color palettes matter

using RGB or HSV to select colors for a palette does not yield optimal results

palette colors should be
- perceived as equally important
- perceived as equally distant
- pereived to have a natural order (if applicable)

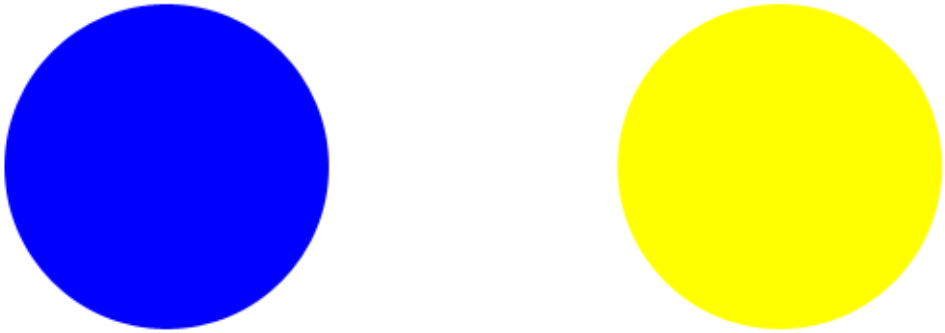
neither RGB or HSV spaces take into account color perception

SEQUENTIAL PALETTES

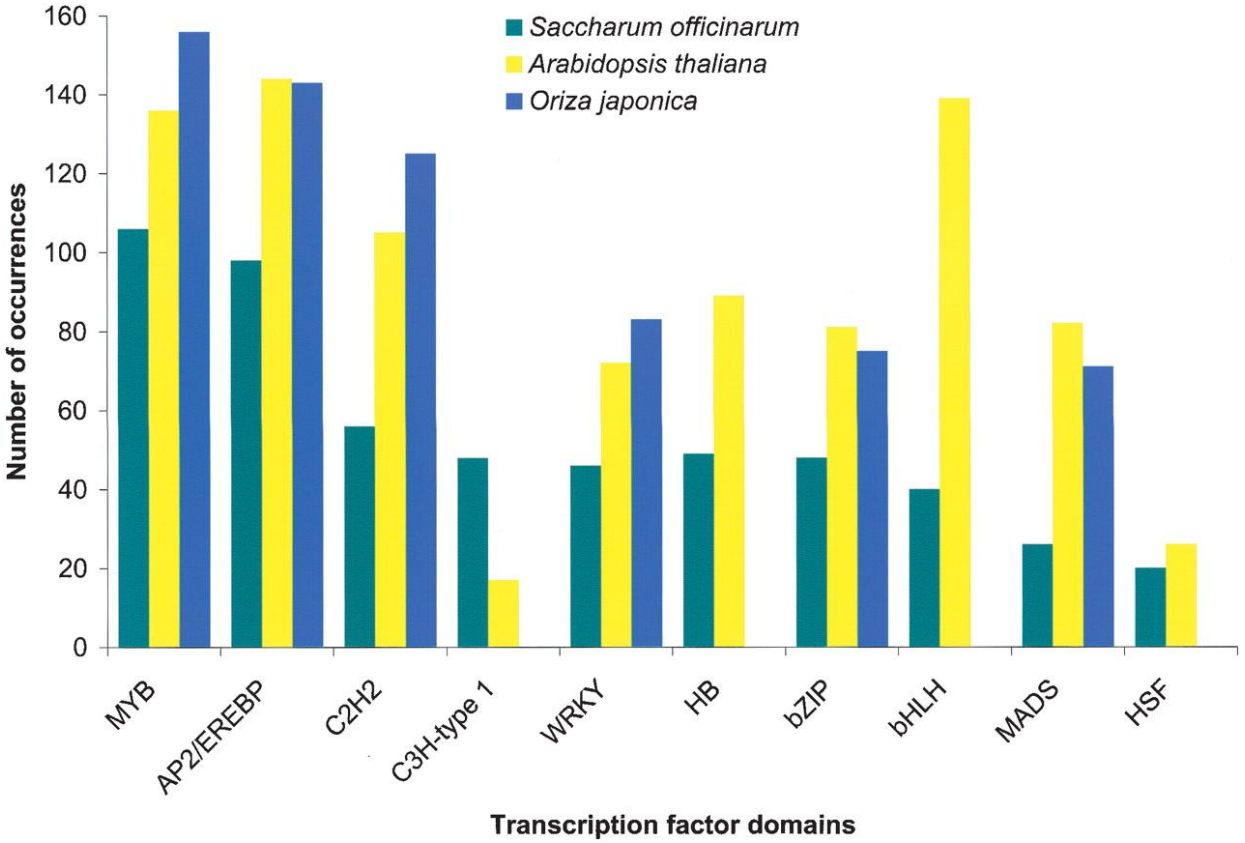
QUALITATIVE PALETTES

some hues appear brighter

yellow appears brighter



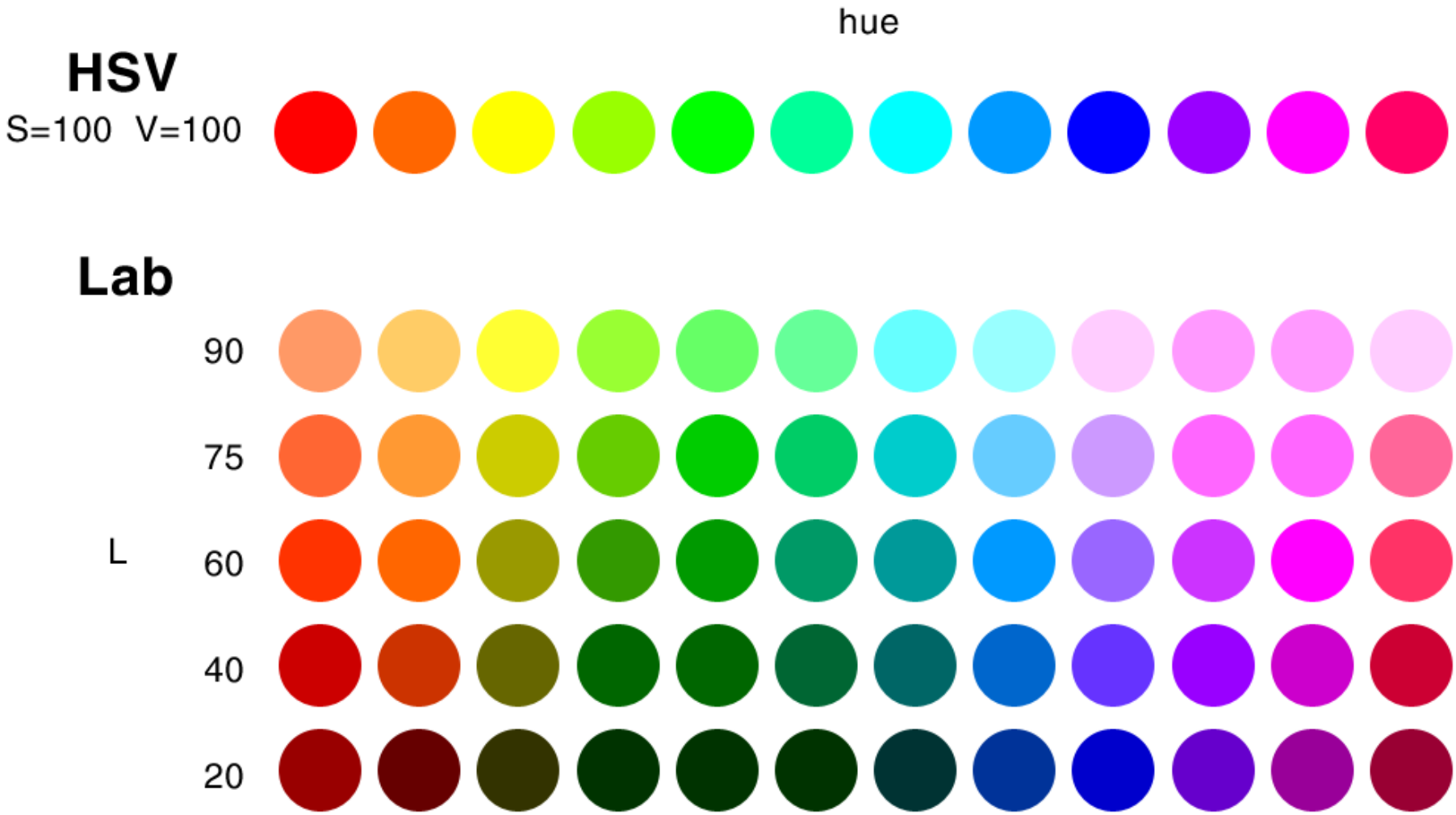
yellow commands attention

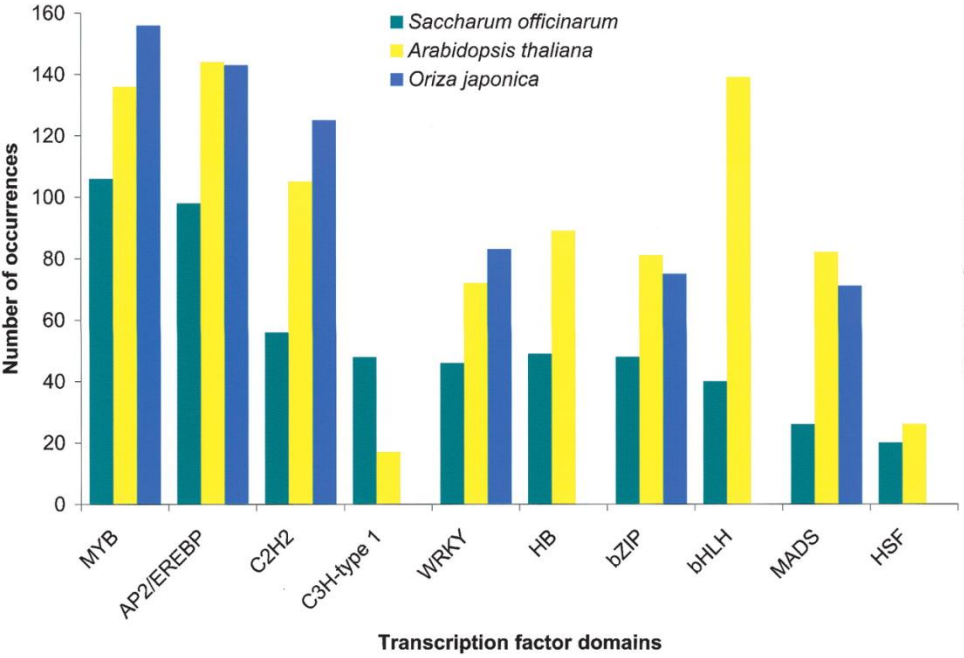


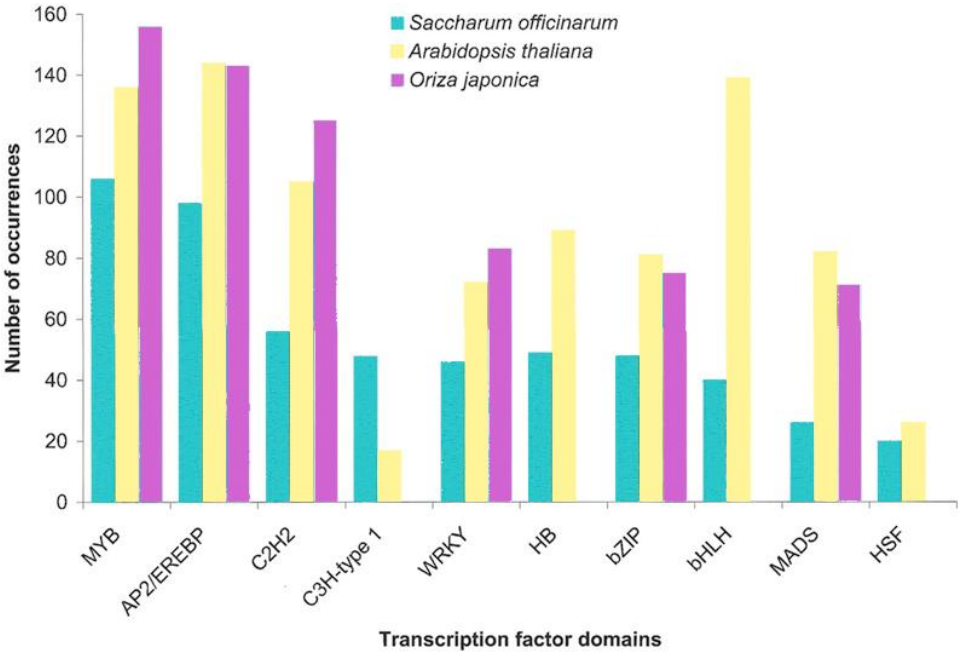
THE 10 MOST COMMON TRANSCRIPTION FACTOR PFAM DOMAINS IN SAS PROTEINS.

Vettore, A.L., et al., *Analysis and functional annotation of an expressed sequence tag collection for tropical crop sugarcane. Genome Res, 2003.* ***13(12): p. 2725-35.***

taking perception into account





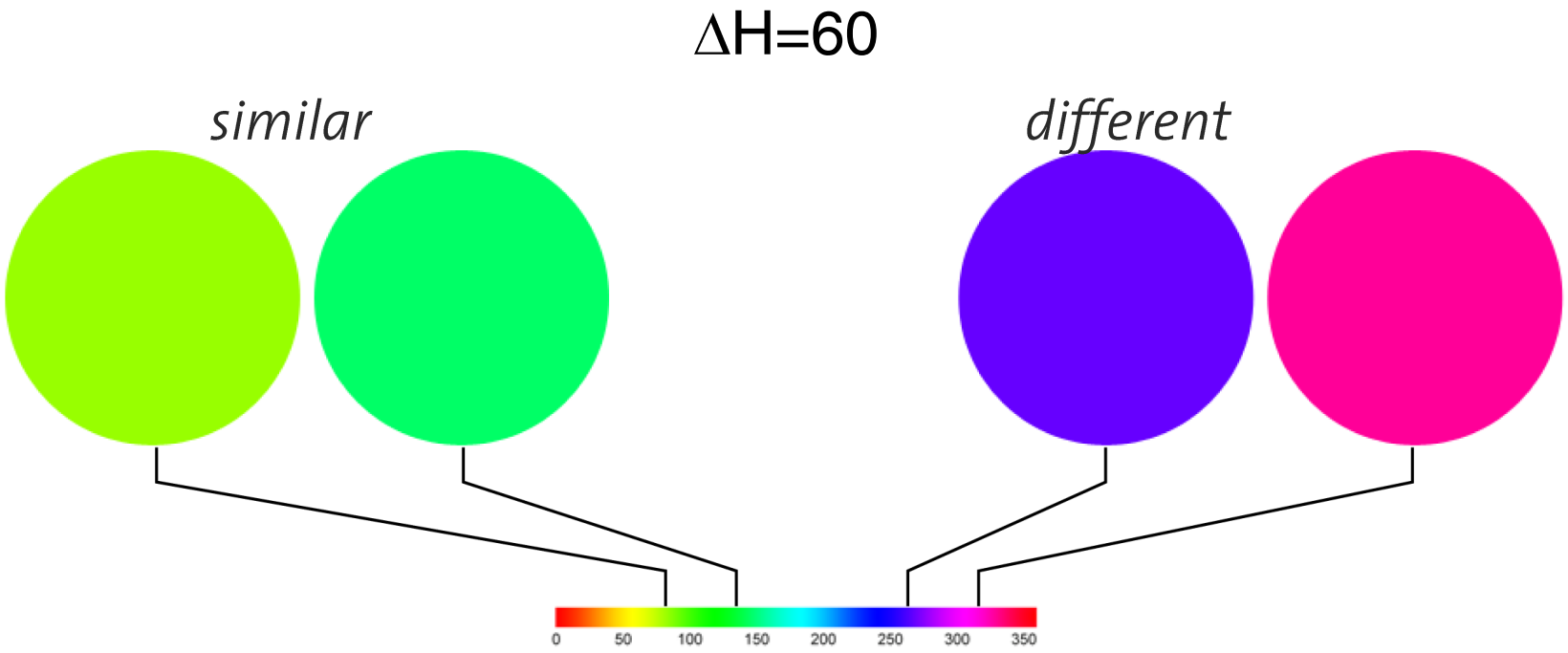


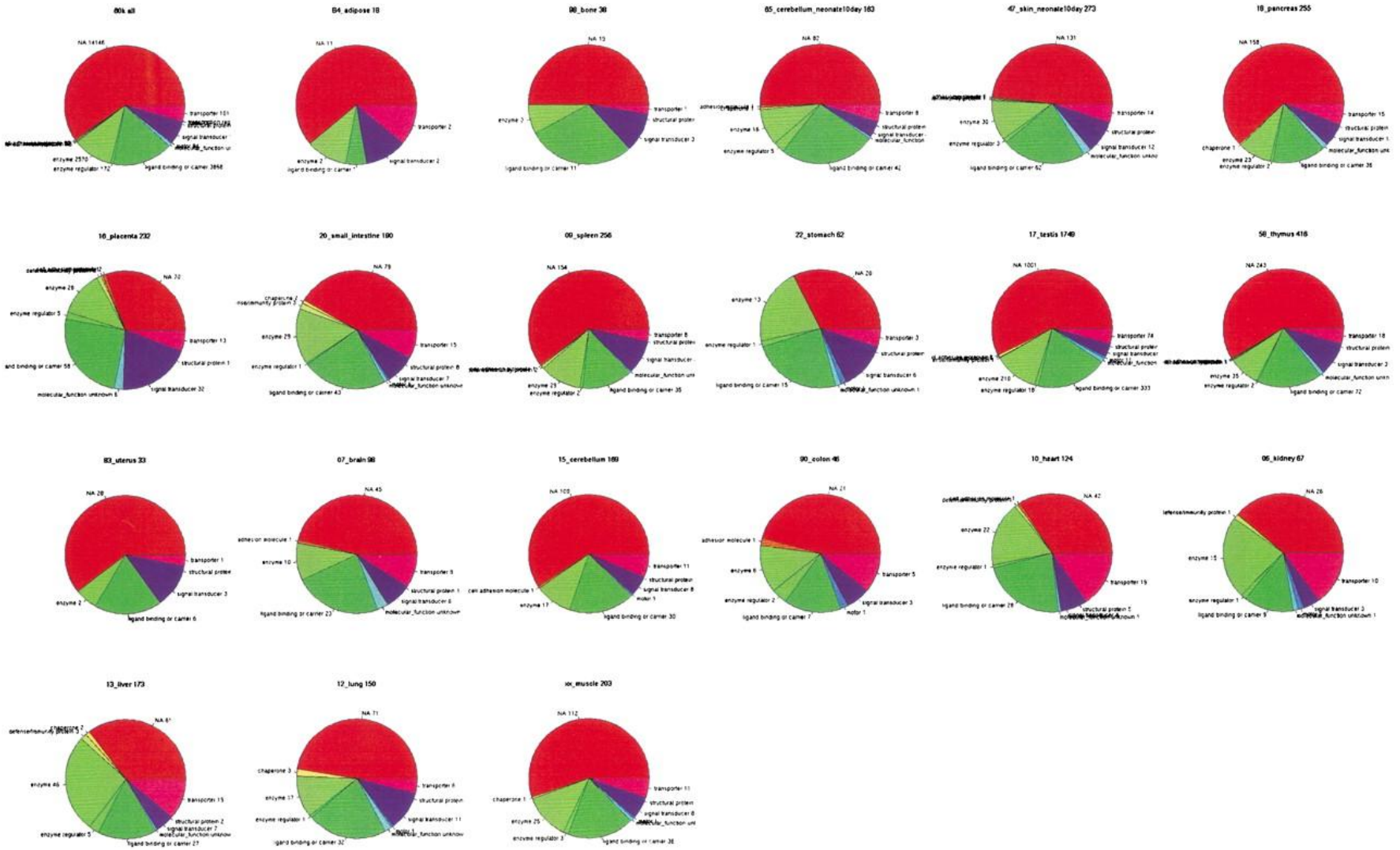
ORIGINAL **MODIFIED**

THE 10 MOST COMMON TRANSCRIPTION FACTOR PFAM DOMAINS IN SAS PROTEINS.

Vettore, A.L., et al., *Analysis and functional annotation of an expressed sequence tag collection for tropical crop sugarcane.* *Genome Res, 2003.* ***13(12): p. 2725-35.***

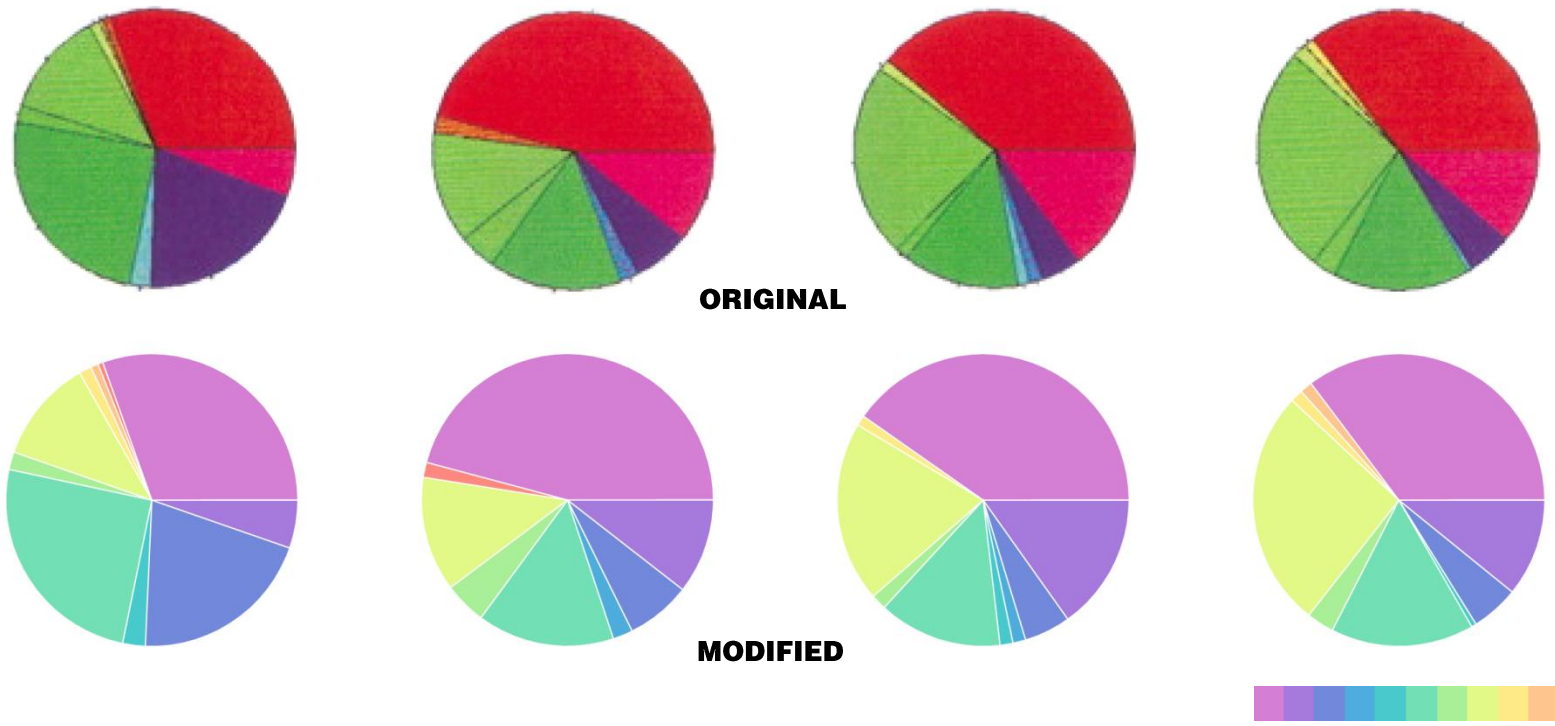
perceptual uniformity





PIE CHARTS FOR TISSUE PROFILING BY GENE ONTOLOGY.

Bono, H., et al., *Systematic expression profiling of the mouse transcriptome using RIKEN cDNA microarrays. Genome Res, 2003.* ***13(6B): p. 1318-23.***



PIE CHARTS FOR TISSUE PROFILING BY GENE ONTOLOGY.

Bono, H., et al., *Systematic expression profiling of the mouse transcriptome using RIKEN cDNA microarrays. Genome Res, 2003.* ***13(6B): p. 1318-23.***

palette selection – color space

to take aspects of perception into account, palettes are chosen from a color space that is designed to model human vision

all color spaces that implement response of the eye are based on the CIE XYZ color space

the human eye contains three kinds of cones

- S – short wavelength – blue
- M – medium wavelength – green
- L – long wavelength – red

the tristimulus value of a color is the amount of each primary color needed to match a test color

- matching is done empirically, with large number of human subjects

tristimulus values are defined in X,Y,Z color space

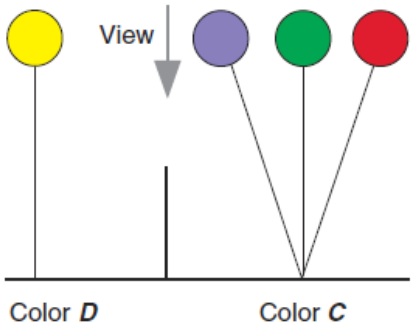
XYZ – briefly

color matching was performed by Herman Grassman

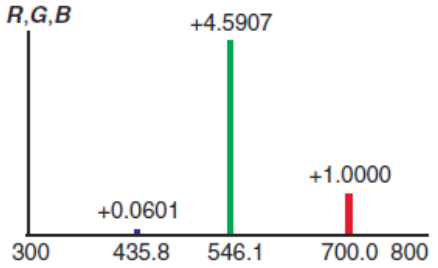
later, results were reinterpreted for monochromatic primaries at standardized wavelengths of 436, 546 and 700 nm (red, green, blue) .

the result were the CIE 1931 RGB Color matching functions, giving the amounts of primaries needed to match the monochromatic test primary

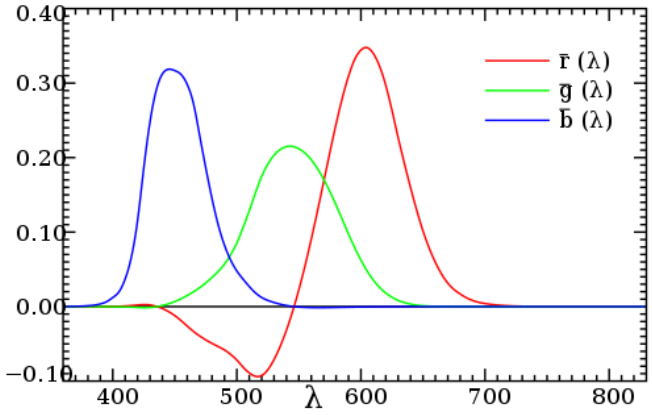
$$R = \int_0^\infty I(\lambda)\,\bar{r}(\lambda)\,d\lambda$$
$$G = \int_0^\infty I(\lambda)\,\bar{g}(\lambda)\,d\lambda$$
$$B = \int_0^\infty I(\lambda)\,\bar{b}(\lambda)\,d\lambda$$



Color matching experiment



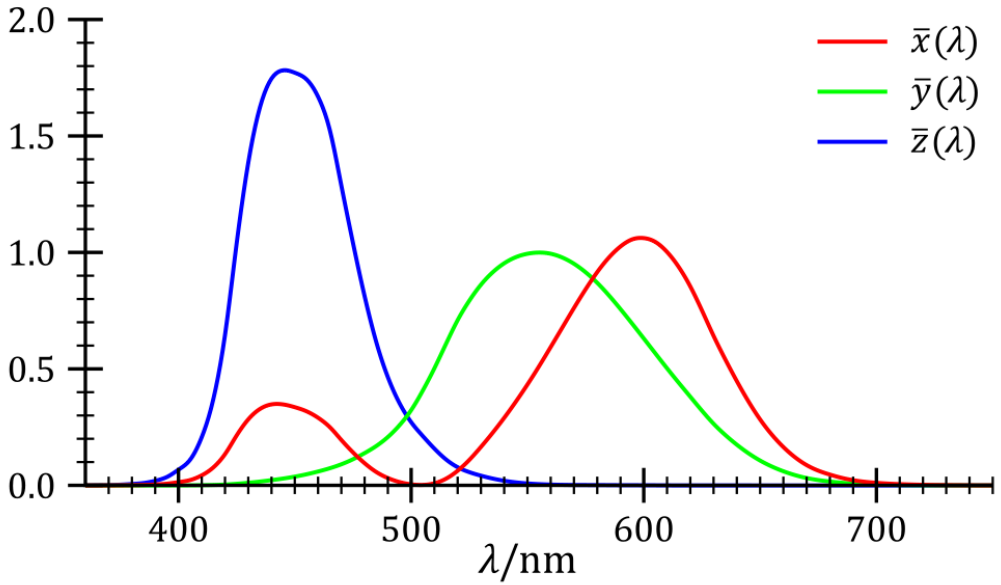
CIE Standard Primaries



XYZ - briefly

CIE proposed to modify the color matching functions (essentially a change of basis)

- everywhere greater than or equal to zero.
- the color matching function would take into account the variation of perceived brightness with wavelength (Y component).
- were be set to zero in certain regions for computational simplicity



$$X = \int_0^\infty I(\lambda)\,\bar{x}(\lambda)\,d\lambda$$

$$Y = \int_0^\infty I(\lambda)\,\bar{y}(\lambda)\,d\lambda$$

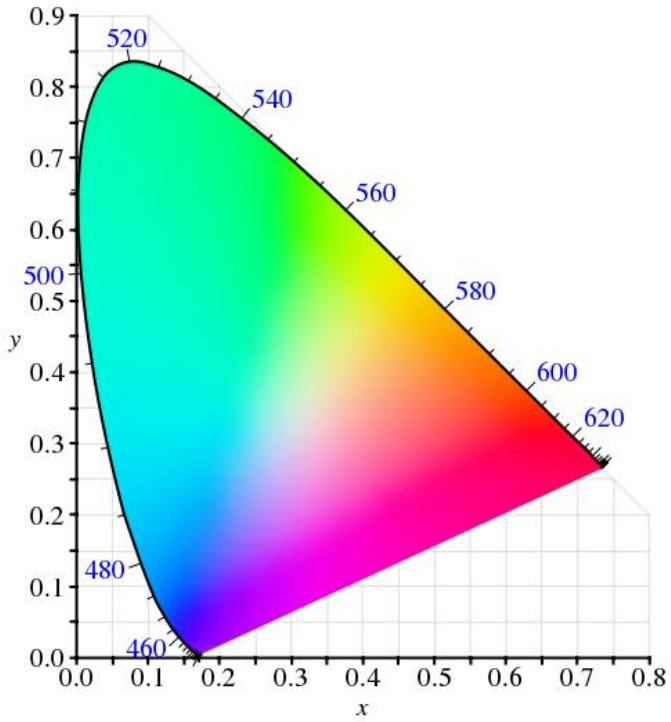
$$Z = \int_0^\infty I(\lambda)\,\bar{z}(\lambda)\,d\lambda$$

XYZ to xyY

color can be characterized by brightness and chromaticity

white and grey have the same chromaticity, but different brightness

$$x = \frac{X}{X+Y+Z}$$
$$y = \frac{Y}{X+Y+Z}$$
$$z = \frac{Z}{X+Y+Z} = 1 - x - y$$



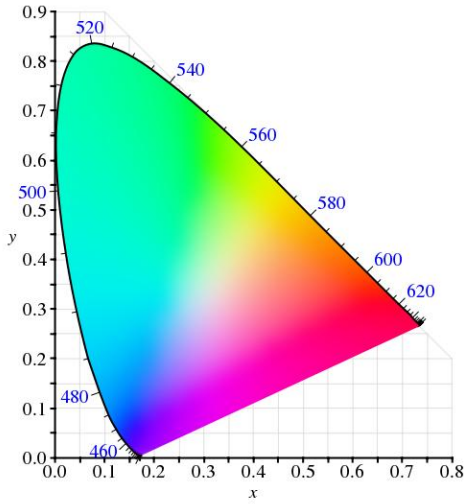
perceptual uniformity

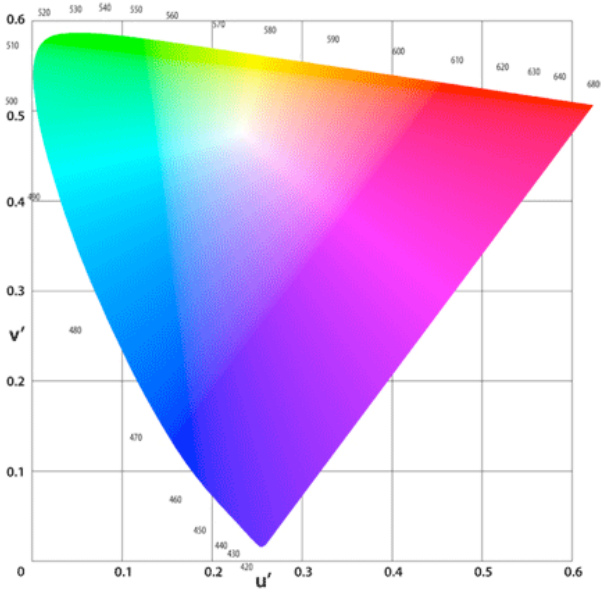
XYZ space is not perceptually uniform

relative distances in XYZ space do not correspond to relative perceived differences

to include uniformity, XYZ is transformed to LUV

lightness and two chromaticities u, v

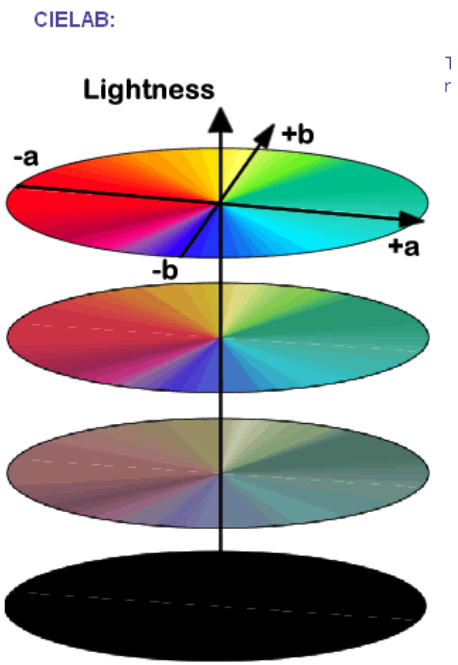


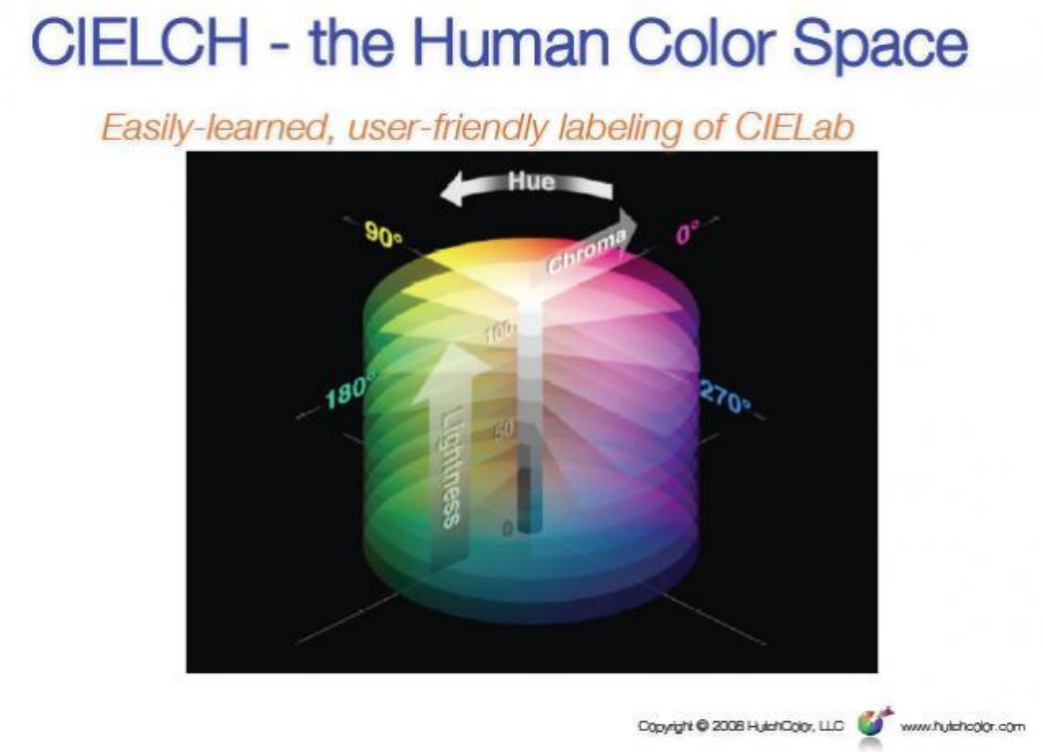


LUV to LCH

LUV u,v chromaticities are not intuitive (just like a,b in LAB).

cylindrical form remaps u,v to chroma and hue (c,h)





Brewer palletes

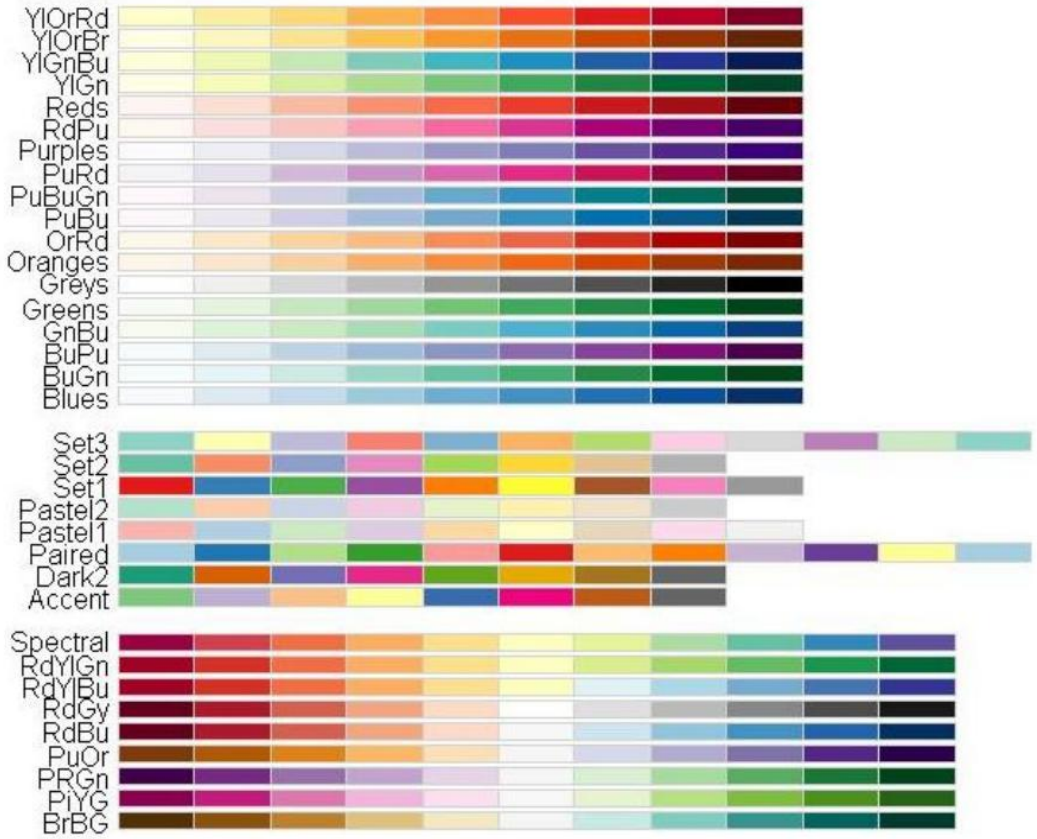
hand-picked by Cynthia Brewer

commonly used for their perceptual qualities

sequential

qualitative

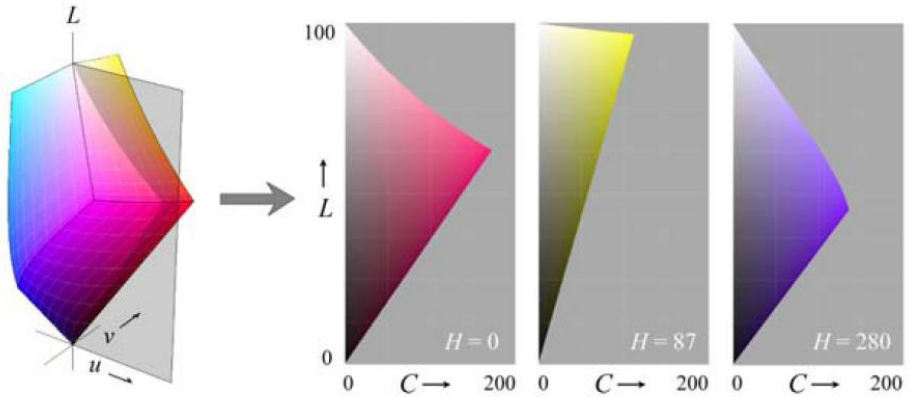
diverging

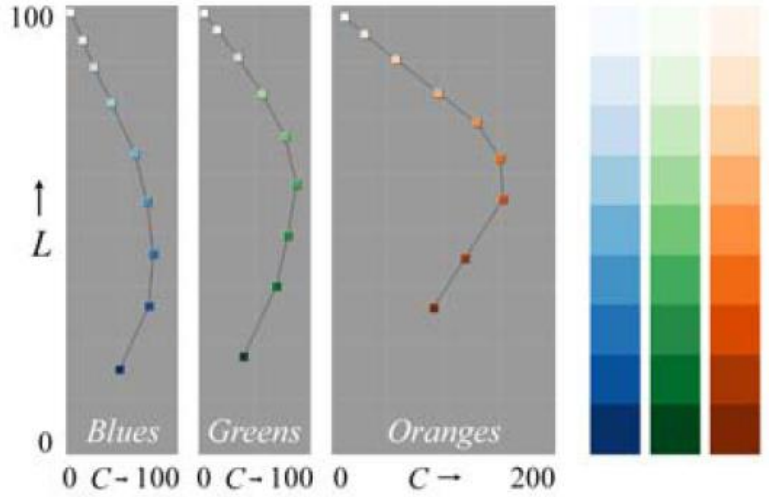


method by Wijffelaars *et al*.

the paper develops a method to select color palettes from LCH space to automate and extend Brewer's approach

below – three Brewer sequential palletes in LCH





method by Wijffelaars *et al.*

the paper develops a method to select color palettes from LCH space to automate and extend Brewer's approach

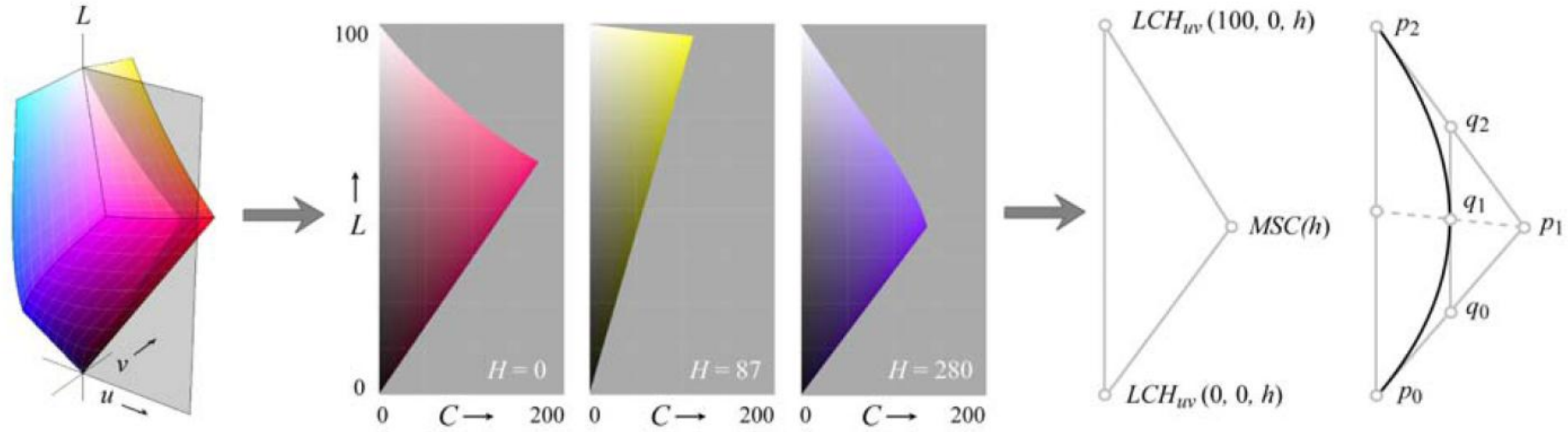
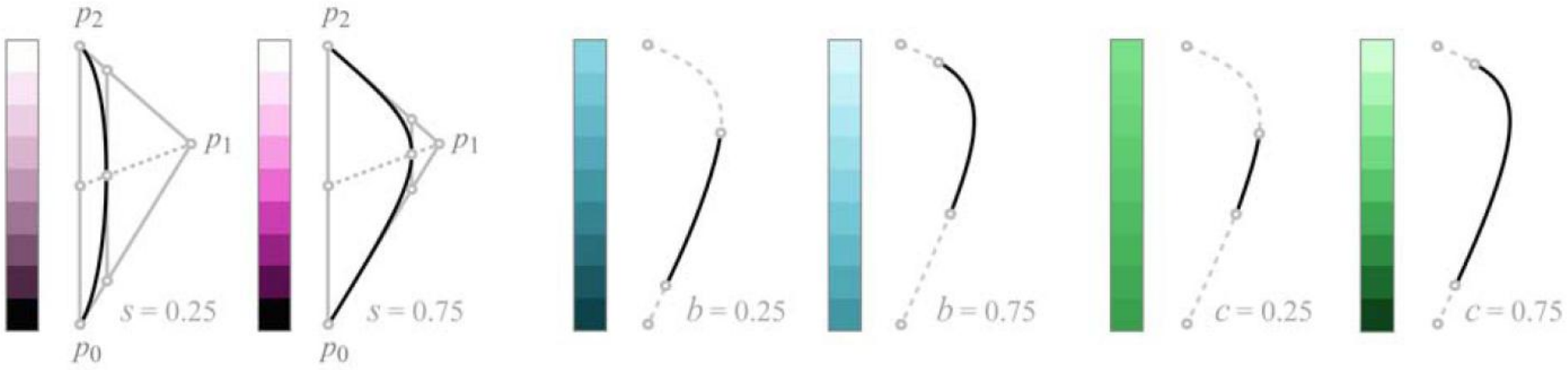
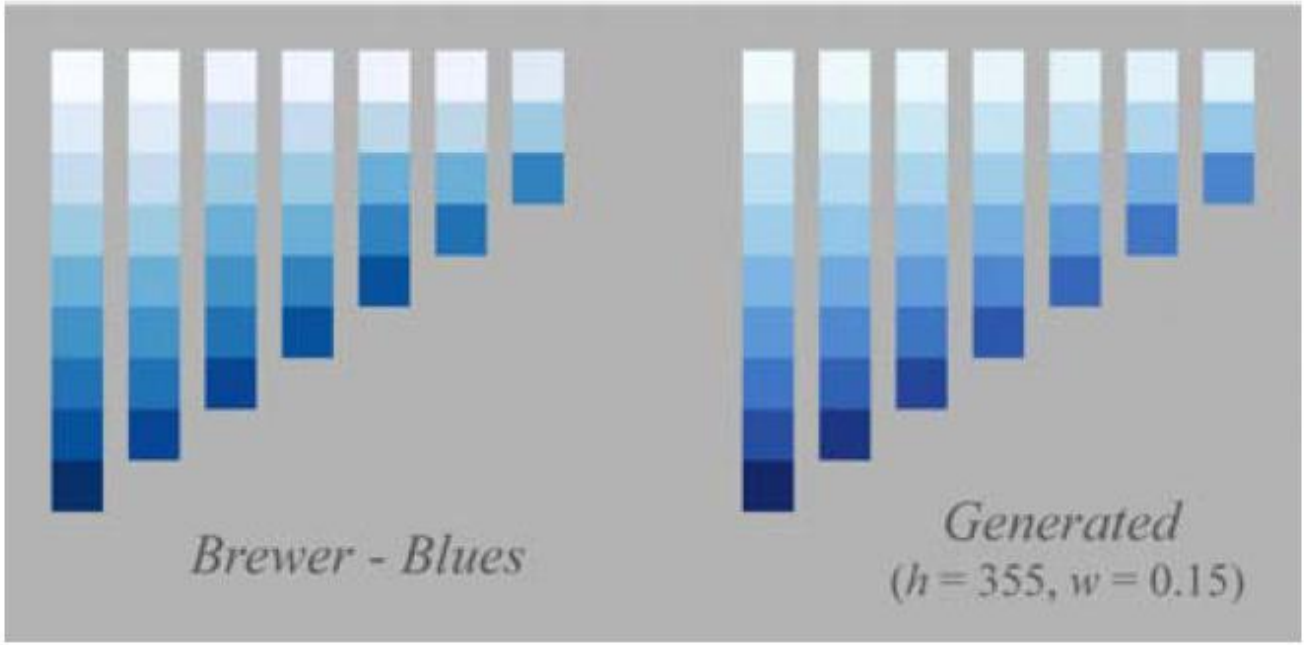


Figure 3: *The volume of displayable colors in CIELUV space, three hue slices of CIELUV space generated with PaletteView and the triangle that approximates the boundary of the displayable colors of a hue slice*

pallete parameters



a. Saturation *b. Brightness* *c. Contrast*


Brewer - Blues
Generated
(h = 355, w = 0.15)

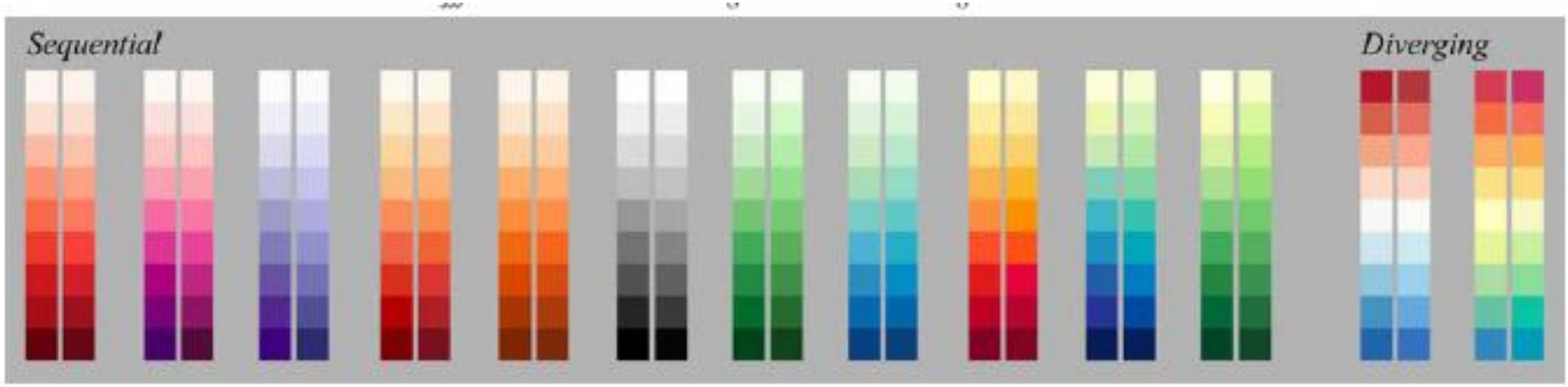
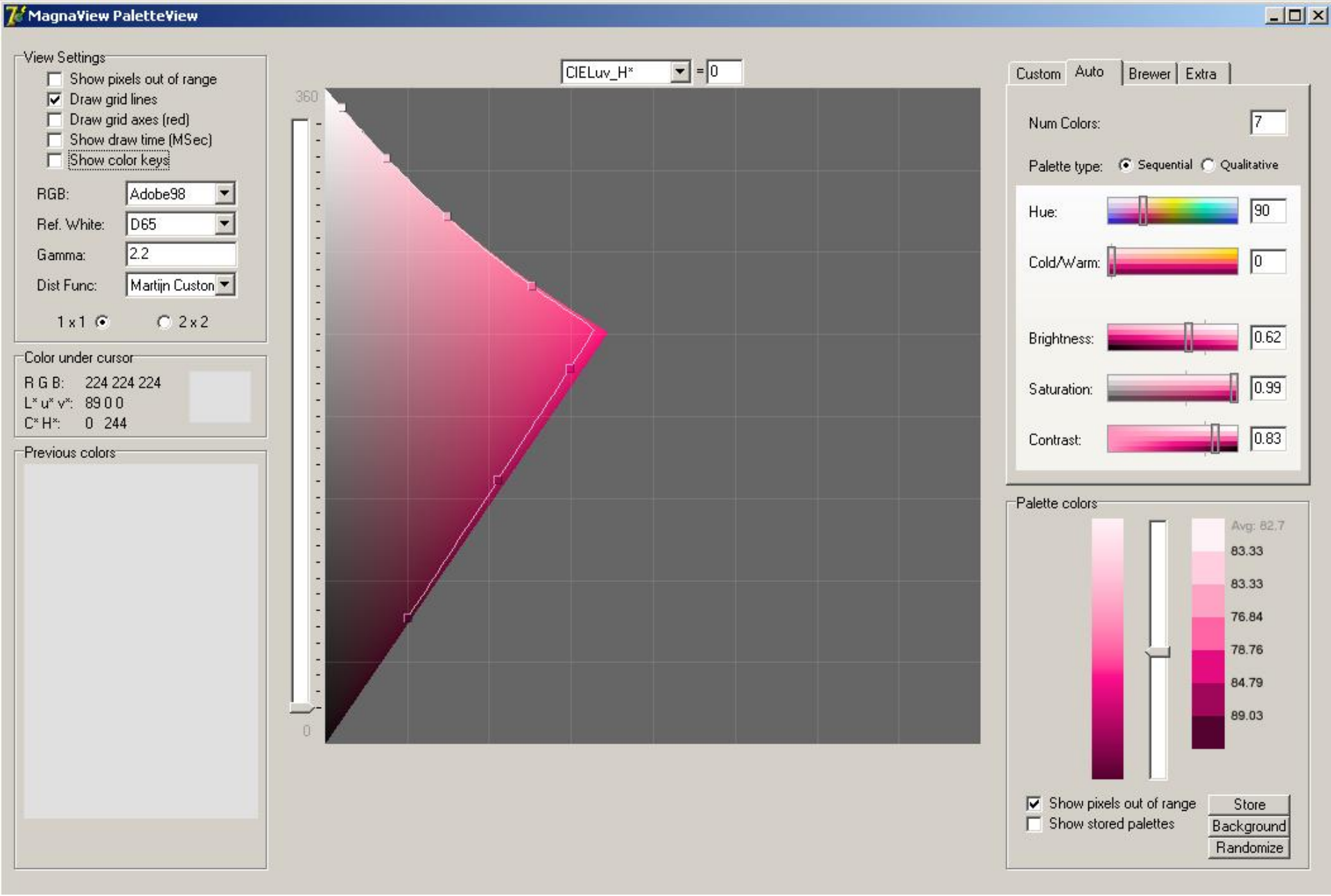
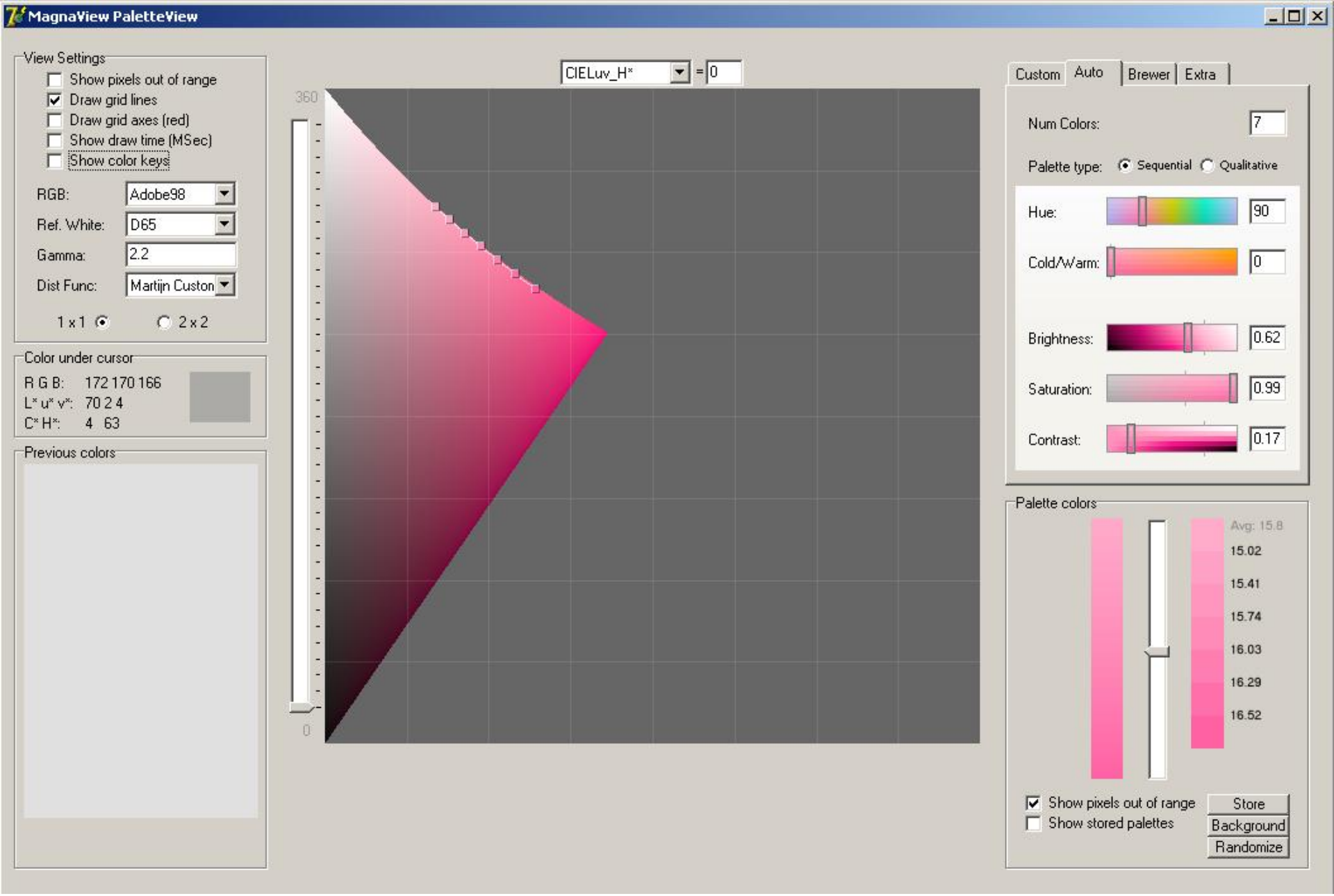
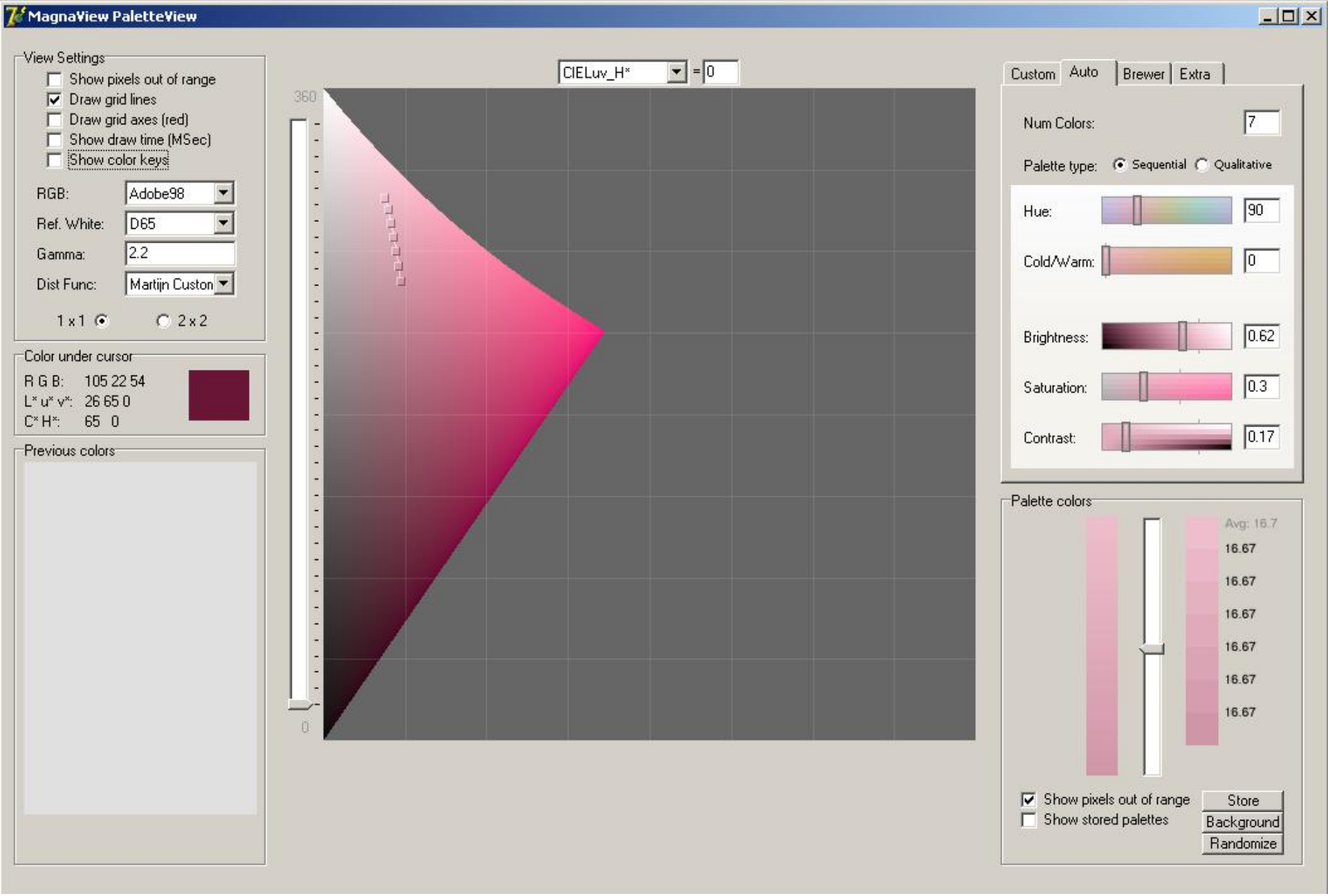
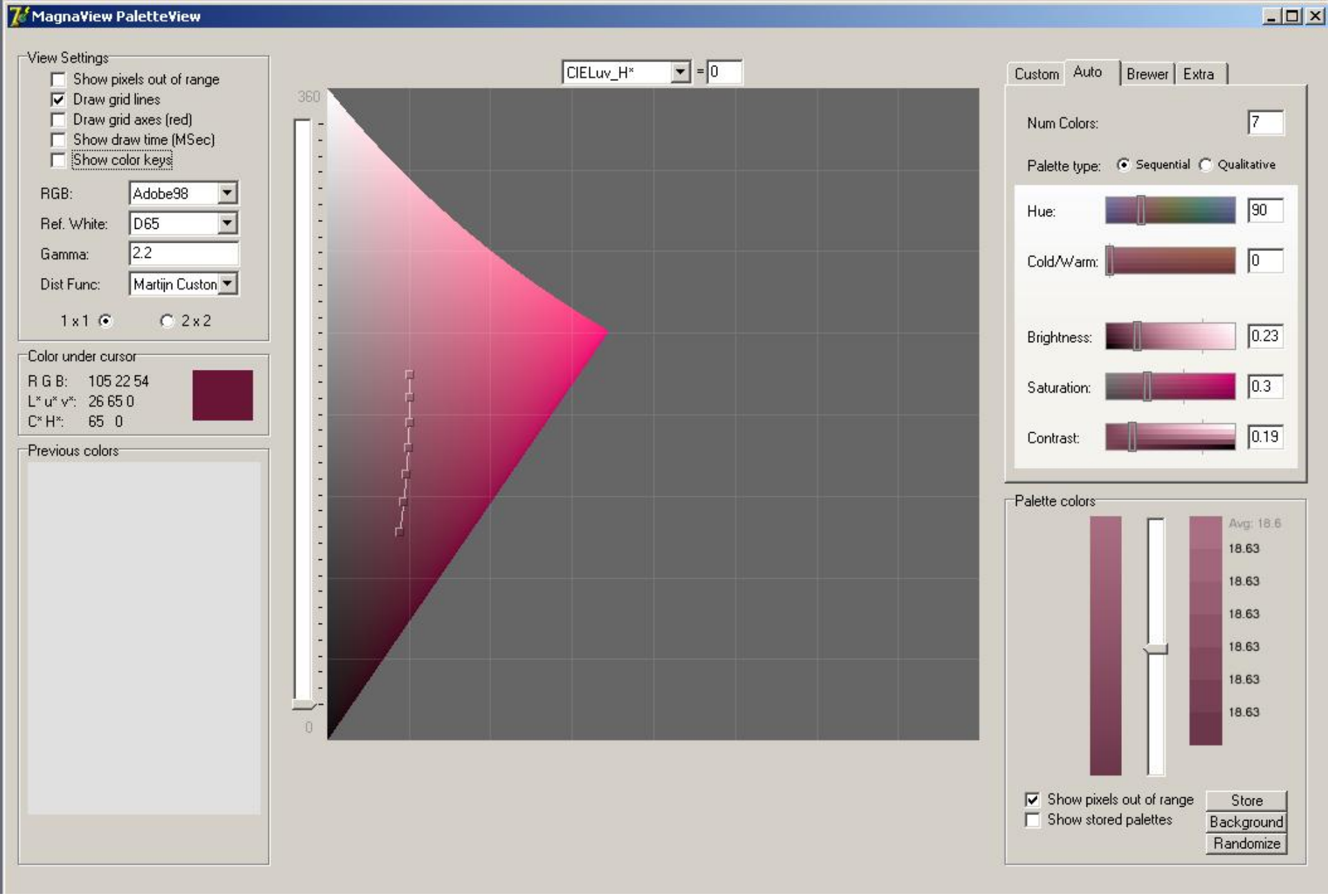


Figure 9: *Pairs of palettes of which the left palettes are defined by Brewer, and the right palettes are generated with* P_{seq}.


MagnaView PaletteView
View Settings
Show pixels out of range
Draw grid lines
Draw grid axes (red)
Show draw time (MSec)
Show color keys
RGB:
Adobe98
Ref. White:
D65
Gamma:
2.2
Dist Func:
Martijn Custon
1 x 1
2 x 2
Color under cursor
R G B: 224 224 224
L* u* v*: 89 0 0
C* H*: 0 244
Previous colors
CIELuv_H*
= 0
360
0
Custom
Auto
Brewer
Extra
Num Colors:
7
Palette type:
Sequential
Qualitative
Hue:
90
Cold/Warm:
0
Brightness:
0.62
Saturation:
0.99
Contrast:
0.83
Palette colors
Avg: 82.7
83.33
83.33
76.84
78.76
84.79
89.03
Show pixels out of range
Show stored palettes
Store
Background
Randomize


MagnaView PaletteView
View Settings
Show pixels out of range
Draw grid lines
Draw grid axes (red)
Show draw time (MSec)
Show color keys
RGB:
Adobe98
Ref. White:
D65
Gamma:
2.2
Dist Func:
Martijn Custon
1 x 1
2 x 2
Color under cursor
R G B: 172 170 166
L* u* v*: 70 2 4
C* H*: 4 63
Previous colors
CIELuv_H*
= 0
360
0
Custom
Auto
Brewer
Extra
Num Colors:
7
Palette type:
Sequential
Qualitative
Hue:
90
Cold/Warm:
0
Brightness:
0.62
Saturation:
0.99
Contrast:
0.17
Palette colors
Avg: 15.8
15.02
15.41
15.74
16.03
16.29
16.52
Show pixels out of range
Show stored palettes
Store
Background
Randomize


MagnaView PaletteView
View Settings
Show pixels out of range
Draw grid lines
Draw grid axes (red)
Show draw time (MSec)
Show color keys
RGB:
Adobe98
Ref. White:
D65
Gamma:
2.2
Dist Func:
Martijn Custon
1 x 1
2 x 2
Color under cursor
R G B: 105 22 54
L* u* v*: 26 65 0
C* H*: 65 0
Previous colors
CIELuv_H*
= 0
360
0
Custom
Auto
Brewer
Extra
Num Colors:
7
Palette type:
Sequential
Qualitative
Hue:
90
Cold/Warm:
0
Brightness:
0.62
Saturation:
0.3
Contrast:
0.17
Palette colors
Avg: 16.7
16.67
16.67
16.67
16.67
16.67
16.67
Show pixels out of range
Show stored palettes
Store
Background
Randomize


MagnaView PaletteView
View Settings
Show pixels out of range
Draw grid lines
Draw grid axes (red)
Show draw time (MSec)
Show color keys
RGB:
Adobe98
Ref. White:
D65
Gamma:
2.2
Dist Func:
Martijn Custon
1 x 1
2 x 2
Color under cursor
R G B: 105 22 54
L* u* v*: 26 65 0
C* H*: 65 0
Previous colors
CIELuv_H*
= 0
360
0
Custom
Auto
Brewer
Extra
Num Colors:
7
Palette type:
Sequential
Qualitative
Hue:
90
Cold/Warm:
0
Brightness:
0.23
Saturation:
0.3
Contrast:
0.19
Palette colors
Avg: 18.6
18.63
18.63
18.63
18.63
18.63
18.63
Show pixels out of range
Show stored palettes
Store
Background
Randomize

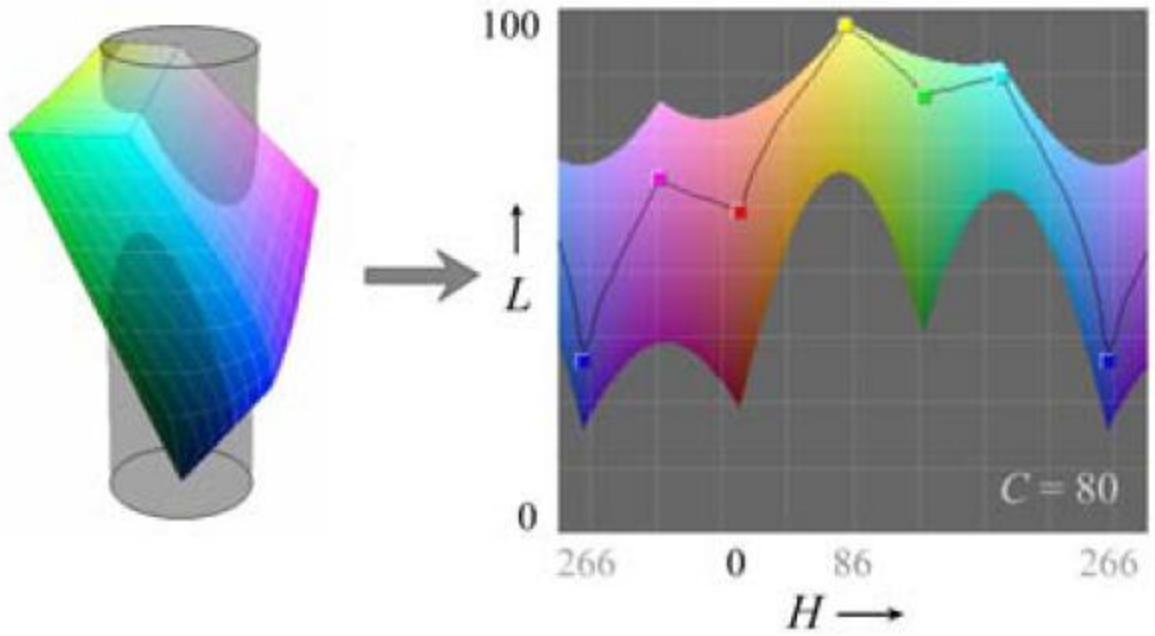
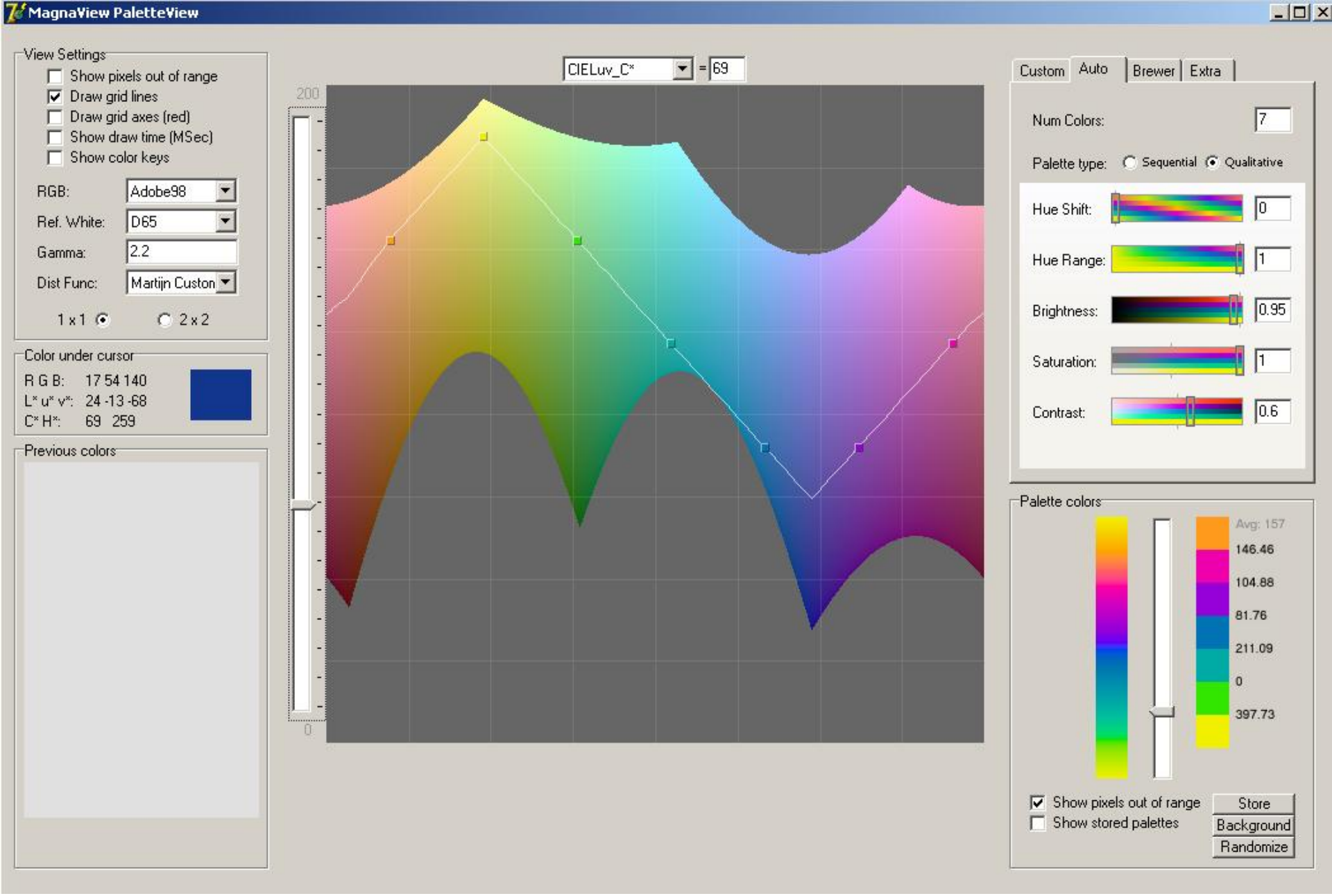
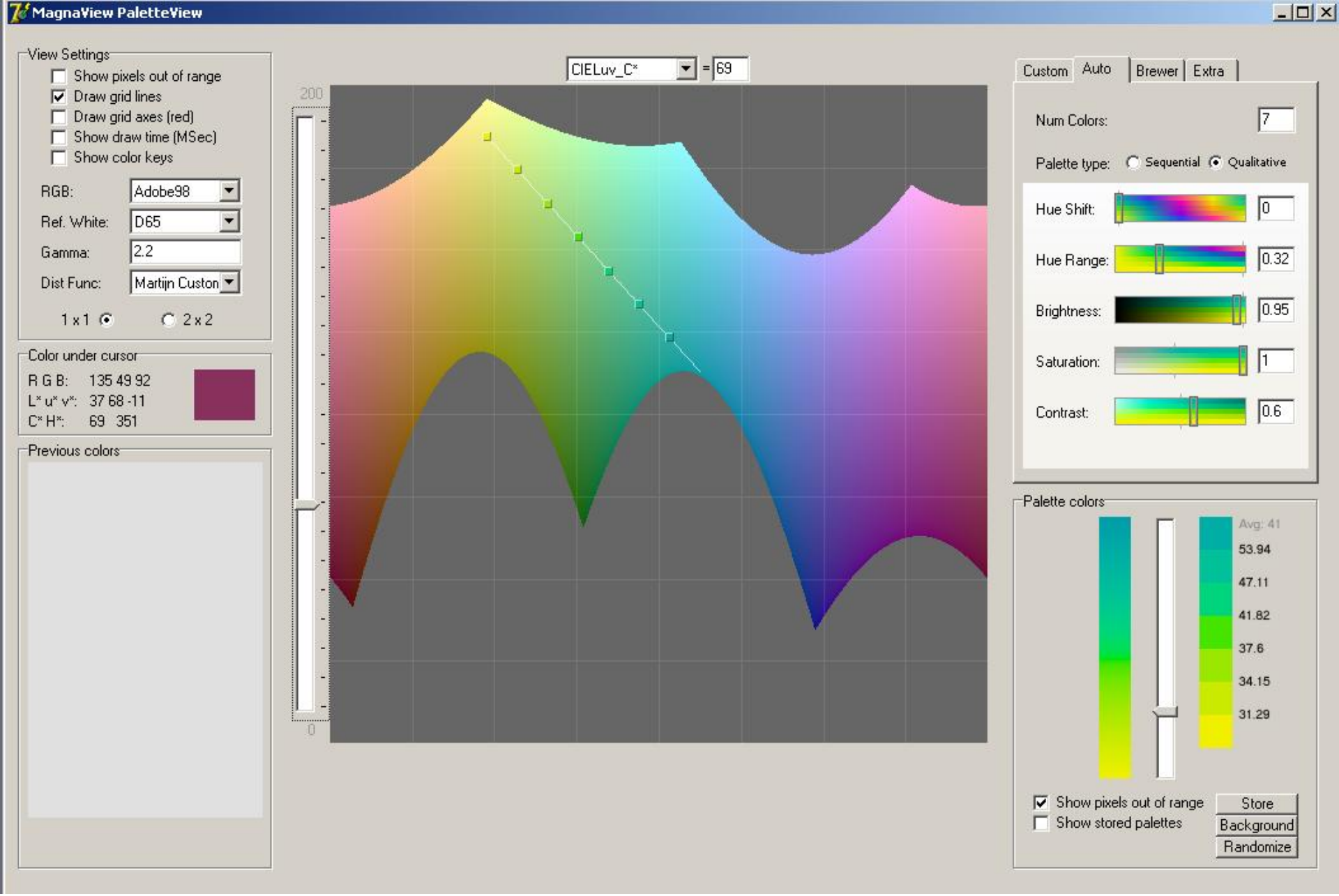
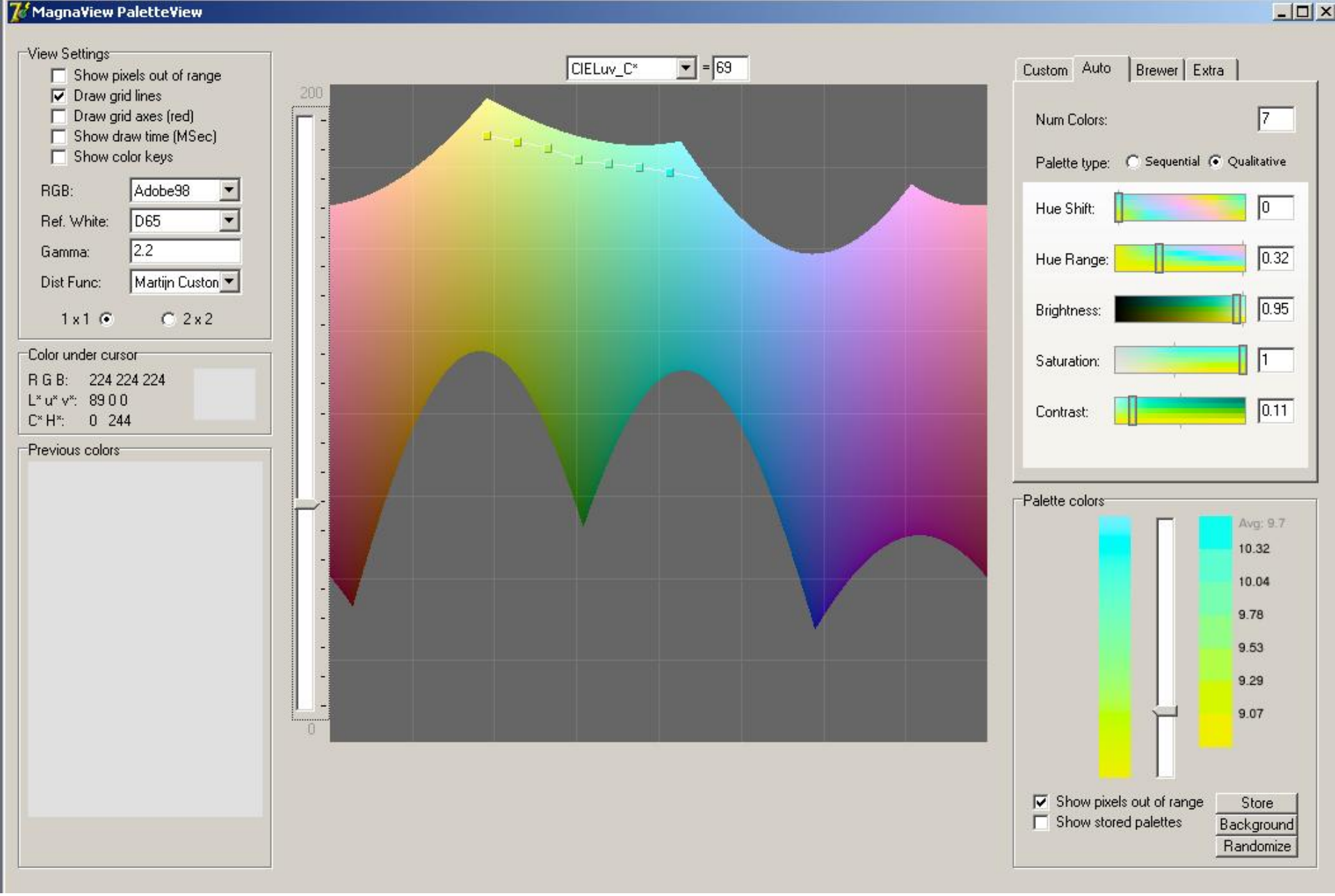


Figure 5: ***Left:*** *the CIELUV displayable color volume with a cylinder that defines all colors of similar saturation.* ***Right:*** *the corresponding saturation slice generated with Palette-View. The path of the MSCs of all hues is shown, indicating the lightness of each MSC.*


MagnaView PaletteView
View Settings
Show pixels out of range
Draw grid lines
Draw grid axes (red)
Show draw time (MSec)
Show color keys
RGB:
Adobe98
Ref. White:
D65
Gamma:
2.2
Dist Func:
Martijn Custon
1 x 1
2 x 2
Color under cursor
R G B: 17 54 140
L* u* v*: 24 -13 -68
C* H*: 69 259
Previous colors
CIELuv_C*
= 69
200
0
Custom
Auto
Brewer
Extra
Num Colors:
7
Palette type:
Sequential
Qualitative
Hue Shift:
0
Hue Range:
1
Brightness:
0.95
Saturation:
1
Contrast:
0.6
Palette colors
Avg: 157
146.46
104.88
81.76
211.09
0
397.73
Show pixels out of range
Show stored palettes
Store
Background
Randomize


MagnaView PaletteView
View Settings
Show pixels out of range
Draw grid lines
Draw grid axes (red)
Show draw time (MSec)
Show color keys
RGB:
Adobe98
Ref. White:
D65
Gamma:
2.2
Dist Func:
Martijn Custon
1 x 1
2 x 2
Color under cursor
R G B: 135 49 92
L* u* v*: 37 68 -11
C* H*: 69 351
Previous colors
CIELuv_C*
= 69
200
0
Custom
Auto
Brewer
Extra
Num Colors:
7
Palette type:
Sequential
Qualitative
Hue Shift:
0
Hue Range:
0.32
Brightness:
0.95
Saturation:
1
Contrast:
0.6
Palette colors
Avg: 41
53.94
47.11
41.82
37.6
34.15
31.29
Show pixels out of range
Show stored palettes
Store
Background
Randomize


MagnaView PaletteView
View Settings
Show pixels out of range
Draw grid lines
Draw grid axes (red)
Show draw time (MSec)
Show color keys
RGB:
Adobe98
Ref. White:
D65
Gamma:
2.2
Dist Func:
Martijn Custon
1 x 1
2 x 2
Color under cursor
R G B: 224 224 224
L* u* v*: 89 0 0
C* H*: 0 244
Previous colors
CIELuv_C*
= 69
200
0
Custom
Auto
Brewer
Extra
Num Colors:
7
Palette type:
Sequential
Qualitative
Hue Shift:
0
Hue Range:
0.32
Brightness:
0.95
Saturation:
1
Contrast:
0.11
Palette colors
Avg: 9.7
10.32
10.04
9.78
9.53
9.29
9.07
Show pixels out of range
Show stored palettes
Store
Background
Randomize

colorconvert – convert color spaces

I've created a script to convert a color from one color space to a list of popular spaces

```
> ~martink/work/colorconvert/current/colorconvert
using white point / rgb space D65 sRGB
could not initialize color - please us one of the available color spaces:
rgb rgb255 rgbhex hsv hsl cmyk yiq yuv lab luv lch xyz xyy
e.g. colorconvert -rgb 255,255,0

using a nice green RGB = 127,231,75 as default

rgb        0.498    0.906    0.294
rgb255       127      231       75
rgbhex    7FE74B
hsv          100    0.675    0.906
hsl          100    0.765    0.600
cmyk       0.408        0    0.612
yiq        0.775    0.006   -0.246
yuv        0.775   -0.210   -0.129
lab       83.004  -56.476   63.808
luv       83.004  -50.307   85.982
lch       83.004   99.618  120.332
xyz        0.386    0.622    0.166
xyy        0.329    0.530    0.622
```

```
> ~martink/work/colorconvert/current/colorconvert -lch 85,90,120
using white point / rgb space D65 sRGB
rgb         0.560    0.920    0.400
rgb255        143      235      102
rgbhex     8FEB66
hsv       101.525    0.566    0.920
hsl       101.525    0.766    0.660
cmyk        0.360        0    0.521
yiq         0.804   -0.000   -0.221
yuv         0.804   -0.185   -0.120
lab            85  -50.613   55.015
luv            85      -45   77.942
lch            85   90.000      120
xyz         0.433    0.660    0.230
xyy         0.327    0.499    0.660
```

RGB = 127 231 75 LCH = 83 100 120

RGB = 0 113 0	LCH = **40 90 120**	HSB = 120 100 44
RGB = 53 152 0	LCH = **55 90 120**	HSB = 99 100 60
RGB = 99 192 42	LCH = **70 90 120**	HSB = 97 78 75
RGB = 143 245 102	LCH = **85 90 120**	HSB = 103 58 96
RGB = 186 255 150	LCH = **100 90 120**	HSB = 99 41 100
RGB = 231 255 197	LCH = **115 90 120**	HSB = 85 23 100

colorbrewer.org to choose palettes

kuler.adobe.com to peruse/create attractive color combinations