Technical Report

ISO/TR 26478

Digital imaging — Skin tone representation for use in photographic testing, including test charts and test spectra

Imagerie numérique — Représentation des carnations pour utilisation dans les essais photographiques, y compris les mires et les analyses spectrales

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Foreword

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This document was prepared by Technical Committee ISO/TC 42, *Photography*

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Introduction

Photography is widely used to depict a wide range of human subjects, and thus a wide range of skin tones. It is important that photographic systems appropriately represent and reproduce this wide range of skin tones.

ISO/TC 42 has developed numerous standards which include colour patches or spectral data intended to represent various skin tones. (See Reference [12]) These include standards for characterizing digital cameras and for image permanence.

This report documents some of the work of an ISO/TC 42 Ad Hoc Group (AHG) created in the fall of 2023 to consider the test chart skin tone patches used in ISO/TC 42 standards. One goal of this AHG was to provide information for TC 42 working groups to consider regarding the use of skin tone representations for ISO/TC 42 related work. For example, when colour patches for skin tones are used in TC 42 standards, it is important that they be inclusive and represent a broad range of skin types. (See Reference [12].)

The AHG reviewed all ISO standards developed by TC 42 and identified eight relevant documents which include patches or spectra that could be considered to represent skin tones. The relevant image capture-related standards and technical reports are listed in 4.1 and discussed in Annex A, and the relevant image permanence and printing related standards and technical reports are listed in 4.2 and discussed in Annex B.

Ideally, the colour patches and spectral reflectance data intended to represent skin tones in TC 42 standards would be inclusive and represent a broad range of skin types. This document provides information which is helpful when selecting skin tones for use in image capture testing of digital imaging devices (e.g. digital cameras), specifically test charts which include skin tone patches and test spectra which represent skin tones. It also provides links to spectral reflectance data intended to represent a broad range of skin types.

The validity of a set of reference skin tones for photographic testing depends on its validation against criteria appropriate for the photographic-imaging application. For photographic systems that capture and reproduce images for viewing by humans, these criteria are not limited to spectral and colorimetric accuracy, which are necessary for spectral-domain applications but not sufficient for applications in which the reproduced image is judged perceptually by diverse human viewers across diverse populations of subjects. For applications in photographic testing of skin tone reproduction, additional relevant criteria include perceptual validation across diverse perceivers, cross-cultural inclusivity in the populations against which perceptual validation has been established, comparative discriminative validity against alternative references in independent evaluation, and documented validation in use.

This report supports UN Sustainable Development Goal SDG 10 (Reduced inequality) by providing information related to the selection of an inclusive set of colour patches.

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Digital imaging — Skin tone representation for use in photographic testing, including test charts and test spectra

1 Scope

This document provides information related to the representation of skin tones for use in photographic testing in order to be inclusive and represent a broad range of skin types. This includes the selection of colour patches intended to represent skin tones and spectral reflectance data intended to represent skin tones.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

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3.1
digital camera
device which incorporates an image sensor and produces a digital signal representing a picture

Note 1 to entry: A digital camera is typically a portable, hand-held device. The digital signal is usually recorded on a removable or an internal memory.

3.2
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.

3.3
photography
acquisition, processing, or reproduction of optically formed images using chemical or electronic technologies

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3.4
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 digital camera image data before colour-rendering is performed. Generally, digital cameras do not write scene-referred image data in image files, but some may do so in a special mode intended for this purpose. Typically, digital cameras 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 colorimetry estimates. Absolute scene colorimetry 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 digital camera 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.

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3.5
skin tone
perceived colour of the surface of human skin

Note 1 to entry: A colour is expressed by the CIELAB colour space and characterized by lightness, hue, and chroma.

3.6
test chart
arrangement of test patterns designed to test particular aspects of an imaging system

3.7
test pattern
specified arrangement of spectral reflectance or transmittance characteristics used in measuring an image quality attribute

4 Image capture standards

4.1 General

The following published ISO standards or Technical Reports developed by ISO/TC 42 relate to digital image capture and include test patches or spectra intended to represent skin tones. These standards are described in Annex A:

— ISO 19093:2018;

— ISO 17321-1:2012;

— ISO/TR 17321-2:2012;

— ISO/TR 19263-1:2017;

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— ISO 19264-1.

Except for ISO 19093, these four documents use only two skin tone patches, a “dark skin” patch and a “light skin” patch, from the ColorChecker colour rendition chart first defined in 1976. (See Reference [7]).

4.2 Printing and image permanence

The following image permanence and printing standards or technical specifications were reviewed by experts from ISO/TC 42. These standards are described in Annex B:

— ISO/PAS 18940-1:2025;

— ISO/TS 21139-22:2023;

— ISO 18946:2023;

— ISO/TS 20791-2:2021;

One of these documents uses only two relevant patches, a lighter patch and a darker patch similar to those defined for the original Macbeth ColorChecker test chart in 1976 as discussed above. (See Reference [7]). Two more recent standards documents use the same two patches along with a third, darker brown patch. The fourth document uses a total of 6 different light brown patches, intended to represent brownish colours from many origins, such as landscape, leather, fur, but no dark brown patches.

In addition, ISO 18944 specifies requirements and recommendations for the digital test file content used to generate target prints for image stability testing of reflection colour photographic prints.

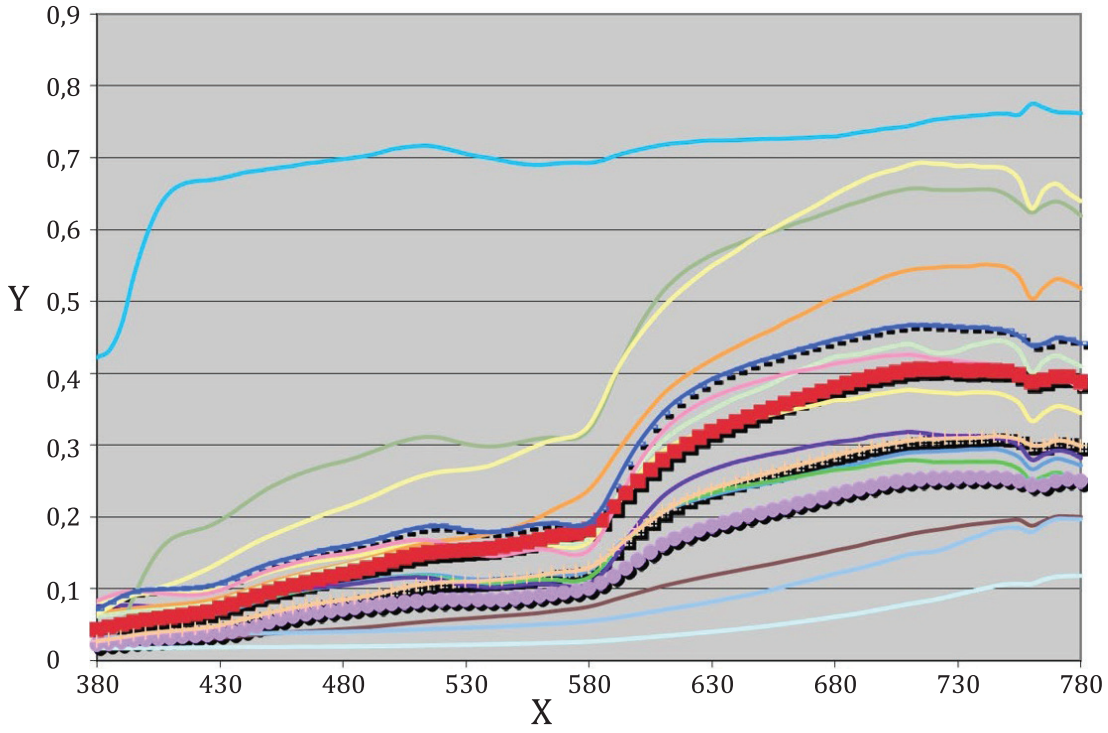
The image permanence test targets defined in the standards described above were designed to cover the printed colour space in general and are not intended to spectrally reproduce any specific natural colours such as skin tones, blue sky or the colours of other natural objects. Photographic prints are based on a limited number of pigments or dyes and therefore cannot spectrally match the wide range of colours of the natural world but typically provide metameric matches. Therefore, a typical set of test patches for image permanence contains single and mixed colorant patches to study the stability of the colorants separately or in combination. These test targets have been validated by inter-laboratory comparison tests and have been used for many years, providing a database of comparable permanence data for contemporary and historical photographic material. If a permanence test is developed to specifically probe colour permanence of skin tones, this report can provide relevant information regarding how to select such patches.

5 Skin tone spectra

A large percentage of photographs depict at least one person, and people are very sensitive to skin tone reproduction errors in photography, so properly capturing and reproducing a diverse range of skin tones is very important. (See Reference [10]). Examples of the relative radiance spectra of real skin tones are shown in Figure 1. (See Reference [11]).

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Key

X wavelength

Y relative radiances

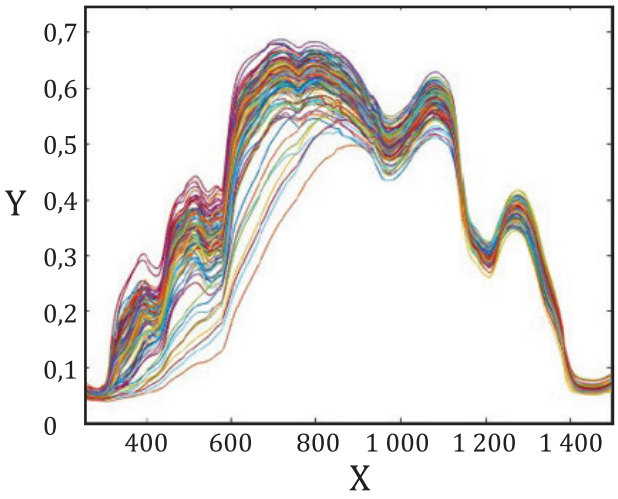
Figure 1 — Examples of the relative radiance spectra of real skin tones

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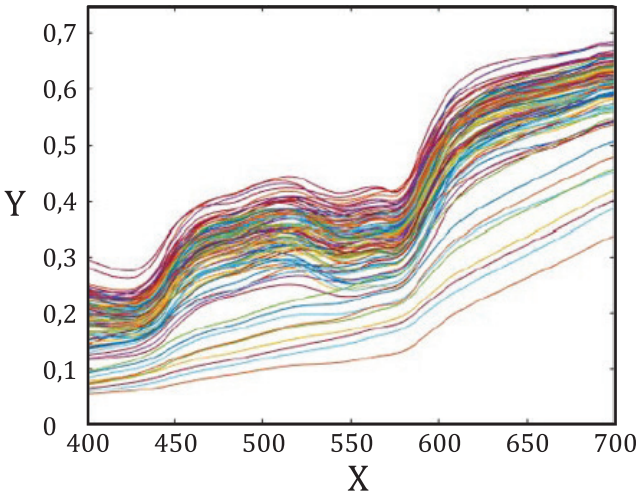
In addition, a set of 100 spectral measurements of human skin reflectance is available from the US National Institute of Standards and Technology (NIST), as described in Cooksey, et al.[3].

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The text file posted at this URL was converted to Excel format, and the spectra are shown in Figure 2 (see Reference [2]). Note that the spectral reflectance values range between 250 nm and 2 500 nm, in 3 nm intervals. The wide wavelength range of the posted data was based on a range of potential uses, including medical applications, that are beyond our area of focus.



a) NIST 100 reflectance spectra (250 to 1 400) nm



b) Visible wavelengths (400 to 700) nm

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Key

X wavelength
Y reflectance

Figure 2 — NIST 100 reflectance spectra

CIE Technical Committee 1-92 has developed and published a Human Skin Colour Database (CIE 256) which provides valuable data for research and applications related to skin colour measurement. This database is available at: https://www.cie.co.at/publications/measuring-skin-colour/dataset1-humanskincolourdatabase

In addition, skin tone spectral data has been reported by Wang, et. al[9] and Xiao, et. al.[13] Kaida Xiao has published a version of the skin tone database at https://www.kaidaxiao.co.uk/about-1

6 Test charts and colour palettes with skin tone patches

6.1 General

Over the last fifty years, various colour test charts and colour palettes have been developed which include patches intended to represent skin tones. These palettes serve different purposes. Some are designed for medical use, some for cosmetics, and others to represent skin tones in print, display and image capture. These charts and palettes are described in 6.2 to 6.11.

6.2 ColorChecker classic test chart

The original design of the most widely used colour test chart was described in a 1976 publication. (See Reference [7]). The original name for this test chart was the "Macbeth ColorChecker", which was also referred to as the "Macbeth chart". The current version of the test chart, now known as the Calibrite ColorChecker Classic test chart, is shown in Figure 3. The 24 patches are surrounded by a black border and include 6 patches in a grey lightness scale and saturated red, green, blue, cyan, magenta and yellow patches in the two bottom rows of the chart. The original spectral reflectances of the colour patches in the top two rows were chosen to approximate natural objects such as blue sky and green foliage.

The two colour patches in the upper left were intended to represent dark skin and light skin. The designers of the original Macbeth ColorChecker test chart contended that the lightest human skin being photographed is practically white, due to the use of talcum powder, while the darkest human skin is practically black, and that both have nearly uniform spectral reflectances. They also contended that the characteristic spectrum of human skin is primarily due to absorption by melanin and hemoglobin, such that the spectra for all types of human skin form a continuous homologous series. The medium light skin and medium dark skin patches were selected to test the ability of systems to reproduce the colour associated with this typical spectrum at two different exposure levels. (See Reference [7]).

1) Macbeth ColorChecker, Gretag-Macbeth ColorChecker, X-rite ColorChecker, and Calibrite ColorChecker Classic are examples of commercially available products. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

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Figure 3 — ColorChecker classic test chart

The selection and arrangement of colour patches in the Macbeth ColorChecker was based on an earlier colour chart developed by Kodak Research Labs, which was reported in 1957. See Reference [1]. The Kodak chart had 24 patches arranged in a (6 × 4) grid. Each patch was produced by applying pigments to (2 × 2) inch pieces of cover glass which were held in a wooden frame. The chart included six neutral patches (including a titanium white patch with 78 % reflectance and an ivory black patch with 0,22 % reflectance), nine highly saturated colours, and several "familiar" colours including foliage, blue sky, and flesh. While it included only a single "flesh" patch (produced using a combination of cadmium red, strontium yellow, ultramarine blue, and titanium white pigments with 32 % reflectance), it also included a "brown" patch (produced using burnt umber, burnt sienna, yellow ochre, and zinc oxide with 2,7 % reflectance), see Reference [1].

NOTE The decimal sign is a comma in ISO standards.

In 1997, the Gretag Color Control System Division merged with the Macbeth division of Kollmorgen Instruments to form Gretag-Macbeth, which sold the similar Gretag-Macbeth ColorChecker chart. In 2006, X-Rite acquired the holding company which owned Gretag-Macbeth and began selling the X-rite ColorChecker. In 2021, X-Rite photo and video products were transferred to a new company named Calibrite, which currently sells the Calibrite ColorChecker Classic test chart.

The ISO/TC 42 standards described earlier in 4.1 and 4.2 that include dark skin and light skin patches are based on the spectral reflectances of the original Macbeth ColorChecker described in Reference [7]. A comparison of this original ColorChecker chart and an X-Rite ColorChecker chart was made using a SpectraScan PR-740 Spectroradiometer. The data is provided in Annex D. It shows that the spectral data in the TC 42 standards provides a reasonably accurate representation of the original Macbeth ColorChecker test chart. However, several colour patches on the X-Rite ColorChecker are substantially different from the ISO data and the original Macbeth ColorChecker test chart. In particular, Patches 1 (dark skin), 3 (blue sky), 4 (foliage), 5 (blue flower), 8 (purplish blue), and 13 (blue) of the X-Rite ColorChecker are significantly different than the original Macbeth ColorChecker test chart. While the original test chart appears to mimic these items spectrally, the X-Rite ColorChecker test chart seems to only mimic them colorimetrically. Patches 2 (light skin), 6 (bluish green), 7 (orange), 10 (purple), 14 (green), and 17 (magenta), are slightly different, while the remaining colour patches are essentially the same.

6.3 ColorChecker digital SG test chart

The ColorChecker digital SG chart, currently available from Calibrite, is shown in Figure 4. This test chart is A4-sized and features 140 patches designed for digital camera calibration and ICC Profile determination.

2) The Calibrite ColorChecker Digital SG chart is an example of a commercially available product. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

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