International Color Consortium®

Black point compensation

The following document is the final approved ICC version of ISO 18619, *Image technology colour management — Black Point Compensation*, as prepared by the ICC and TC130 in WG7

This document will now be balloted in ISO TC130 for approval as an ISO Standard.

Comments on this document should be submitted through ISO TC 130 member bodies.

ISO TC 130/WG7 N 063

Date: 2013-05-2

ISO/CD 18619

ISO TC 130 WG 7

Secretariat: DIN

Image technology colour management — Black point compensation

Élément introductif — Élément central

Warning

This document is not an ISO International Standard. It is distributed for review and comment. It is subject to change without notice and may not be referred to as an International Standard.

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Document type: International Standard
Document subtype:
Document stage: (30) Committee
Document language: E

E:\WorkE-Current\Stds_InWrk\BPC for ICC\Drafts & Comments\2013-03-24 2nd Technical Review\jWG7N063 ISO_18619_(E).doc STD Version 2.1c2

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

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. This procedure was first implemented in Adobe Photoshop in the late1990's. The International Color Consortium (ICC) and ISO Technical Committee 130 (Graphic technology) have created this document to allow black point compensation to be used in a consistent manner across applications.

The purpose of BPC is to adjust a colour transform between the colour spaces of source and destination ICC profiles, so that it retains shadow details and utilises available black levels. 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 and rendering intent can be computed once, and then efficiently applied to many images which use the same ICC profile colour transform pair and rendering intent.

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 dark end of 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*

ICC.1:2001-04, *File Format for Color Profiles*, Available from www.color.org

3 Terms and definitions

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

3.1
Black point compensation (BPC)
computational procedure by which a transform between the colour spaces of 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 gamut

3.3
DestinationProfile
destination ICC profile

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

3.5
output-capable CMYK profile
CMYK profile containing a transform from the ICC PCS encoding to the colour space encoding

3.6
SourceBlackPoint
coordinate representing a dark neutral colour in the source colour gamut

3.7
SourceProfile
source ICC profile

3.8
RenderingIntent
rendering intent of the conversion from a source ICC profile's colour space to a destination ICC profile's colour space.

3.9
transform
mathematical operations that define the change in representation of a colour between two colour spaces

3.10
gamut
range of colours that a given system is capable of reproducing

3.11
LabIdentityProfile
real or virtual ICC profile that contains a bi-directional (identity) transform between CIELAB and 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 source ICC profile, and a rendering intent (in this document called DestinationProfile, SourceProfile and RenderingIntent respectively).

Applications that apply black point compensation shall support ICC profiles that conform to ISO 15076-1 and ICC profiles that conform to ICC.1:2001-04.

NOTE 1 This requirement ensures that processing applications will properly process all Version 2 and Version 4 ICC profiles.

NOTE 2 ISO 15076-1 provides a description of source and destination ICC profiles.

The rendering intent shall be one of: RelativeColorimetric; Perceptual; or Saturation. The rendering intent used with DestinationProfile shall be the same as the rendering intent used with SourceProfile.

NOTE 3 Other black point compensation procedures might allow different source and destination rendering intents

The versions of SourceProfile and DestinationProfile do not need to match.

SourceProfile and DestinationProfile types shall be Input, Display, Output, or ColorSpace. The types of SourceProfile and DestinationProfile do not need to match.

DestinationProfile shall contain a transform from the ICC PCS encoding to the colour space encoding.

The device colour spaces of the SourceProfile and DestinationProfile shall be Gray, RGB, CMYK or CIELAB. The colour spaces of SourceProfile and DestinationProfile do not need to match.

NOTE 4 Other black point compensation procedures might support other colour spaces.

4.2 Computation

4.2.1 Outline

Black point compensation shall be performed according to the following procedure:

1) The SourceBlackPoint of SourceProfile shall be calculated as specified in section 4.2.3,

2) The DestinationBlackPoint of DestinationProfile shall be calculated as specified in sections 4.2.4 and 4.2.5,

3) A mapping from SourceBlackPoint to DestinationBlackPoint shall be calculated as specified in section 4.2.6, and

4) The mapping shall be applied in a colour conversion as specified in section 4.2.7.

4.2.2 Functions used

4.2.2.1 Colour transform with profiles

T shall denote a function to transform a point in the device colour space of Profile1 to a point in the device colour space of Profile2, using a rendering intent, such that

$y = \boldsymbol{T}\,(x, \mathit{Profile1}, \mathit{Profile2}, \mathit{Intent})$

where

x is a point in the colour space of Profile1,

y is a point in the colour space of Profile2 and

Intent is the rendering intent.

4.2.2.2 Darkest colour of a profile

D shall denote a function to provide the darkest colour coordinate in the device colour space of Profile for a rendering intent, such that

$dc = \mathbf{D}\,(\mathit{Profile}, \mathit{Intent})$

where

dc is the darkest color

Profile is the Profile being evaluated,

Intent is the rendering intent.

dc shall be determined as follows:

A subset of the vertices within the colour space of Profile, V, shall be defined as follows

If the colour space of Profile is Gray

V shall be the set of {(0) (1)}.

If the colour space of Profile is RGB

V shall be the set of {(0, 0, 0) (1, 1, 1)}.

If the colour space of Profile is CMYK

V shall be the set of {(0, 0, 0, 0) (1, 1, 1, 1) (0, 0, 0, 1) (1, 1, 1, 0)}.

The darkest colour, dc, shall be the element of V, v, with the lowest value of L* resulting from the transform

T (v, Profile, LabIdentityProfile, Intent).

NOTE 1 *dc* is intended to be the value of black or darkest colour in the colour space of Profile.

NOTE 2 Determining the darkest colour in this way works for profiles with both the normal polarity and inverse polarity.

4.2.3 Computing the SourceBlackPoint

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

A *LocalBlack* value for the source colour space shall be defined as follows:

If *SourceProfile* is an output-capable CMYK ICC profile

LocalBlack shall be set to *T* ((0, 0, 0), *LabIdentityProfile*, *SourceProfile*, Perceptual)

If *SourceProfile* is not an output-capable CMYK ICC profile

If the colour space of *SourceProfile* is CIELAB,

LocalBlack shall be set to (0, 0, 0).

If the colour space of *SourceProfile* is Gray, RGB, or CMYK,

LocalBlack shall be set to *D* (*SourceProfile*, *RenderingIntent*).

The *SourceBlackPoint* is then calculated as follows

Li shall be set to the L component of T (*LocalBlack, SourceProfile, LabIdentityProfile, RenderingIntent*).

If *Li* is greater than 50,

SourceBlackPoint shall be set to (50, 0, 0),

else

SourceBlackPoint shall be set to (*Li*, 0, 0).

4.2.4 Computing the DestinationBlackPoint for ICC profiles that are not LUT-based

If *DestinationProfile* is not LUT-based, then its *DestinationBlackPoint* shall be determined as follows:

A *LocalBlack* value for the destination colour space shall be determined as follows:

LocalBlack shall be set to *D* (*DestinationProfile*, *RenderingIntent*).

NOTE Only Gray and RGB are valid colour spaces for a DestinationProfile that is not LUT-based.

The *DestinationBlackPoint* is then calculated as follows

Li shall be set to the L component of T (*LocalBlack*, *DestinationProfile, LabIdentityProfile*, *RenderingIntent*).

If *Li* is greater than 50,

DestinationBlackPoint shall be set to (50, 0, 0),

else

DestinationBlackPoint shall be set to (Li, 0, 0).

4.2.5 Computing the DestinationBlackPoint for ICC profiles that are LUT-based

4.2.5.1 Overview

If *DestinationProfile* is LUT-based, then its *DestinationBlackPoint* shall be determined as follows:

InitialLab, *inRamp*, and *outRamp* shall be calculated as specified in section 4.2.5.2.

If *outRamp* is not valid as specified in section 4.2.5.3,

DestinationBlackPoint shall be set to (0, 0, 0),

else if *RenderingIntent* is RelativeColorimetric, and the *outRamp* meets the mid range straight test specified in section 4.2.5.4,

DestinationBlackPoint shall be set to *InitalLab*,

else

DestinationBlackPoint shall be determined as specified in section 4.2.5.5.

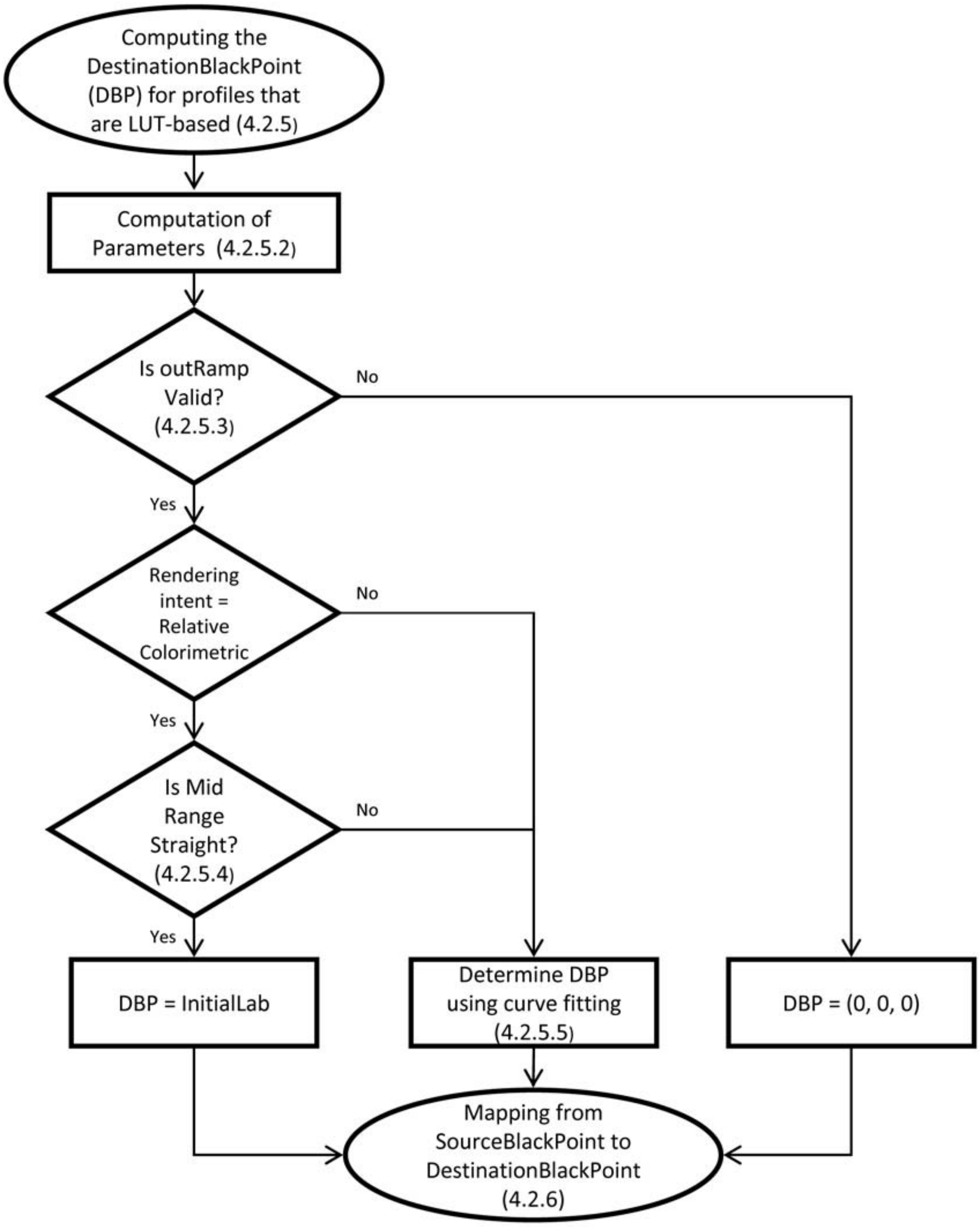

Figure 1 — DestinationBlackPoint computation logic sequence

4.2.5.2 Computation of parameters

4.2.5.2.1 InitialLAB Calculation

If *RenderingIntent* is not RelativeColorimetric, then *InitialLab* shall be set to (0,0,0), else *InitialLab* shall be calculated as follows:

If the colour space of *DestinationProfile* is CMYK

LocalBlack shall be set to *T* ((0,0,0), *LabIdentityProfile*, *DestinationProfile*, Perceptual)

If the colour space of *DestinationProfile* is CIELAB,

LocalBlack shall be set to (0,0,0).

If the colour space of *DestinationProfile* is Gray, or RGB,

LocalBlack shall be set to *D* (*DestinationProfile, RenderingIntent*).

InitialLab shall be set to *T* (*LocalBlack*, *DestinationProfile*, *LabIdentityProfile*, RenderingIntent).

If the colour space of *DestinationProfile* is CMYK, then the *a** and *b** components of *InitialLab* shall be set to 0.

If the L* of *InitialLab* exceeds 50, then the *L** component of *InitialLab* shall be set to 50.

4.2.5.2.2 Calculation of inRamp

i*nRamp* (a list of L* values) 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 a list of Lab values interpolated from (0, ka, kb) to (100, 0, 0) in 256 equal steps,

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

4.2.5.2.3 Calculation of outRamp

BT is a transform that converts CIELAB colour values from CIELAB space to destination device colour space to CIELAB space, as shown in Figure 2.

BT(x) shall be defined as *T*(*y*, *DestinationProfile*, *LabIdentityProfile*, RelativeColorimetric) where:

x is a CIELAB colour value,

y is the result of the transform T(*x*, *LabIdentityProfile*, *DestinationProfile*, *RenderingIntent*),

LabIdentityProfile is as defined in 3.11,

DestinationProfile and RenderingIntent are as defined in section 4.1.

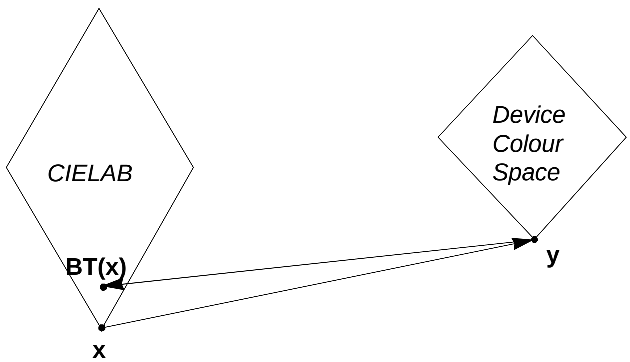

Figure 2 — BT transform

outRampLab shall be set to a list of transformed Lab values found by applying BT to each of the elements of *inRampLab*

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

If *outRamp* is not monotonically increasing, its values shall be modified to make the list monotonically increasing. This adjustment shall not change the *last* (lightest) value in the list. This can be accomplished by looping from the second to last element to the *first* element of outRamp and setting the i^{th} element 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* and

last identifies the last index of *outRamp*

4.2.5.3 Test for outRamp valid

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).

4.2.5.4 Test for mid range straight

If RenderingIntent is RelativeColorimetric and the outRamp is valid as determined by section 4.2.5.3, then the following test shall be applied, otherwise DestinationBlackPoint shall be determined using curve fitting as defined by section 4.2.5.5.

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 ((*inRamp*[i] > *Min*L + 0.2 ∗ (*MaxL* - *MinL*))
and
(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 as specified in section 4.2.5.5.

4.2.5.5 Computation of DestinationBlackPoint using curve fitting

This section defines how to calculate *DestinationBlackPoint* using curve fitting of *inRamp* and *outRamp*.

yRamp shall be set to a list of values:

yRamp[i] = (*outRamp[i]*-*MinL*) / (*MaxL* – *MinL*) for all valid index values i

where

MinL=*outRamp*[first] and

MaxL=*outRamp*[last].

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 RenderingIntent is RelativeColorimetric 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).

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

Otherwise the scalar values, a, b, c, shall be determined by using a least-squares error algorithm to fit a quadratic curve of the following form:

$y = ax^2 + bx + c$

using the shadow curve points, SP, as the set of input values to the algorithm.

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

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

z shall be set to max(0, min(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 shall be set to max(0, min(50, (-*b* + sqrt(*d*)) / (2 *a*))).

NOTE 1 *z* has been assigned to the root of the quadratic with the positive gradient. This is either the upper or lower root depending on the sign of *a*.

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

Figure 3 shows an example of estimating the *DestinationBlackPoint* using curve fitting. This figure shows an example *outRamp*, the range of shadow points, the fitted quadratic curve, and the *DestinationBlackPoint*.

NOTE 2 Curve fitting is actually performed using *yRamp* which is a scaled version of *outRamp*.

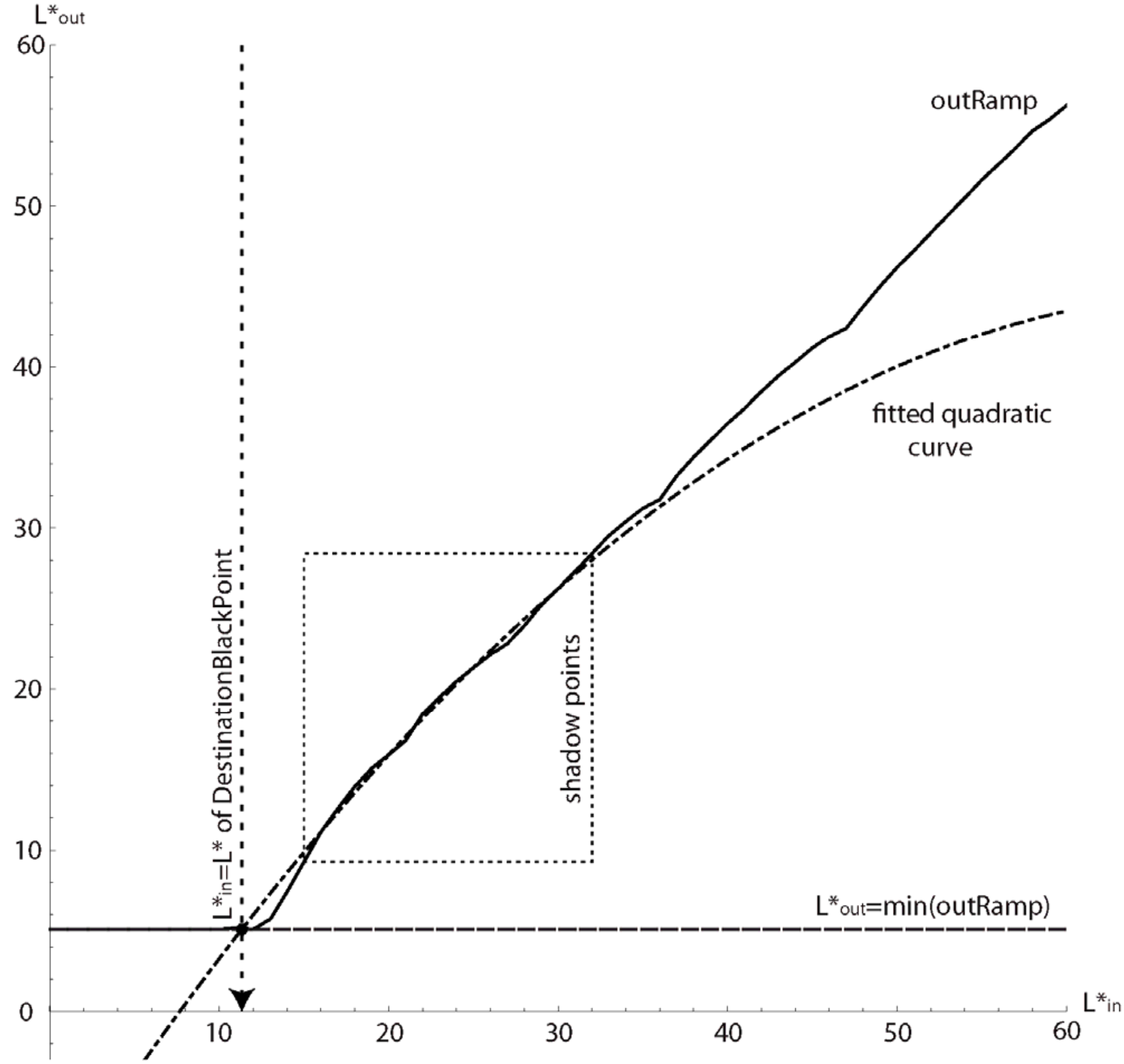

Figure 3 — Example Curve Fitting

4.2.6 Computing the mapping from SourceBlackPoint to DestinationBlackPoint

The mapping from *SourceBlackPoin*t to *DestinationBlackPoin*t shall be accomplished as follows:

Only the L components of the *SourceBlackPoin*t and *DestinationBlackPoint* values are used, while the a and b components are ignored.

Y_{DST} shall be obtained by converting the *L* value of *DestinationBlackPoin*t to a PCSXYZ *Y* value using the formula below,

Y_{SRC} shall be obtained by converting the *L* value of *SourceBlackPoint* to a PCSXYZ *Y* value using the formula below:

scaleXYZ shall be set to $(1 - Y_{DST}) / (1 - Y_{SRC})$, *offsetXYZ* shall be set to (1 - *scaleXYZ*) * *W*.

where

W= (0.9642, 1.0000, 0.8249), which is the PCSXYZ white point,

and

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

$= L \times (((8 + 16) / 116)^3) / 8.0$, for $0 \le L \le 8.0$.

4.2.7 Applying the black point compensation in a colour conversion

Black point compensation is applied at the point in the colour transforms where output results from applying SourceProfile are used as the input for applying DestinationProfile as follows:

The source device space value shall be converted to PCSXYZ using SourceProfile 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.

A 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 DestinationProfile, including conversion from PCSXYZ to PCSLAB when the ICC profile's PCS is PCSLAB.

Annex A
(informative)

Why black point compensation is neccessary

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

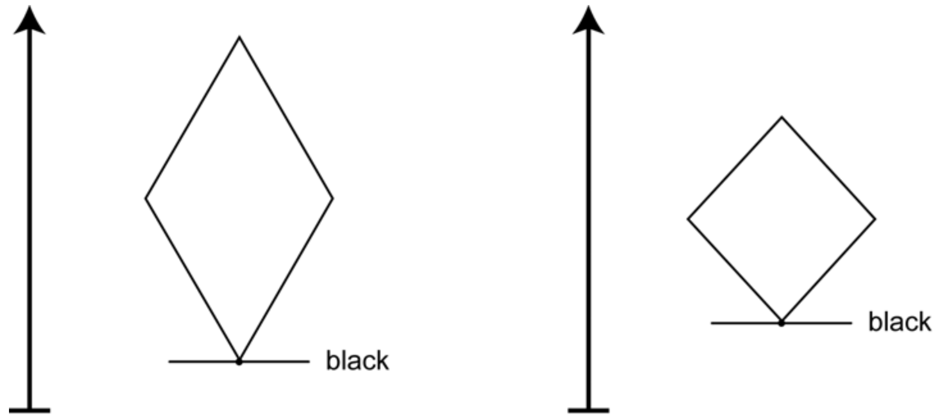

Figure A.1 — Source vs. destination colour spaces

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.

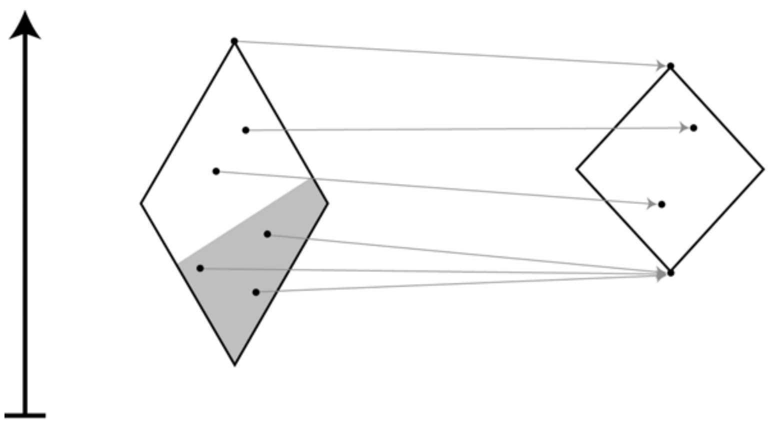

Figure 2 — Compression without black point compensation

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 black point and white point compensation.

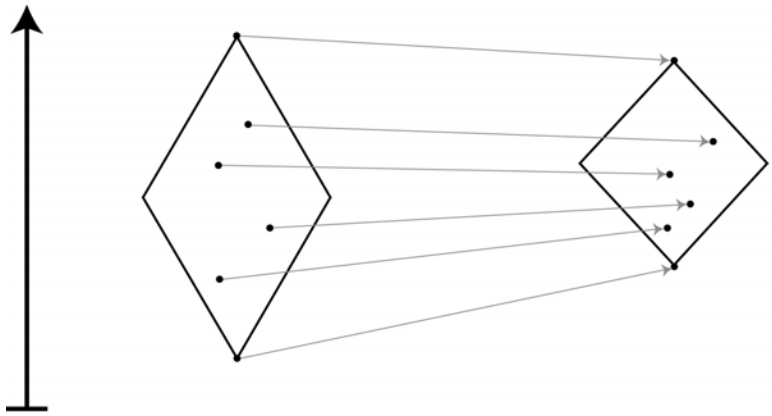

Figure A.3 — Compression with black point compensation

Bibliography

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

[2] The Least-Squares Parabola available from http://www.efunda.com/math/leastsquares/lstsqr2dcurve.cfm