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Image technology colour management — Black point compensation

Élément introductif — Élément central — Élément complémentaire

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Foreword

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ISO 18619 was prepared by Technical Committee ISO/TC 130, *Graphic technology*, , in cooperation with the International Color Consortium.

Introduction

Black point compensation (BPC) is a technique used to address colour conversion problems caused by differences between the darkest level of black achievable on one device and the darkest level of black achievable on another. It was first introduced by Adobe in Adobe Photoshop® and permission has been given by Adobe Systems Incorporated to the International Color Consortium (ICC) and ISO Technical Committee 130 (Graphic technology) to create this Technical Specification to allow black point compensation to be used in a consistent manner.

The purpose of BPC is to adjust a colour transform so that it retains shadow details and utilizes available black levels. Each ICC profile contains one or more colour transforms. These colour transforms are identified according to ICC rendering intent (media-relative colorimetric, perceptual, saturation) and operational direction (B2A: from the ICC PCS encoding to the colour space encoding, or A2B: from the colour space encoding to the ICC PCS encoding). When the black points of the source ICC profile transform and the destination ICC profile transform are identical, BPC has no effect.

The procedure depends only on the rendering intent(s) and the source and destination ICC profiles, not on any points in a particular image. Therefore, the colour transform using specific source and destination ICC profiles can be computed once, and then efficiently applied to many images which use the same ICC profile colour transform pair.

Image technology colour management — Black point compensation

1 Scope

This International Standard specifies a procedure, including computation, by which a transform between ICC profiles can be adjusted (compensated) to take into account differences between the dark end of the source colour space and the destination colour space. This is referred to as black point compensation (BPC). The relative colorimetric encoding of ICC profile transforms already provides a mechanism for such adjustment of the light (white) end of the tone scale.

2 Normative references

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

ISO 15076-1, *Image technology colour management — Architecture, profile format and data structure — Part 1: Based on ICC.1:2010*

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 15076-1and the following terms and definitions apply.

3.1
Black point compensation (BPC)
computational procedure by which a transform between ICC profiles can be adjusted (compensated) to take into account differences between the dark end of the source colour space and the dark end of the destination colour space.

3.2
DestinationBlackPoint
coordinate representing a dark neutral reproducible colour in the destination colour space

3.3
DProfile
ICC destination profile

3.4
L, a, b
L*, a*, or b* component of the *PCSLAB* colour space.

3.5
SourceBlackPoint
coordinate representing a dark neutral colour in the source gamut

3.6
SProfile
ICC source profile

3.7
RenderingIntent
rendering intent of the conversion from a source ICC profile's colour space to a destination ICC profile's colour space.

3.8
transform
mathematical operations that define the change in representation of a colour between two colour spaces

3.9
gamut
range of colours that a given system is capable of reproducing

3.10
LabProfile
real or virtual ICC profile that performs an identity transform to and from PCSLAB

4 Requirements

4.1 Constraints

The black point compensation procedure defined in this International Specification shall take as its inputs a destination ICC profile, a ICC source profile, and a rendering intent, all of which shall be compliant with ISO 15076-1.

NOTE ISO 15076-1 provides a description of source and destination ICC profiles.

The rendering intent shall be one of: media-relative colorimetric; perceptual; or saturation.

For this definition of black point compensation, the rendering intent used with the destination ICC profile shall be the same as the rendering intent used with the source ICC profile.

NOTE Other definitions allow different source and destination rendering intents

The versions of the source and destination ICC profiles do not need to match.

The source and destination ICC profile types shall be Input, Display, Output, or Color Space. The types of the source and destination ICC profiles do not need to match.

For generalized n-Color spaces the device values that result in the black point may not be readily identifiable and therefore BPC is not defined for generalized n-Color spaces.

4.2 Computation

4.2.1 Outline

Four steps are used in accomplishing black point compensation. They are:

1) Computing the `SourceBlackPoint`

2) Computing the DestinationBlackPoint,

3) Computing the mapping from `SourceBlackPoint` to `DestinationBlackPoint`, and

4) Applying the mapping computed in step 3 in a colour conversion

In the description of various steps, the following transforms are used:

— T is the function to transform a point in one ICC profile's device colour space to another ICC profile's device colour space, using a given intent.

— *y* = **T** (*x, SProfile, DProfile, RenderingIntent*)

where

x is a point in the Source Profile's colour space and

y is a point in Destination Profile's colour space.

4.2.2 Computing the SourceBlackPoint

The SourceBlackPoint is computed by first defining LocalBlack of the source ICC profile and then using this to compute the SourceBlackPoint.

The source *LocalBlack* shall be defined as follows:

If the source ICC profile is a CMYK output ICC profile

LocalBlack shall be set to T ((0,0,0), *LabProfile, SProfile, PerceptualIntent*)

For source ICC profiles that are not CMYK output ICC profiles

If the source ICC profile's colour space is RGB or *PCSLAB*, *LocalBlack* shall be set to (0,0,0).

If the source ICC profile's colour space is CMYK, *LocalBlack* shall be set to the max colorant in each channel (1,1,1,1).

If the source ICC profile's colour space is Gray with zero as black, *LocalBlack* shall be set to (0).

If the source ICC profile's colour space is Gray with zero as white, *LocalBlack* shall be set to max colorant (1).

For other colour spaces, *LocalBlack* shall be the value of black or darkest colour according to the source ICC profile's colour space.

The SourceBlackPoint is then calculated as follows

L_i shall be set to the L component of T (*LocalBlack, SProfile, LabProfile, RenderingIntent*).

If L_i is greater than 50, *SourceBlackPoint* shall be set to (50,0,0).

Else *SourceBlackPoint* shall be set to (L_i,0,0).

4.2.3 Computing the DestinationBlackPoint for ICC profiles that are not LUT-based Gray, RGB, or CMYK

The DestinationBlackPoint for ICC profiles that are not LUT-based Gray, RGB, or CMYK is computed by first determining LocalBlack of the destination ICC profile and then using this to compute the DestinationBlackPoint.

The destination *LocalBlack* shall be determined as follows:

If the destination ICC profile is a CMYK ICC profile

LocalBlack shall be set to T ((0,0,0), *LabProfile, DProfile, PerceptualIntent*)

For destination ICC profiles that are not CMYK ICC profiles

If the destination ICC profile's colour space is RGB or *PCSLAB*, *LocalBlack* shall be set to (0,0,0).

If the destination ICC profile's colour space is CMYK, *LocalBlack* shall be set to the max colorant in each channel (1,1,1,1).

If the destination ICC profile's colour space is Gray with zero as black, *LocalBlack* shall be set to (0).

If the destination ICC profile's colour space is Gray with zero as white, *LocalBlack* shall be set to max colorant (1).

NOTE For use of black point compensation with other colour spaces (outside the scope of this document), *LocalBlack* is the value of black or darkest colour according to the destination ICC profile's colour space.

The DestinationBlackPoint is then calculated as follows

L_i shall be set to the L component of T (*LocalBlack, DProfile, LabProfile, RenderingIntent*).

If L_i is greater than 50, *DestinationBlackPoint* shall be set to (50,0,0).

Else *DestinationBlackPoint* shall be set to (L_i,0,0).

4.2.4 Computing the DestinationBlackPoint for ICC profiles that are LUT-based Gray, RGB, or CMYK

4.2.4.1 Overview

The DestinationBlackPoint for ICC profiles that are LUT-based Gray, RGB, or CMYK is computed using one of three procedures that depend on the relationship between source x and converted L. To determine this relationship it is necessary to compute InitialLAB, inRamp, and outRamp (including the destination black transform, BT).

Based on these parameters the following tests are used, in sequence, to determine the computation of the DestinationBlackPoint:

— Is the outRamp valid? (see 4.2.4.3) If not the DestinationBlackPoint is set to (0,0,0)

— Is the destination ICC profile relative colorimetric? If not the DestinationBlackPoint is determined using curve fitting as described in 4.2.4.5.

— Is the mid range of the relationship between the inRamp and outRamp "straight"?.(see 4.2.4.5) If not the DestinationBlackPoint is determined using curve fitting as described in 4.2.4.5 otherwise the DestinationBlackPoint is set to InitialLAB.

Figure 1 outlines the sequence used in computing the DestinationBlackPoint for ICC profiles that are LUT-based Gray, RGB, or CMYK.

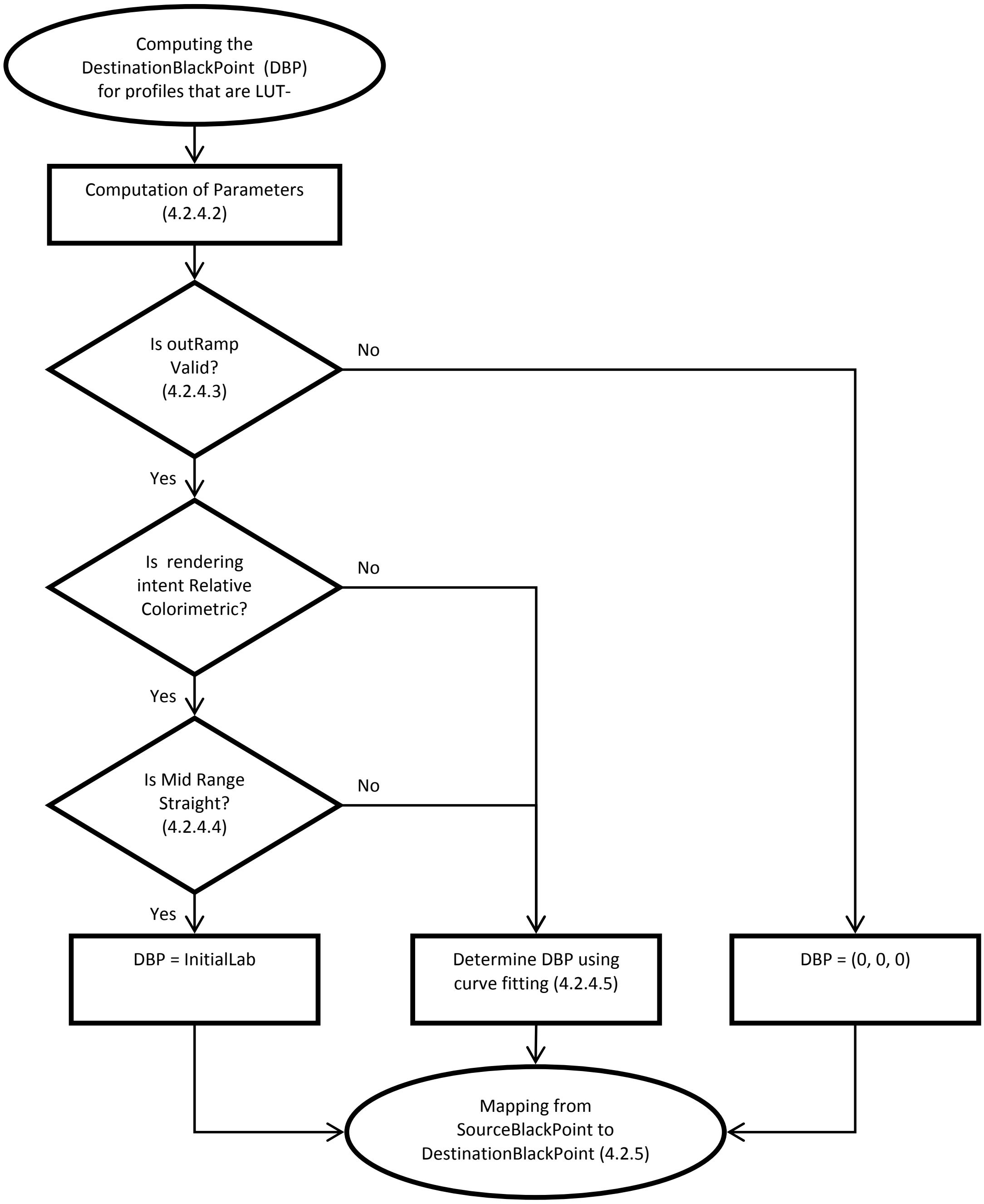

Figure 1 — DestinationBlackPoint computation logic sequence

4.2.4.2 Computation of parameters

4.2.4.2.1 InitialLAB Calculation

If the destination ICC profile is a CMYK ICC profile

InitialLab shall be set to `T` ((0,0,0), *LabProfile,* `DProfile`, *PerceptualIntent*)

For destination ICC profiles that are not CMYK ICC profiles

If the destination ICC profile's colour space is RGB or *PCSLAB*, *InitialLab* shall be set to (0,0,0).

If the destination ICC profile's colour space is CMYK, *InitialLab* shall be set to the minimum colorant in each channel (0,0,0,0).

If the destination ICC profile's colour space is Gray with zero as black, *InitialLab* shall be set to (0, 0, 0).

If the destination ICC profile's colour space is Gray with zero as white, *InitialLab* shall be set to minimum colorant (0).

NOTE For use of black point compensation with other colour spaces (outside the scope of this document), *InitialLab* is the value of black or darkest colour according to the destination ICC profile's `colour` space.

4.2.4.2.2 Calculation of inRamp

The list of L* values i`nRamp shall be calculated as follows:`

`ka shall be min(50, max(-50, a* component of InitialLab)`

`kb shall be min(50, max(-50, b* component of InitialLab)`

`inRampLab shall be the interpolated list of Lab values from (0, ka, kb) to (100, 0, 0) in 256 equal steps`

inRamp shall be a list of the L component values from inRampLab

4.2.4.2.3 Calculation of outRamp

BT shall be a transform of a Lab colour that provides a round trip to and from the PCS as follows:

BT(*x, Profile, UserIntent*) = T(*y, Profile, LabIdentityProfile, RelativeColorimetricIntent*)

Where:

x is a source Lab color

y is a device space color defined found using the transform T(*x, LabIdentityProfile, Profile, UserIntent)*

Profile defines the ICC profile to round trip with

UserIntent defines the rendering intent to round trip with.

*LabIdentityProfil**e*** defines the use of an ICC profile that uses the Lab color space and performs an identity transform into and out of PCS

RelativeColorimetricIntent identifies that the relative color intent should be used

`BT` is a transform that converts data from *PCSLAB* to device colour space to *PCSLAB* as shown in Figure 2

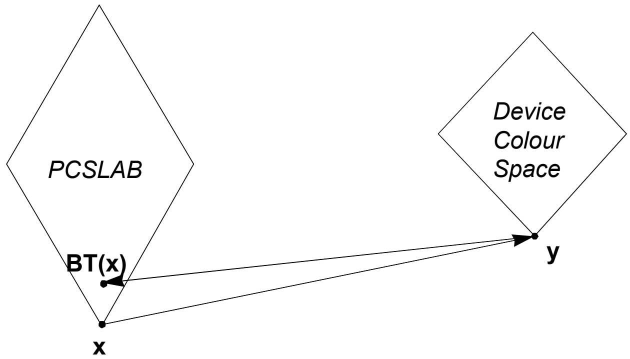

Figure 2 — BT transform

outRampLab shall list of transformed Lab values found by applying BT(inRampLab[i], *Profile*, *Userintent*) to each of the elements of inRampLab

outRamp shall be set to a list of the L* components of outRampLab.

outRamp shall then be modified as needed to ensure that it is monotonically increasing. This can be accomplished by looping from the second to last element to the first element of outRamp and setting the i^{th} elment to the minimum of the i^{th} element and the element just after the i^{th} element. This is shown in the following pseudo code:

for (i=*last*-1 to *first*)

outRamp[i] = min (outRamp[i], outRamp[i+1])

where

first indicates the first index of outRamp

last identifies the last index of outRamp

4.2.4.3 Test for outRamp valid

The calculation of outRamp in 4.2.4.2.3 adjusts outRamp to ensure that it is monotonically increading. However, if the first entry was greater than the last entry the adjustement will resunt in all the values in outRamp set to the same value. The DestinationBlackPoint calculations require outRamp is monotonically increasing. When outRamp[first] is not less than outRamp[last] then the outRamp is considered invalid and the *DestinationBlackPoint* shall be set to (0, 0, 0).

4.2.4.4 Test for mid range straight

If the distance between inRamp and outRamp entries is within 4 units over 80% of the range of `L`, then *`DestinationBlackPoint`* `equals` *`InitialLab`*`. If this distance is greater than 4 units one of the methods described in 4.2.3.3.5 shall be used. This has been traditionally referred to as "midrange straight".`

`The test for "midrange straight". Is as follows:`

`Assume that mid range is straight`

`MinL` shall be the value of the first element of outRamp

`MaxL` shall be the value of the last element of outRamp

For `all index values i in inRamp and outRamp`

```
If (not((inRamp[i] <= MinL + 0.2 * (MaxL - MinL) ) or
      (abs(inRamp[i] – outRamp[i]) < 4 ))) Then
```

Mid range is not straight.

If the mid range is straight (as determined above) then the DestinationBlackPoint shall be the same as initialLab. Otherwise, the DestinationBlackPoint shall be determined using curve fitting.

4.2.4.5 Computation of DestinationBlackPoint using curve fitting

The DestinationBlackPoint estimation by means of curve fitting is performed using transform T defined in 4.2.1 along with the following:

yRamp shall be list of values where yRamp[i] = (outRamp[i]-MinL) / (MaxL – MinL) for all valid index values i

The shadow curve points, SP = { (inRamp[i], yRamp[i] } , shall define a set of (inRamp[i], yRamp[i]) points for limited range of index values of i as follows:

If UserIntent is relative colorimetric then shadow points are points defined by indices *i* where 0.1 ≤ yRamp[i] < 0.5

Otherwise shadow points are points defined by indices *i* where (0.03 ≤ yRamp[i] < 0.25)

The curve fitting approach used to estimate the DestinationBlackPoint requires that the number of shadow points in SP be equal to or greater than 3.

If there are fewer than 3 points in SP then curve fitting cannot be applied to the data, and the the DestinationBlackPoint shall be set to (0, 0, 0)

Otherwise the shadow curve points SP shall be fit using a least squares error approach to the quadratic curve y'(*x*) = a*x*^2 + b*x* + c and the values for a, b, and c are determined.

A value of z shall be determined to define the DestinationBlackPoint as follows:

If (abs(a)<1.0E-10)

z shall be set to min(0, max(50, –c / b))

else

d shall be set to (b^2 – 4 a c)

if (d <=0)

z shall be set to 0

else

z = min(0, max(50, (-b + sqrt(d)) / (2 a)))

The DestinationBlackPoint shall be set to (z, 0, 0).

Figure 3 shows an example of estimating the DestinationBlackPoint using curve fitting:

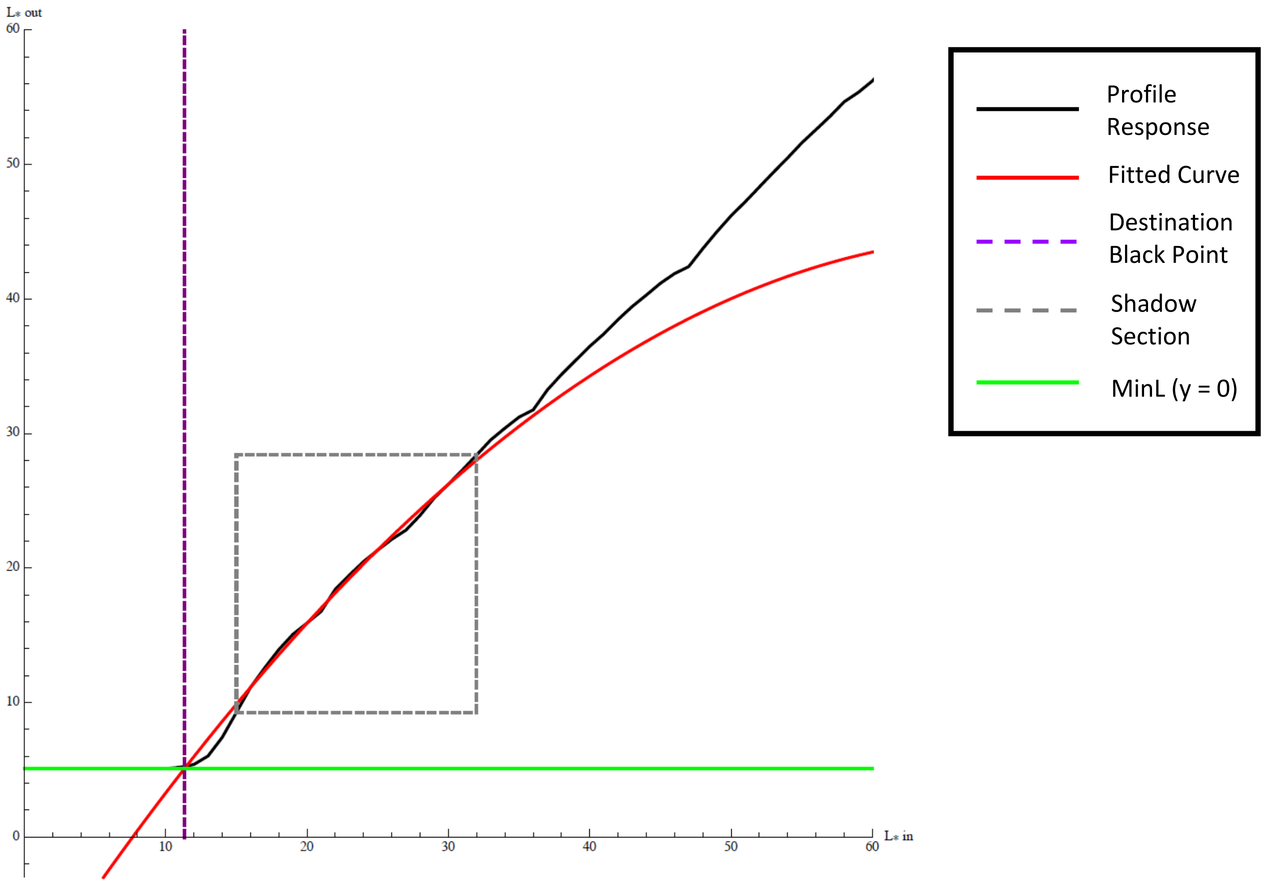

Figure 3 — Example Curve Fitting

4.2.5 Computing the mapping from SourceBlackPoint to DestinationBlackPoint

The mapping from SourceBlackPoint to DestinationBlackPoint shall be accomplished as follows:

Only the `L` components of the `SourceBlackPoint` and `DestinationBlackPoint` values are used, while the a and b components are ignored.

`scaleXYZ` shall be set to $(1 - Y_{DST}) / (1 - Y_{SRC})$,

`offsetXYZ` shall be set to (1 - `scaleXYZ`) * `W`,

where

Y_{DST} = `Y` of `DestinationBlackPoint`

Y_{SRC} = `Y` of `SourceBlackPoint`

`W` = { 0.9642, 1.0000, 0.8249 }, which is the *PCSXYZ* white point,

And

$Y = L \times (((8 + 16) / 116)^3) / 8.0$, for $0 \leq L \leq 8.0$;

$= ((L + 16) / 116)^3$, for $L > 8.0$

$= -((-L + 16) / 116)^3$ for $L < 0$

4.2.6 Applying the black point compensation in a colour conversion

Black point compensation shall be applied at the point in the colour transforms where output results from applying the source ICC profile are used as the input for applying the destination ICC profile as follows:

The source device space value shall be converted to PCSXYZ using the SProfile according to RenderingIntent, (including conversion from PCSLAB to PCSXYZ when the ICC profile's PCS is PCSLAB). XYZ_{SRC} shall be the PCSXYZ value resulting from this conversion.

The black point compensated PCSXYZ value (XYZ_{DST}) shall be calculated using the equation:

$$XYZ_{DST} = scaleXYZ * XYZ_{SRC} + offsetXYZ.$$

The XYZ_{DST} value shall be converted to device colour space using the DProfile, including conversion from PCSXYZ to PCSLAB when the ICC profile's PCS is PCSLAB.

Annex A
(informative)

Why black point compensation is necessary

.Figure A.1 shows the comparison of a source and destination colour space where no compensation or compression is provided.

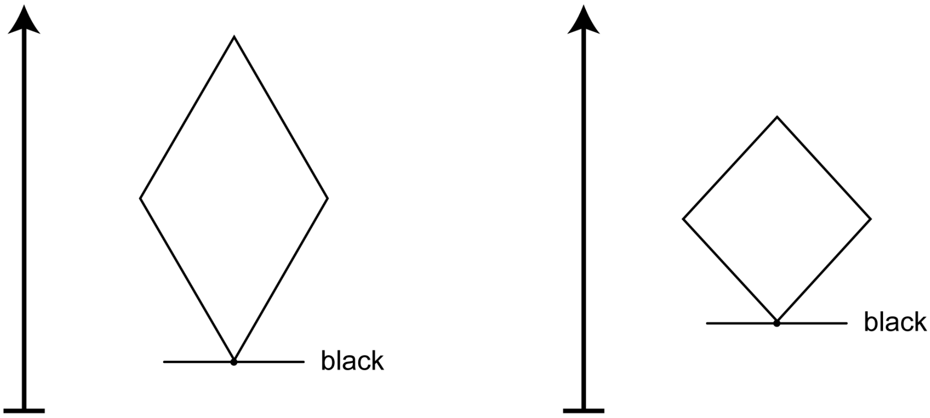

Figure A.1 — Source vs. destination colour spaces

The colour conversion algorithm consults the ICC profiles of the two devices (the source device and destination device) and the user's rendering intent (or intent) in order to perform the conversion. Although ICC profiles specify how to convert the lightest level of white from the source device to the destination device, the ICC profiles do not specify how black should be converted. The user observes the effect of this missing functionality in ICC profiles when a detailed black or dark space in an image is transformed into an undifferentiated black or dark space in the converted image. The detail in dark regions (called the shadow section) of the image can be lost in standard colour conversion.

Figure A.2 shows the effect of white point compensation alone as presently defined in ICC profiles.

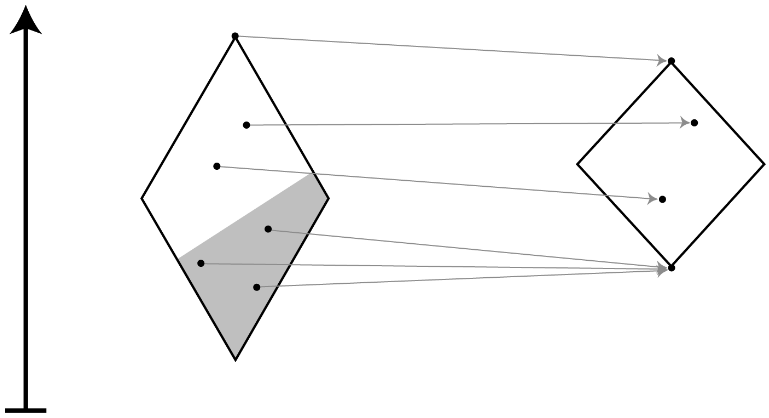

Figure 2 — Compression without black point compensation

BPC can be implemented to address this conversion problem by adjusting for differences between the darkest level of black achievable on one device and the darkest level of black achievable on another. Because BPC is an optional feature that the user can enable or disable when converting an image, the user can always decide whether the conversion of a particular image looks better with or without BPC.

Figure A.3 shows the effect of using both e black point and white point compensation.

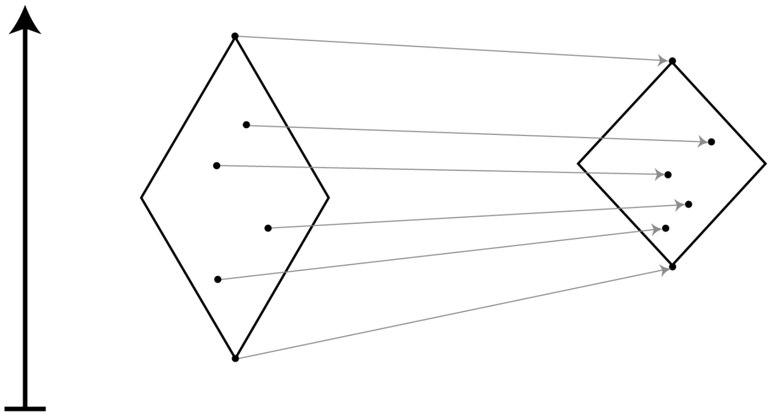

Figure A.3 — Compression with black point compensation

Bibliography

[1] ICC White Paper 40, *Black Point Compensation*, 2010-07-27, available from http://www.color.org.