes. Additional features and extensions that may be defined in other Annexes of JPEG 2000 Part 2 shall not be included in the compressed bitstream.

Note: the arbitrary wavelet transformations, as defined in Annex H of JPEG 2000 Part 2 (ISO/IEC 15444-2) are not allowed for these two Transfer Syntaxes. The only wavelet transformations that are allowed to be used as multiple component transformations are the reversible 5-3 wavelet transformation and the irreversible 9-7 wavelet transformation, as defined in Annex F of JPEG 2000 Part 1 (ISO/IEC 15444-1).

If the object allows multi-frame images in the pixel data field, then, for these JPEG 2000 Part 2 Transfer Syntaxes, the frames in the object are first processed using the multi-component transformation. After the multiple component transformation has been applied, the transformed frames are encoded using the process described in JPEG 2000 Part 1.

Optionally, the frames can be grouped into one or more component collections. The multiple component transformations are then applied to each component collection independently. The use of component collections can be used to reduce computational complexity and to improve access to specific frames on the decoder. If component collections are used, each fragment shall contain encoded data from a single component collection.

Notes: 1. The 3rd dimension transformations that are described in this Supplement are treated in Part 2 of JPEG 2000 as direct extensions to the color component transformations (RGB to YUV) that are described in Part 1 of JPEG 2000. For this reason, each image or frame in the sequence is called a "component". Although the term component is used as a generic term to identify an element of the 3rd dimension, no restriction is made or implied that the transformations in this Supplement apply only to multi-component (or multiple color channel) data. To compress a volumetric data set using this transfer syntax, each frame of the DICOM image is treated as a component of a multi-component image.

2. The progressive nature of the JPEG 2000 codestream allows for the decompression of the image before the complete image has been transferred. If a storage SCP truncates the code stream by aborting the association, the instance has not been completely transferred and hence should not persist unless different UIDs are assigned (even though it may have been transiently used for display purposes).

3. It has been shown that the use of component collections does not significantly affect the compression efficiency (for details, see [http://medical.nema.org/Dicom/minutes/WG-04/2004/2004-02-18/3D compression RSNA 2003 ver2.pdf](http://medical.nema.org/Dicom/minutes/WG-04/2004/2004-02-18/3D%20compression%20RSNA%202003%20ver2.pdf)).

Add JPEG 2000 Part 2 to Annex F:

Annex F (Informative) Encapsulated images as part of a DICOM message

F.3 ENCAPSULATED JPEG 2000 ENCODED IMAGES

The International Standards Organization (ISO/IEC JTC1/SC2/WG10) has prepared an International Standard, ISO/~~IEC~~-15444 (JPEG 2000-~~Part 1~~), for the digital compression and coding of continuous-tone still images. This standard is known as the JPEG 2000 Standard.

~~Part 1 of it~~The JPEG 2000 Standard sets out requirements and implementation guidelines for the coded representation of compressed image data to be interchanged between applications. The processes and representations are intended to be generic in order to support the broad range of applications for color and grayscale still images for the purpose of communications and storage within computer systems.

Though a different coding process from those specified in ISO 10918-1 is used, the syntax of the encoded bit stream is closely related.

A single JPEG 2000 process is used for bit depths up to 16 bits.

Inclusion of a JPEG 2000 coded image in a DICOM message is facilitated by the use of specific Transfer Syntaxes that are defined in Annex A.

Changes to NEMA Standards Publication PS3.6-2004

Digital Imaging and Communications in Medicine (DICOM)

Part 6: Data Dictionary

Add new UIDs for JPEG 2000 Part 2 to Annex A

Annex A (Normative) Registry of DICOM unique identifiers (UID)

UID Value	UID NAME	UID TYPE	Part
1.2.840.10008.1.2.4.90	JPEG 2000 Image Compression (Lossless Only)	Transfer Syntax	PS 3.5
1.2.840.10008.1.2.4.91	JPEG 2000 Image Compression	Transfer Syntax	PS 3.5
<u>1.2.840.10008.1.2.4.92</u>	<u>JPEG 2000 Part 2 Multi-component Image Compression (Lossless Only)</u>	<u>Transfer Syntax</u>	<u>PS 3.5</u>
<u>1.2.840.10008.1.2.4.93</u>	<u>JPEG 2000 Part 2 Multi-component Image Compression</u>	<u>Transfer Syntax</u>	<u>PS 3.5</u>