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Photography and graphic technology — Extended colour encodings for digital image storage, manipulation and interchange —

Part 1: Architecture and requirements

Photographie et technologie graphique — Codages par couleurs étendues pour stockage, manipulation et échange d'image numérique —

Partie 1: Architecture et exigences

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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The committee responsible for this document is ISO/TC 42, *Photography*.

This second edition cancels and replaces the first edition (ISO 22028-1:2004), of which it constitutes a minor revision with changes in Annex B and Bibliography. It also incorporates the Technical Corrigendum ISO 22028-1:2004/Cor. 1:2007.

ISO 22028 consists of the following parts, under the general title *Photography and graphic technology — Extended colour encodings for digital image storage, manipulation and interchange*:

— *Part 1: Architecture and requirements*

— *Part 2: Reference output medium metric RGB colour image encoding (ROMM RGB)*

— *Part 3: Reference input medium metric RGB colour image encoding (RIMM RGB)*

— *Part 4: European Colour Initiative RGB colour image encoding [eciRGB (2008)]*

Introduction

Modern digital imaging systems serve a variety of consumer and commercial applications. Depending on the application, differing priorities will apply to such system attributes as image quality, interoperability, simplicity of system architecture and computations, and the flexibility for optimally using images for a variety of purposes. Trade-offs among these attributes are application-dependent.

A fundamental choice for any imaging system architecture is how to represent images numerically, in what colour space and with what digital encoding. In some applications, a single colour encoding designed to be compatible with the prevalent mode of image viewing by the end user can suffice. Since both multimedia and Internet-based imaging rely heavily on the viewing of images on a softcopy display, the use of sRGB as a colour encoding makes sense for those applications. However, because the colour gamut of sRGB does not encompass the colour gamuts of many common input and output devices, a system architecture that depends exclusively on the use of sRGB would compromise colour reproduction accuracy unacceptably for some applications.

Colour management systems, such as that defined by the International Colour Consortium (ICC), provide a mechanism for transforming between various device-dependent and device-independent colour encodings through the use of colour profiles that are used to define transformations between the various colour encodings and a standard colour space known as the profile connection space (PCS). (The ICC.1:2001-12 specification defines two different PCS variations; one for colourimetric intent profiles and one for perceptual intent profiles.) The ICC PCS is intended to be a colour space to be used for connecting together different colour profiles and as such has a colour gamut large enough to encompass most common input and output devices and media. However, the ICC PCS was not designed to be used as a colour encoding for the storage, transmission or editing of digital images. Additionally, since ICC colour management is primarily designed to work with colour images in a picture-referred image state, it does not provide any explicit mechanism for the representation and manipulation of image data corresponding to other image states.

There are many different applications in the fields of digital photography and graphic technology that involve editing, storage and interchange of digital images in a variety of image states and colour encodings. In order to clearly communicate colour image information within and between these applications, it is necessary to unambiguously describe the meaning of the colour values used to encode digital images. The colour encoding definitions need to not only include a specification of the relationship between the digital code values and corresponding physical colour values but they also need to clearly specify any other information needed to unambiguously interpret the colour values. Accordingly, there is a need to identify what information is required when defining a colour encoding in order to ensure that digital image data can be clearly communicated between various applications.

This part of ISO 22028 addresses this need by specifying a set of requirements to be met by colour encodings defined for various digital imaging applications. This part of ISO 22028 also describes a reference image-state-based digital imaging architecture that is flexible enough to support a wide variety of applications and workflows. This image-state-based digital imaging architecture can be used to classify colour encodings into a number of different image states. However, this part of ISO 22028 does not specify any particular workflow(s) that needs to be used for any particular digital imaging applications.

There is also a need for the specification of standard extended-gamut colour encodings that can be used in the context of this architecture to preserve the full range of colour information at every stage of the workflow, from the initial image capture through to the final step of producing a softcopy or hardcopy reproduction. It is anticipated that subsequent parts of this multi-part standard will define at least one scene-referred extended-gamut colour encoding and at least one output-referred extended-gamut colour encoding.

The International Organization for Standardization (ISO) draws attention to the fact that it is claimed that compliance with this part of ISO 22028 can involve the use of a patent concerning colour management given in Clause 4 and 5.4.3.

ISO takes no position concerning the evidence, validity and scope of this patent right.

The holder of this patent right has assured ISO that he/she is willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with ISO. Information can be obtained from:

Microsoft Corporation

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Photography and graphic technology — Extended colour encodings for digital image storage, manipulation and interchange —

Part 1: Architecture and requirements

1 Scope

This part of ISO 22028 specifies a set of requirements to be met by any extended-gamut colour encoding that is to be used for digital photography and/or graphic technology applications involving digital image storage, manipulation and/or interchange. This part of ISO 22028 is applicable to pictorial digital images that originate from an original scene, as well as digital images with content such as text, line art, vector graphics and other forms of original artwork. This part of ISO 22028 also describes a reference image-state-based digital imaging architecture, encompassing many common workflows, that can be used to classify extended colour encodings into a number of different image states. However, this part of ISO 22028 does not specify any particular workflow(s) that are to be used for digital photography and/or graphic technology applications.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11664-1, *Colorimetry — Part 1: CIE standard colorimetric observers*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
absolute colorimetric coordinates
tristimulus values, or other colorimetric coordinates derived from a tristimulus values, where the numerical values correspond to the magnitude of the physical stimulus

EXAMPLE When CIE 1931 standard colour-matching functions are used, the Y-coordinate value corresponds to the luminance, not the luminance factor (or some scaled value thereof).

3.2
adapted white
colour stimulus that an observer who is adapted to the viewing environment would judge to be perfectly achromatic and to have a luminance factor of unity, i.e. absolute colorimetric coordinates that an observer would consider to be a perfect white diffuser

Note 1 to entry: The adapted white may vary within a scene.

3.3
additive RGB colour space
colorimetric colour space having three colour primaries (generally red, green and blue) such that CIE XYZ tristimulus values can be determined from the RGB colour space values by forming a weighted combination of the CIE XYZ tristimulus values for the individual colour primaries, where the weights are proportional to the radiometrically linear colour space values for the corresponding colour primaries

Note 1 to entry: A simple linear 3 × 3 matrix transformation can be used to transform between CIE XYZ tristimulus values and the radiometrically linear colour space values for an additive RGB colour space.

Note 2 to entry: Additive RGB colour spaces are defined by specifying the CIE chromaticity values for a set of additive RGB primaries and a colour space white point, together with a colour component transfer function.

3.4
adopted white
spectral radiance distribution as seen by an image capture or measurement device and converted to colour signals that are considered to be perfectly achromatic and to have an observer adaptive luminance factor of unity, i.e. colour signals that are considered to correspond to a perfect white diffuser

Note 1 to entry: The adopted white may vary within a scene.

Note 2 to entry: No assumptions should be made concerning the relation between the adapted or adopted white and measurements of near perfectly reflecting diffusers in a scene, because measurements of such diffusers will depend on the illumination and viewing geometry, and other elements in the scene that may affect perception. It is easy to arrange conditions for which a near perfectly reflecting diffuser will appear to be grey or coloured.

3.5
colorimetric colour space
colour space having an exact and simple relationship to CIE colorimetric values

Note 1 to entry: Colourimetric colour spaces include those defined by CIE (e.g. CIE XYZ, CIELAB, CIELUV, etc.), as well as colour spaces that are simple transformations of those colour spaces (e.g. additive RGB colour spaces).

3.6
colour component transfer function
single variable, monotonic mathematical function applied individually to one or more colour channels of a colour space

Note 1 to entry: Colour component transfer functions are frequently used to account for the nonlinear response of a reference device and/or to improve the visual uniformity of a colour space.

Note 2 to entry: Generally, colour component transfer functions will be nonlinear functions such as a power-law (i.e. “gamma”) function or a logarithmic function. However, in some cases a linear colour component transfer function may be used.

3.7
colour encoding
generic term for a quantized digital encoding of a colour space, encompassing both colour space encodings and colour image encodings

3.8
colour gamut
solid in a colour space, consisting of all those colours that are either present in a specific scene, artwork, photograph, photomechanical, or other reproduction or capable of being created using a particular output device and/or medium

3.9
colour image encoding
digital encoding of the colour values for a digital image, including the specification of a colour space encoding, together with any information necessary to properly interpret the colour values such as the image state, the intended image viewing environment and the reference medium

Note 1 to entry: In some cases, the intended image viewing environment will be explicitly defined for the colour image encoding. In other cases, the intended image viewing environment may be specified on an image-by-image basis using metadata associated with the digital image.

Note 2 to entry: Some colour image encodings will indicate particular reference medium characteristics, such as a reflection print with a specified density range. In other cases, the reference medium will be not applicable, such as with a scene-referred colour image encoding, or will be specified using image metadata.

Note 3 to entry: Colour image encodings are not limited to pictorial digital images that originate from an original scene, but are also applicable to digital images with content such as text, line art, vector graphics and other forms of original artwork.

3.10
colour-matching functions
tristimulus values of monochromatic stimuli of equal radiant power

[SOURCE: CIE Publication 17.4, 845-03-23]

3.11
colour rendering
mapping of image data representing the colour-space coordinates of the elements of a scene to output-referred image data representing the colour-space coordinates of the elements of a reproduction

Note 1 to entry: Colour rendering generally consists of one or more of the following: compensating for differences in the input and output viewing conditions, tone scale and gamut mapping to map the scene colours onto the dynamic range and colour gamut of the reproduction, and applying preference adjustments.

3.12
colour re-rendering
mapping of picture-referred image data appropriate for one specified real or virtual imaging medium and viewing conditions to picture-referred image data appropriate for a different real or virtual imaging medium and/or viewing conditions

Note 1 to entry: Colour re-rendering generally consists of one or more of the following: compensating for differences in the viewing conditions, compensating for differences in the dynamic range and/or colour gamut of the imaging media, and applying preference adjustments.

3.13
colour space
geometric representation of colours in space, usually of three dimensions

[SOURCE: CIE Publication 17.4, 845-03-25]

3.14
colour space encoding
digital encoding of a colour space, including the specification of a digital encoding method, and a colour space value range

Note 1 to entry: Multiple colour space encodings may be defined based on a single colour space where the different colour space encodings have different digital encoding methods and/or colour space value ranges. (For example, 8-bit sRGB and 10-bit bg-sRGB are different colour space encodings based on a particular additive RGB colour space.)

3.15
colour space white point
colour stimulus to which colour space values are normalized

Note 1 to entry: The colour space white point may or may not correspond to the assumed adapted white point and/or the reference medium white point for a colour image encoding.

3.16
continuous colour space value
real-valued, unbounded colour space value that has not been encoded using a digital encoding method

3.17
device-dependent colour space
colour space defined by the characteristics of a real or idealized imaging device

Note 1 to entry: Device-dependent colour spaces having a simple functional relationship to CIE colourimetry can also be categorized as colourimetric colour spaces. For example, additive RGB colour spaces corresponding to real or idealized CRT displays can be treated as colourimetric colour spaces.

3.18
digital imaging system
system that records and/or produces images using digital data

3.19
extended gamut
colour gamut extending outside that of the standard sRGB CRT display as defined by IEC 61966-2-1

3.20
film rendering transform
mapping of image data representing measurements of a photographic negative to output-referred image data representing the colour-space coordinates of the elements of a reproduction

3.21
film unrendering transform
mapping of image data representing measurements of a photographic negative to scene-referred image data representing estimates of the colour-space coordinates of the elements of the original scene

3.22
gamut mapping
mapping of the colour-space coordinates of the elements of a source image to colour-space coordinates of the elements of a reproduction to compensate for differences in the source and output medium colour gamut capability

Note 1 to entry: The term “gamut mapping” is somewhat more restrictive than the term “colour-rendering” because gamut mapping is performed on colourimetry that has already been adjusted to compensate for viewing condition differences and viewer preferences, although these processing operations are frequently combined in reproduction and preferred reproduction models.

3.23
hardcopy
representation of an image on a substrate which is self-sustaining and reasonably permanent

[SOURCE: ISO 3664:2009: 3.4, modified]

3.24
ICC profile
International Color Consortium”s file format, used to store transforms from one colour encoding to another, e.g. from device colour coordinates to profile connection space, as part of a colour management system

3.25
image state
attribute of a colour image encoding indicating the rendering state of the image data

Note 1 to entry: The primary image states defined in this part of ISO 22028 are the scene-referred image state, the original-referred image state and the output-referred image state.

3.26
International Color Consortium profile connection space
ICC PCS
standard colour image encoding defined by the International Color Consortium providing a standard connection point for combining ICC profiles

Note 1 to entry: The ICC.1:2001 specification defines two variations of the PCS, an original-referred variation for colourimetric intent profiles, and an output-referred variation for perceptual intent profiles.

3.27
luminance factor
ratio of the luminance of the surface element in the given direction to that of a perfect reflecting or transmitting diffuser identically illuminated

[SOURCE: CIE Publication 17.4, 845-04-69]

3.28
luminance ratio
ratio of the maximum luminance to the minimum luminance that is either present in a specific scene, artwork, photograph, photomechanical, or other reproduction or is capable of being created using a particular output device and medium

3.29
medium black point
neutral colour with the lowest luminance that can be produced by an imaging medium in normal use, measured using the specified measurement geometry

Note 1 to entry: It is generally desirable to specify a medium black point that has the same chromaticity as the medium white point.

3.30
medium white point
neutral colour with the highest luminance that can be produced by an imaging medium in normal use, measured using the specified measurement geometry

3.31
metadata
data associated with a digital image aside from the pixel values that comprise the digital image

Note 1 to entry: Metadata are typically stored as tags in the digital image file.

3.32
original-referred image state
image state associated with image data that represents the colour-space coordinates of the elements of a two-dimensional hardcopy or softcopy image, typically produced by scanning artwork, photographic transparencies or prints, or photomechanical or other reproductions

Note 1 to entry: When the phrase “original-referred” is used as a qualifier to an object, it implies that the object is in an original-referred image state. For example, original-referred image data are image data in an original-referred image state.

Note 2 to entry: Original-referred image data are related to the colour-space coordinates of the original, typically measured according to ISO 13655, and do not include any additional veiling glare or other flare.

Note 3 to entry: The characteristics of original-referred image data that most generally distinguish them from scene-referred image data are that they refer to a two-dimensional surface, and the illumination incident on the two-dimensional surface is assumed to be uniform (or the image data corrected for any non-uniformity in the illumination).

Note 4 to entry: There are classes of originals that produce original-referred image data with different characteristics. Examples include various types of artwork, photographic prints, photographic transparencies, emissive displays, etc. When selecting a colour re-rendering algorithm, it is usually necessary to know the class of the original in order to determine the appropriate colour re-rendering to be applied. For example, a colourimetric intent is generally applied to artwork, while different perceptual algorithms are applied to produce photographic prints from transparencies, or newsprint reproductions from photographic prints. In some cases, the assumed viewing conditions are also different between the original classes, such as between photographic prints and transparencies, and will usually be considered in well-designed systems.

Note 5 to entry: In a few cases, it may be desirable to introduce slight colourimetric errors in the production of original-referred image data, for example, to make the gamut of the original more closely fit the colour space, or because of the way the image data were captured (such as a Status A densitometry-based scanner).

3.33
output-referred image state
image state associated with image data that represents the colour-space coordinates of the elements of an image that has undergone colour-rendering appropriate for a specified real or virtual output device and viewing conditions

Note 1 to entry: When the phrase “output-referred” is used as a qualifier to an object, it implies that the object is in an output-referred image state. For example, output-referred image data are image data in an output-referred image state.

Note 2 to entry: Output-referred image data are referred to the specified output device and viewing conditions. A single scene can be colour-rendered to a variety of output-referred representations depending on the anticipated output-viewing conditions, media limitations, and/or artistic intents.

Note 3 to entry: Output-referred image data may become the starting point for a subsequent reproduction process. For example, sRGB output-referred image data are frequently considered to be the starting point for the colour re-rendering performed by a printer designed to receive sRGB image data.

3.34
picture-referred image state
image state associated with image data that represents the colour-space coordinates of the elements of a hardcopy or softcopy image, encompassing both original-referred image data and output-referred image data

Note 1 to entry: When the phrase “picture-referred” is used as a qualifier to an object, it implies that the object is in a picture-referred image state. For example, picture-referred image data are image data in a picture-referred image state.

Note 2 to entry: Picture-referred image data will generally be colour-rendered for a specific real or virtual imaging medium and viewing condition.

Note 3 to entry: Picture-referred image data can include image data that do not originate from an original scene, such as text, line art, vector graphics and other forms of original artwork.

3.35
scene
spectral radiances of a view of the natural world as measured from a specified vantage point in space and at a specified time

Note 1 to entry: A scene may correspond to an actual view of the natural world or to a computer-generated virtual scene simulating such a view.

3.36
scene-referred image state
image state associated with image data that represents estimates of the colour-space coordinates of the elements of a scene

Note 1 to entry: When the phrase "scene-referred" is used as a qualifier to an object, it implies that the object is in a scene-referred image state. For example, scene-referred image data are image data in a scene-referred image state.

Note 2 to entry: Scene-referred image data can be determined from raw DSC image data before colour-rendering is performed. Generally, DSCs do not write scene-referred image data in image files, but some may do so in a special mode intended for this purpose. Typically, DSCs write standard output-referred image data where colour-rendering has already been performed.

Note 3 to entry: Scene-referred image data typically represent relative scene colourimetry estimates. Absolute scene colourimetry estimates may be calculated using a scaling factor. The scaling factor can be derived from additional information such as the image OECF, FNumber or ApertureValue, and ExposureTime or ShutterSpeedValue tags.

Note 4 to entry: Scene-referred image data may contain inaccuracies due to the dynamic range limitations of the capture device, noise from various sources, quantization, optical blurring and flare that are not corrected for, and colour analysis errors due to capture device metamerism. In some cases, these sources of inaccuracy can be significant.

Note 5 to entry: The transformation from raw DSC image data to scene-referred image data depends on the relative adopted whites selected for the scene and the colour space used to encode the image data. If the chosen scene adopted white is inappropriate, additional errors will be introduced into the scene-referred image data. These errors may be correctable if the transformation used to produce the scene-referred image data are known and the colour encoding used for the incorrect scene-referred image data has adequate precision and dynamic range.

Note 6 to entry: The scene may correspond to an actual view of the natural world or may be a computer-generated virtual scene simulating such a view. It may also correspond to a modified scene determined by applying modifications to an original scene to produce some different desired scene. Any such scene modifications should leave the image in a scene-referred image state and should be done in the context of an expected colour-rendering transform.

3.37
softcopy
representation of an image produced using a device capable of directly representing different digital images in succession and in a non-permanent form

EXAMPLE The most common example is a monitor.

[SOURCE: ISO 3664:2009: 3.14]

3.38
standard original-referred colour encoding
colour encoding for original-referred image data defined and documented by an authorized standards body or industry consortium

3.39
standard output-referred colour image encoding
colour image encoding for output-referred image data defined and documented by an authorized standards body or industry consortium

3.40
standard scene-referred colour image encoding
colour image encoding for scene-referred image data defined and documented by an authorized standards body or industry consortium

3.41
tristimulus value
amounts of the three reference colour stimuli, in a given trichromatic system, required to match the colour of the stimulus considered

[SOURCE: CIE Publication 17.4, 845-03-22]

3.42
veiling glare
light, reflected from an imaging medium, that has not been modulated by the means used to produce the image

Note 1 to entry: Veiling glare lightens and reduces the contrast of the darker parts of an image.

Note 2 to entry: In CIE 122, the veiling glare of a CRT display is referred to as ambient flare.

3.43
viewing flare
veiling glare that is observed in a viewing environment but not accounted for in radiometric measurements made using a prescribed measurement geometry

Note 1 to entry: The viewing flare is expressed as a percentage of the luminance of adapted white.

4 Image-state-based digital imaging architecture

4.1 General

The architecture of a digital imaging system can be described, on the one hand, as the sum of its components and how those components are interconnected and, on the other hand, as the functions of those components and how they interact with each other as an integrated system. One important aspect of a digital imaging architecture is how the digital image data are encoded as it progresses through the system workflow from image capture/creation, through image processing/storage/interchange, and finally to output on one or more output devices.

The need for various colour encodings and the rationale for their specifications can be best understood in the context of the particular industry and workflow for which they are intended. The digital photography and graphic technology industries are very diverse and often complex. However, their core activities can be represented by a fairly simple model where images are classified according to their image state. As shown in Figure 1, this model consists of a generic digital imaging architecture that can be used to describe the workflows for many different applications. Examples showing how a number of typical workflows can be described in the context of this architecture are given in Annex A.

This image-state-based digital imaging architecture, and the associated terminology, facilitates a common framework for classifying different colour encodings and describing imaging chains for many diverse types of digital imaging systems. Any colour image encodings that are defined in this International Standard shall be described within the context of this architecture. In particular, the colour image encoding shall be identified with an appropriate image state. This part of ISO 22028 does not specify any workflows that should be used for any particular applications to transform image data to/from the identified image states.

The digital imaging architecture shows examples of where different types of devices may fit within typical workflows utilizing colour image encodings compliant with this part of ISO 22028. It is not intended to constrain the workflows for any particular applications to those shown in Figure 1. For example, raw digital camera captures may be processed directly to an output-referred colour encoding without stopping in a scene-referred colour encoding.

Workflows associated with particular applications may include additional colour encodings that may correspond to image states different than the standard image states defined in this image-state-based digital imaging architecture. For example, it may be useful to define a colour encoding for representing colour negative scans or an intermediate colour encoding for partially colour-rendered images. While such colour encodings may be valuable internally to particular applications, they should generally not be used for image interchange in an open system environment unless all components in the system are enabled to properly interpret/use the image data and/or provision is made for communicating a transformation of the image data to one of the standard image states.

The image state diagram shown in Figure 1 shows that most colour encodings can broadly be categorized into scene-referred or picture-referred image states.

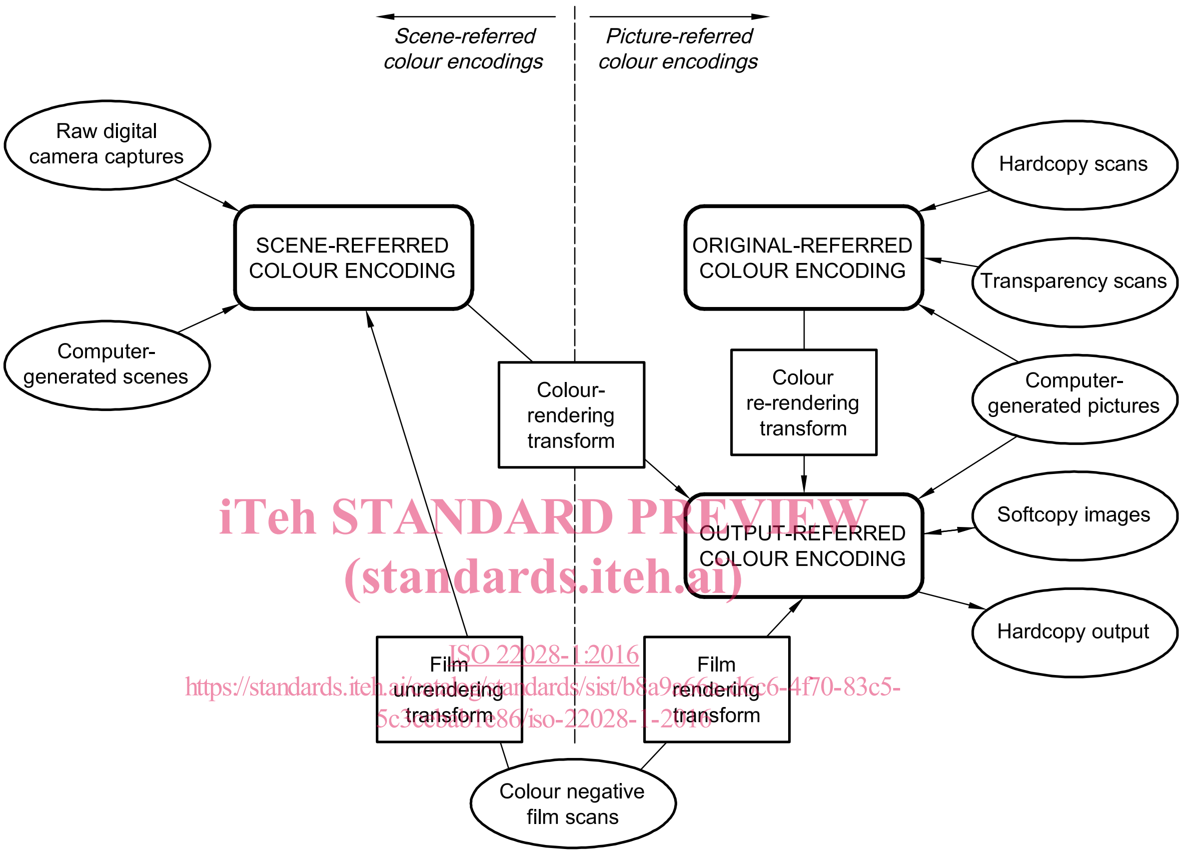

Figure 1 — Image state diagram showing relationship between various types of colour encodings

4.2 Scene-referred colour encodings

Scene-referred colour encodings are representations of the estimated colour-space coordinates of the elements of an original scene, where a scene is defined to be the spectral radiances of a view of the natural world as measured from a specified vantage point in space and at a specified time.

EXAMPLE Scene-referred image data may be represented in many different ways including encoding scene colour values using a CIE colour space such as CIE XYZ or CIELAB or in terms of the response of an idealized scene capture device such as RIMM RGB.

Scene-referred image data may correspond to an actual view of the natural world or to a computer-generated virtual scene simulating such a view. It may also correspond to a modified scene determined by applying modifications to an original scene. For example, such modifications could include removing haze from the captured image or allowing a user to manually adjust the exposure/white balance. It could also include more complex operations such as using a "dodge-and-burn" algorithm to correct over-exposed regions of a back-lit scene. (This can be viewed as being analogous to "re-lighting" the scene.) Scene modifications could also include applying desired changes to the scene such as simulating a "night" scene, making grass greener to make it look healthier, or making the sky bluer to make it

