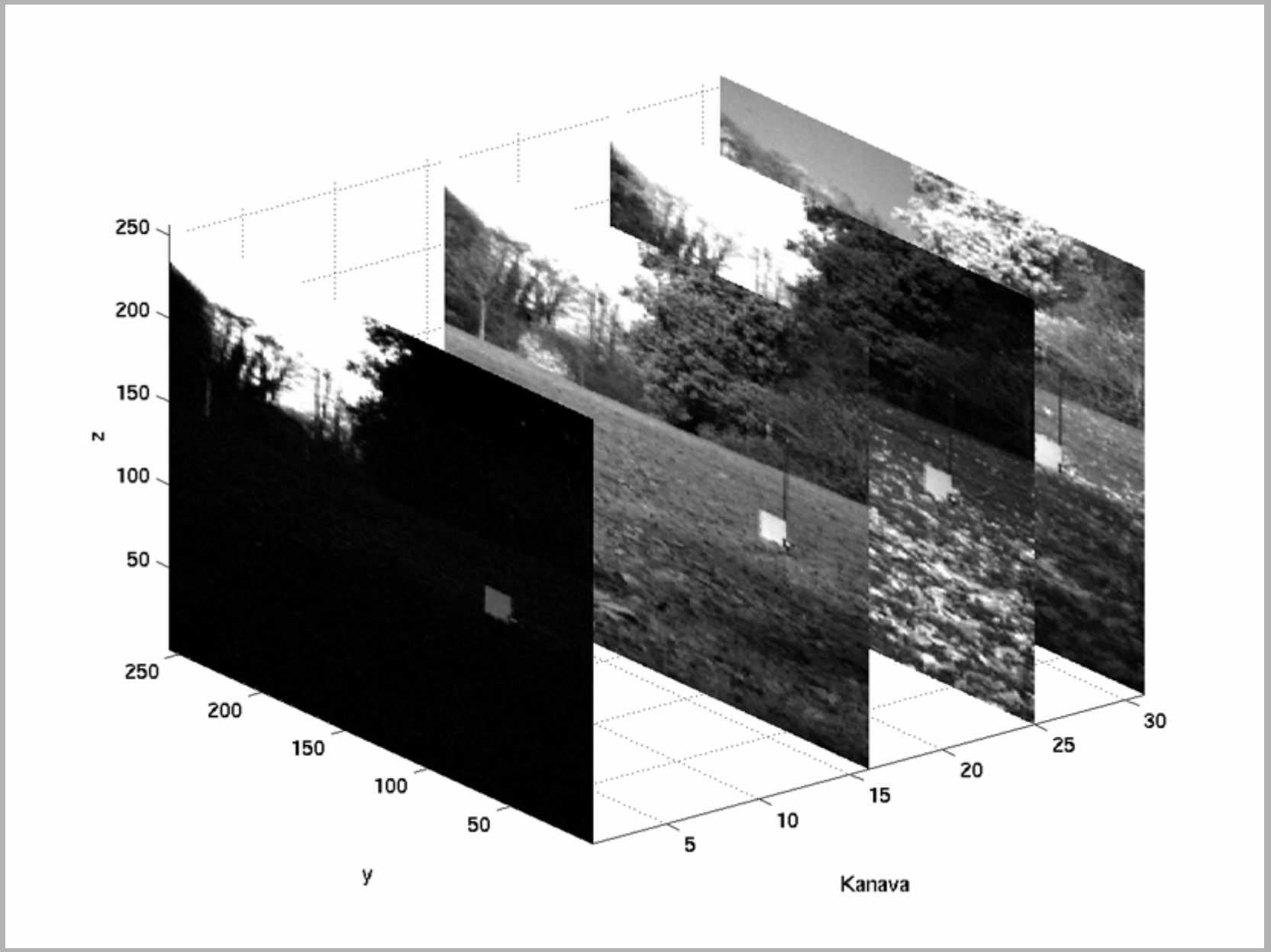
# Digital Color

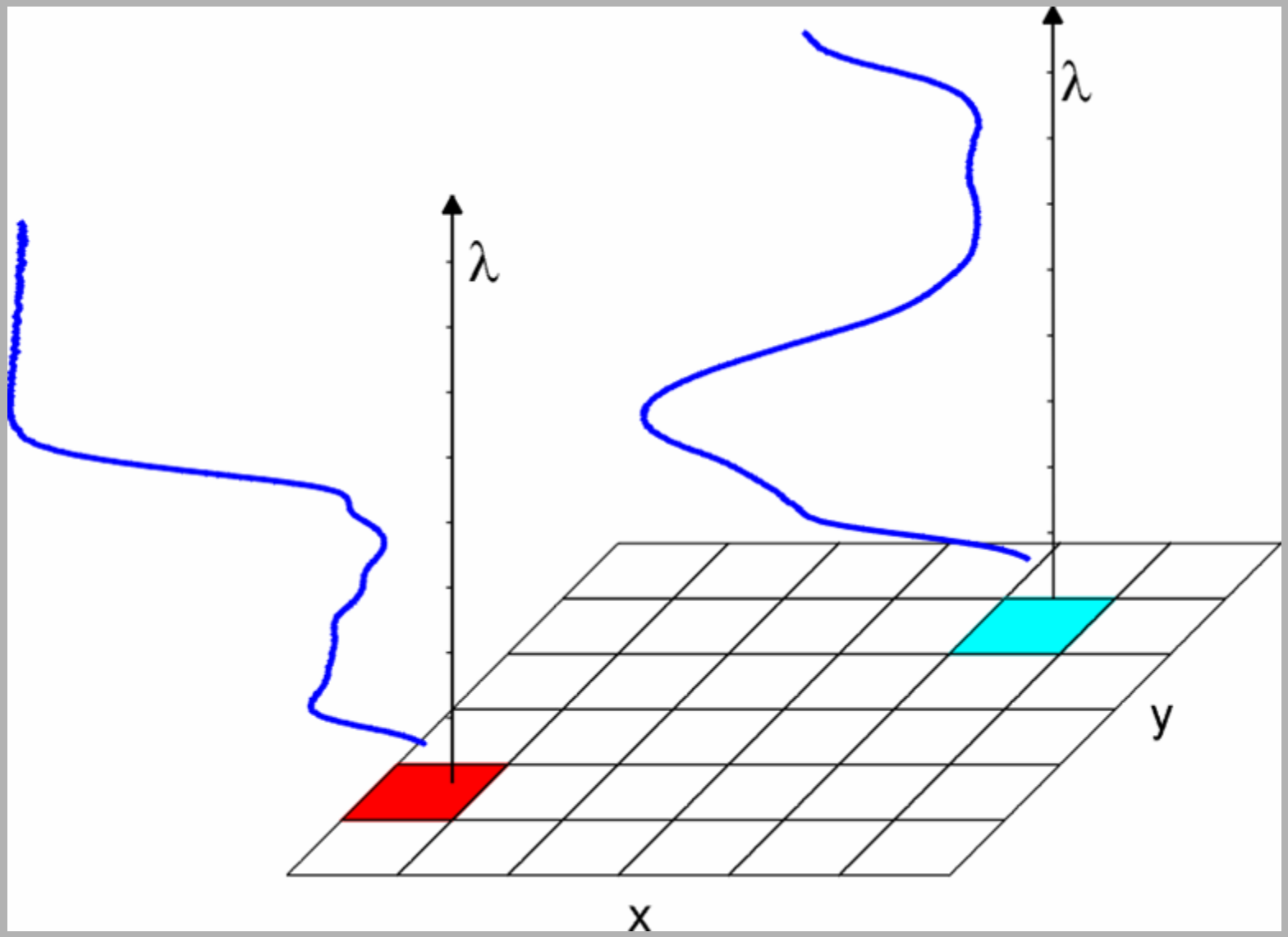
Lecture 7

Spectral color representation and display

# Spectral component images

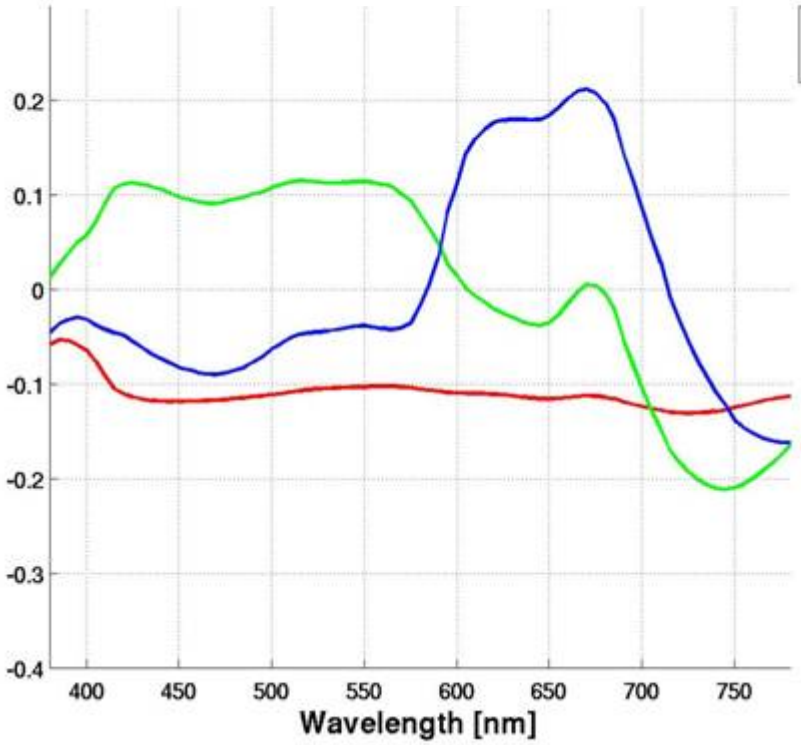


# Spectral Image

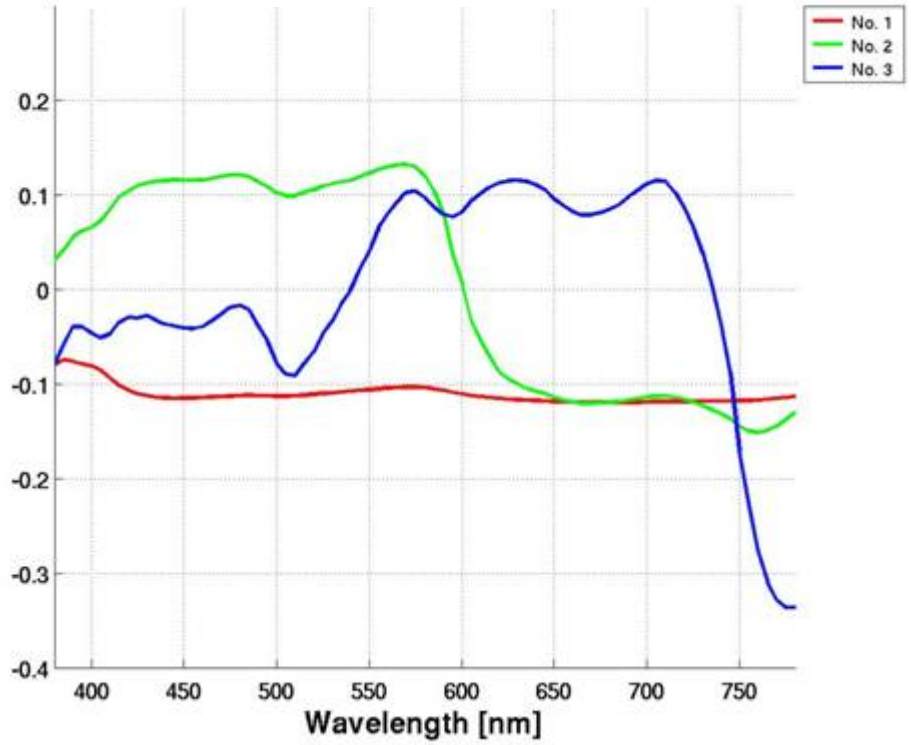


# Compare principal components (trousers data)

pre-print




print



# No1 Eigenimage

pre-print


Almost same

print

# No2 Eigenimage

pre-print


different

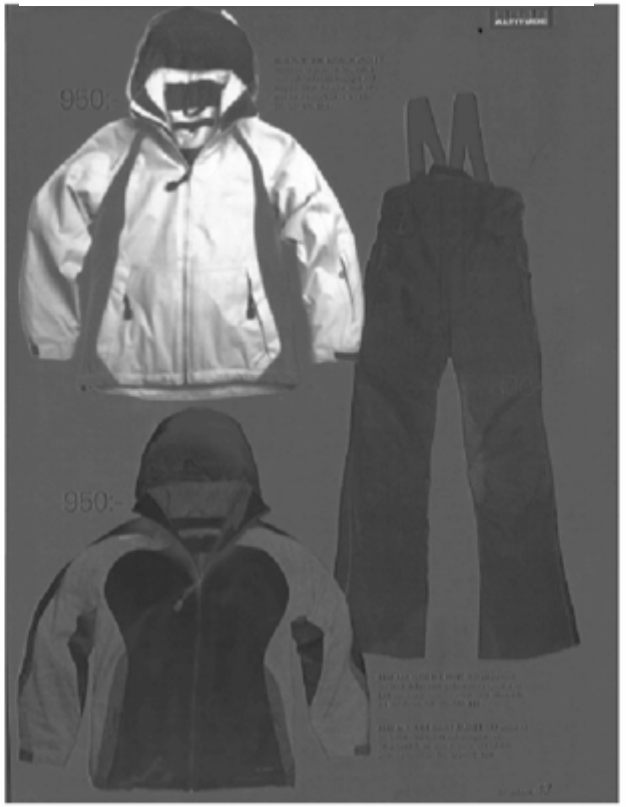
print

# No3 Eigenimage

pre-print

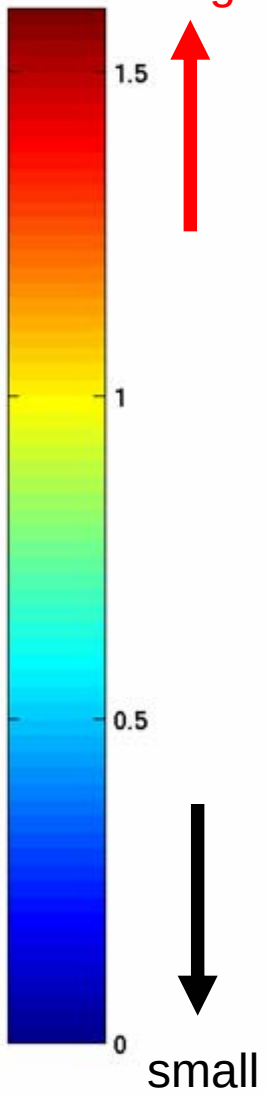

different

print



# Jacket and trousers (Euclidean distance of raw data)

Delta E between pre-print and print of spectra data



# Data: Munsell matte collection

Two pages from Munsell Book of Color (matte collection). Whole set contains 1269 color patches.

## Polynomial regression

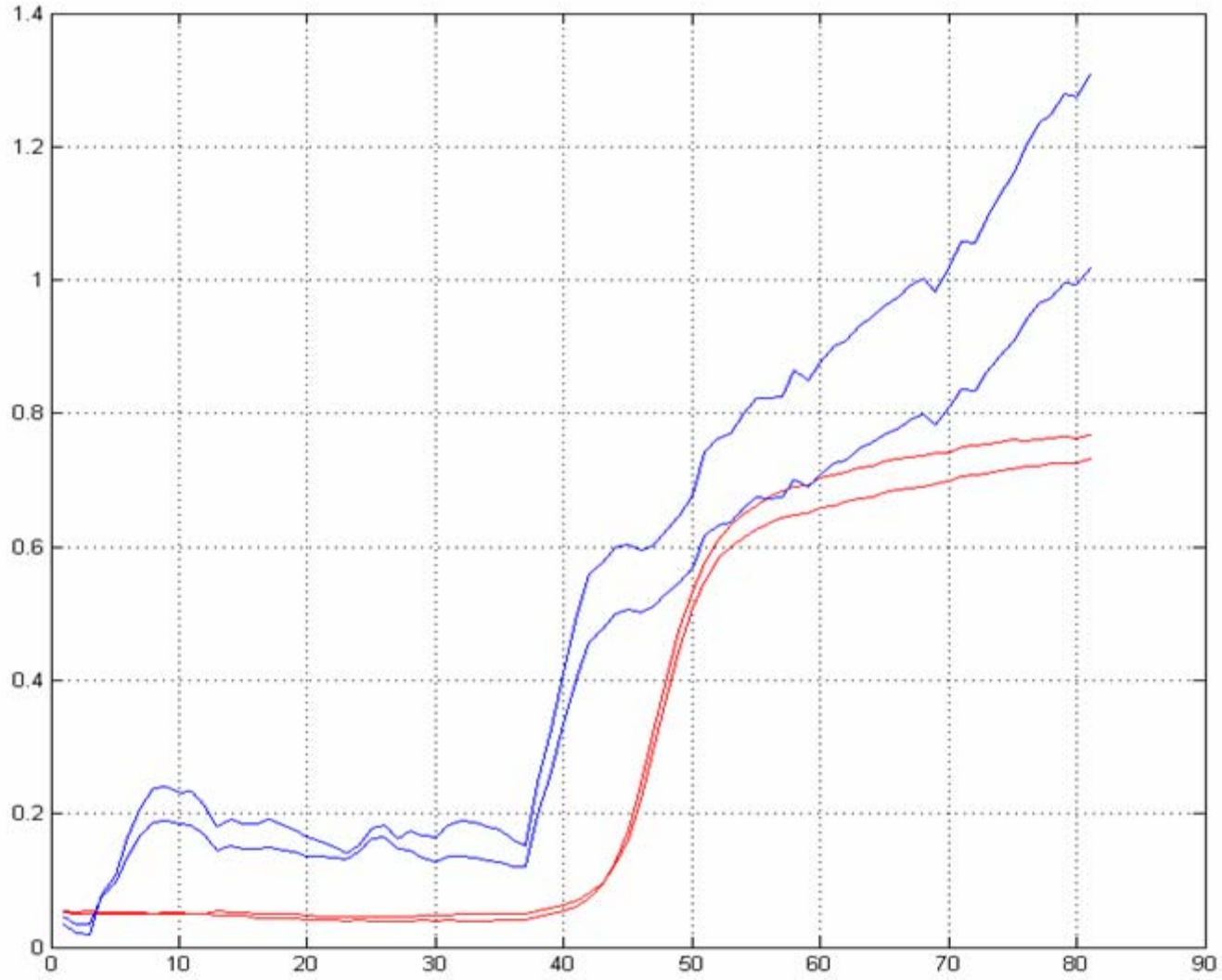
Least squares minimization problem can be formulated as minimization of the $j$ functionals ($j = 1, \ldots, d$)

$$L_j(f_j, S) = \sum_{i=1}^{l} (f_j(x_i) - (r_j)_i)^2 = \sum_{i=1}^{l} (\langle w, \Phi^k(j_i) \rangle - (r_j)_i)^2,$$

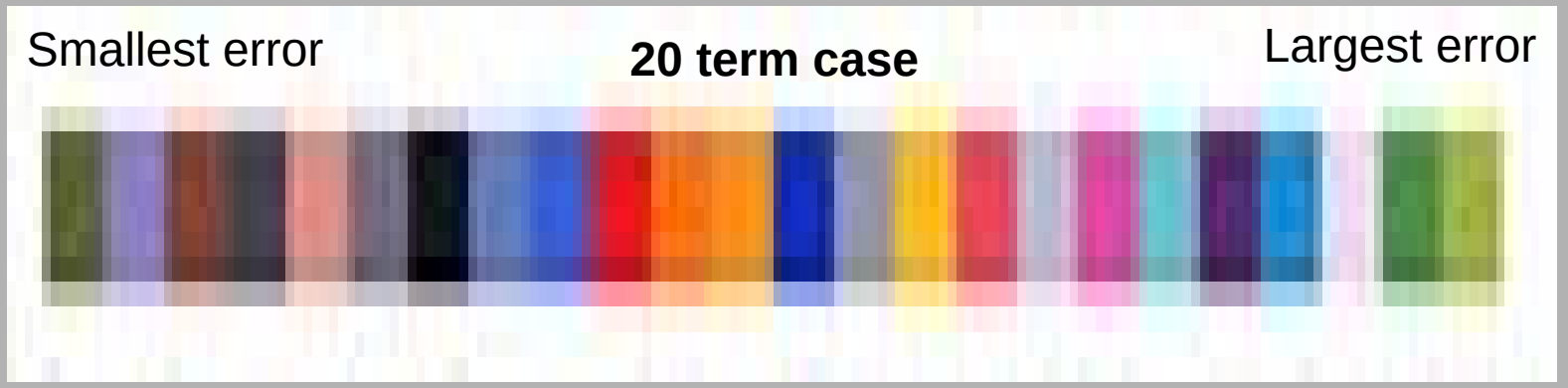
where for example ($k = 2$):
$\Phi^2(R, G, B) = (R, G, B, RG, RB, GB, R^2, G^2, B^2, 1)$.

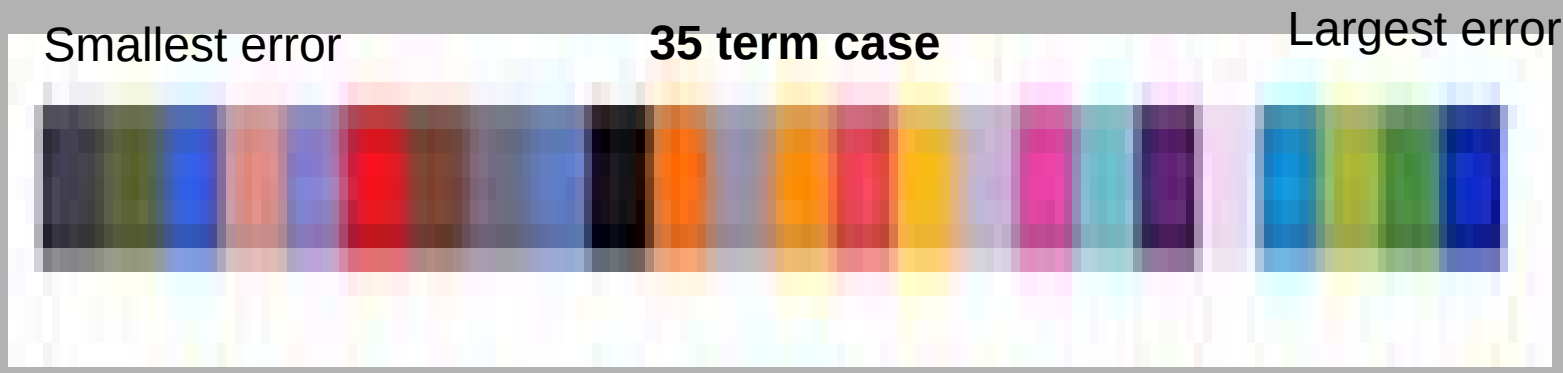
Here $d$ depends on the sampling of the spectra and $l$ denotes the size of the training set $S$.

# Training set of 50 samples, polynomial model



# Order of ColorChecker Patches



## Summary of Results

For the data sets used, we concluded that the Duchon spline gave best results for the chosen training set (600 samples). Results for all the regularized models were quite similar. Comparison of regularized polynomial model and Duchon spline:

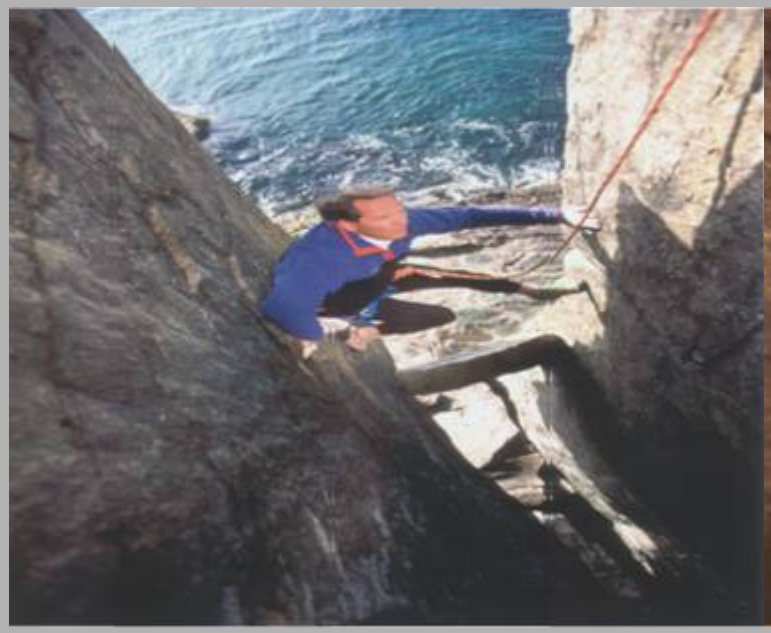
| | $RMSE$ | | | $\Delta E$ | | |
|---|---|---|---|---|---|---|
| | Avg. | Std. | Max. | Avg. | Std. | Max. |
| Reg. Polynomial | 0.0174 | 0.0117 | 0.0902 | 1.85 | 0.98 | 7.20 |
| Duchon spline | 0.0154 | 0.0114 | 0.0699 | 1.80 | 0.98 | 6.43 |

D65

F11

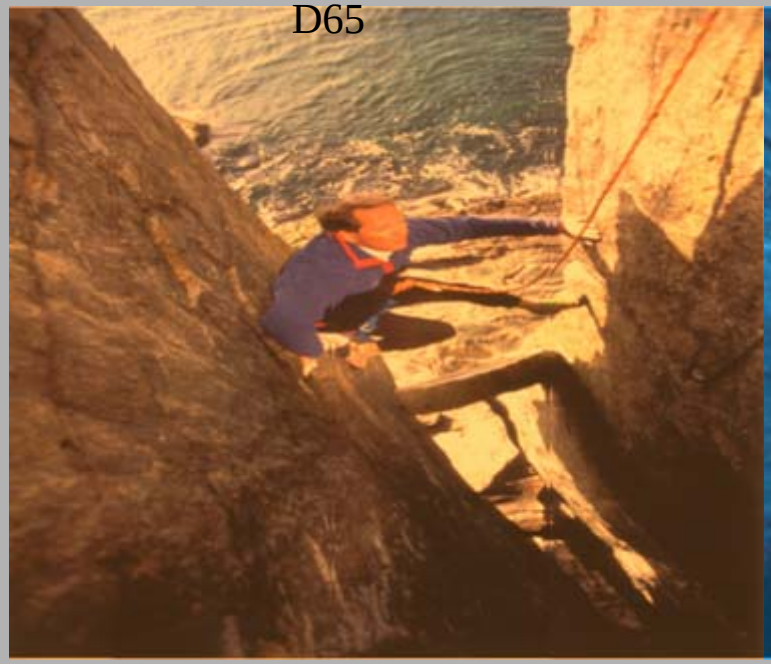
A

White LED



D65

F11

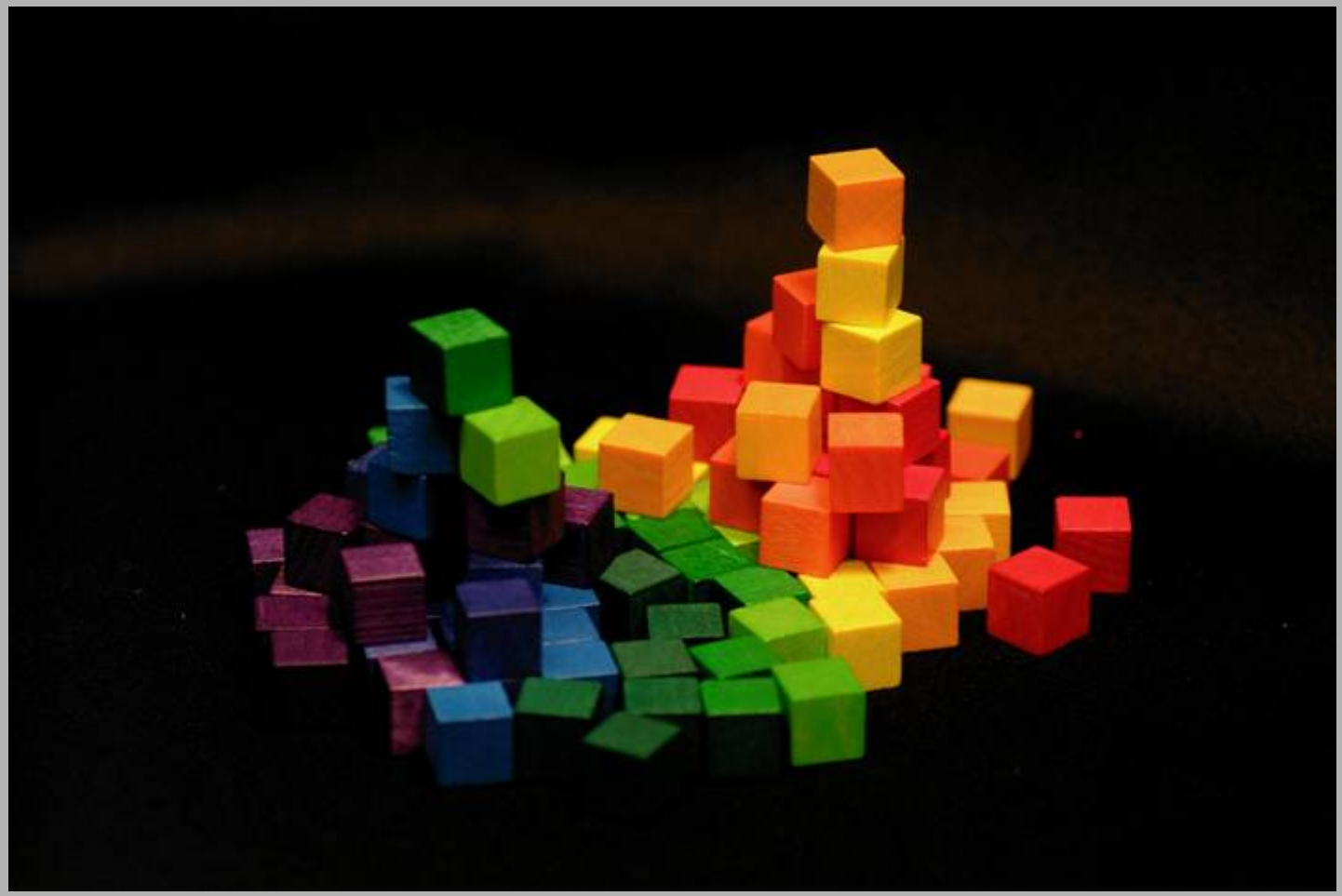


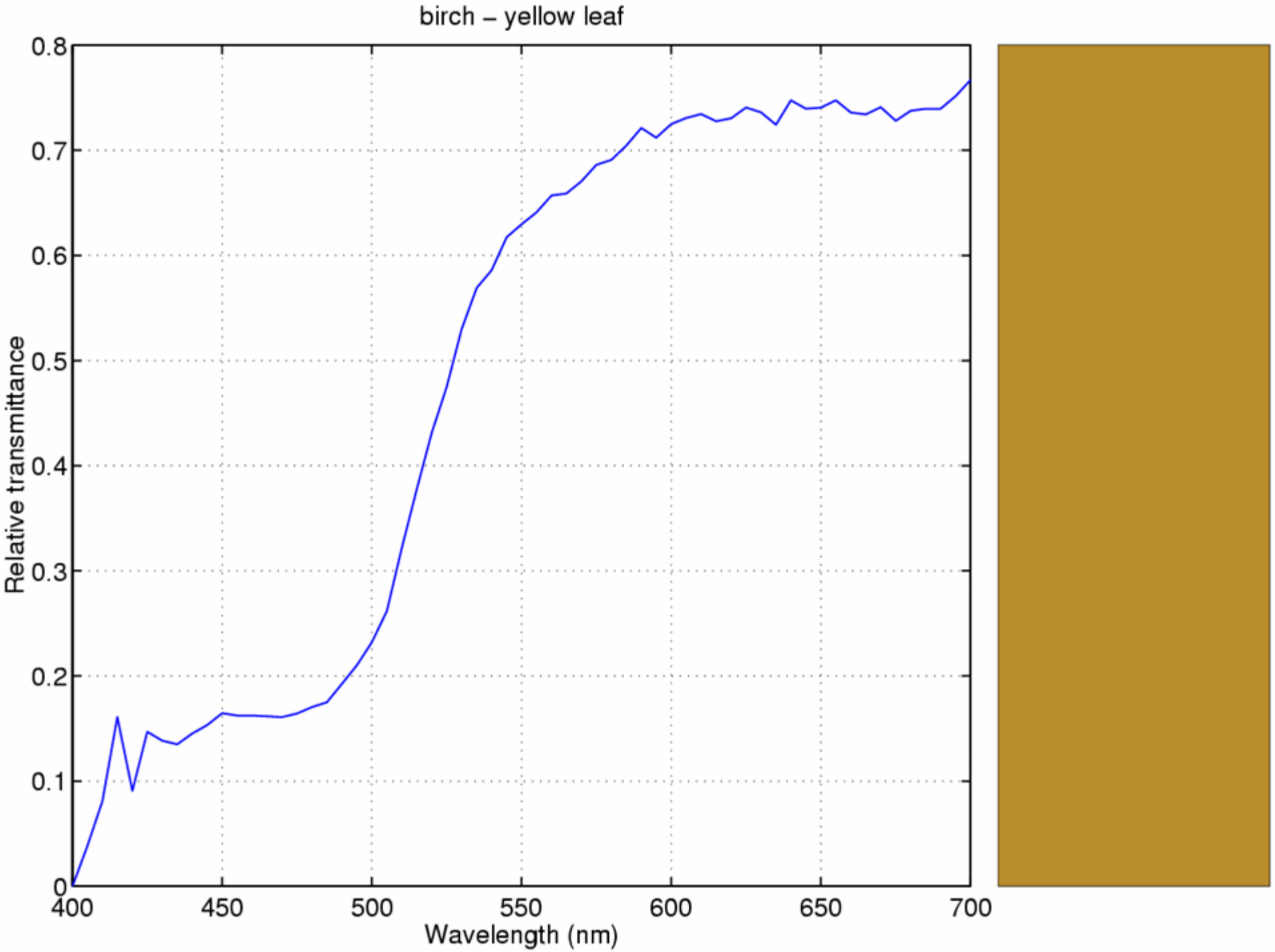
A

White LED

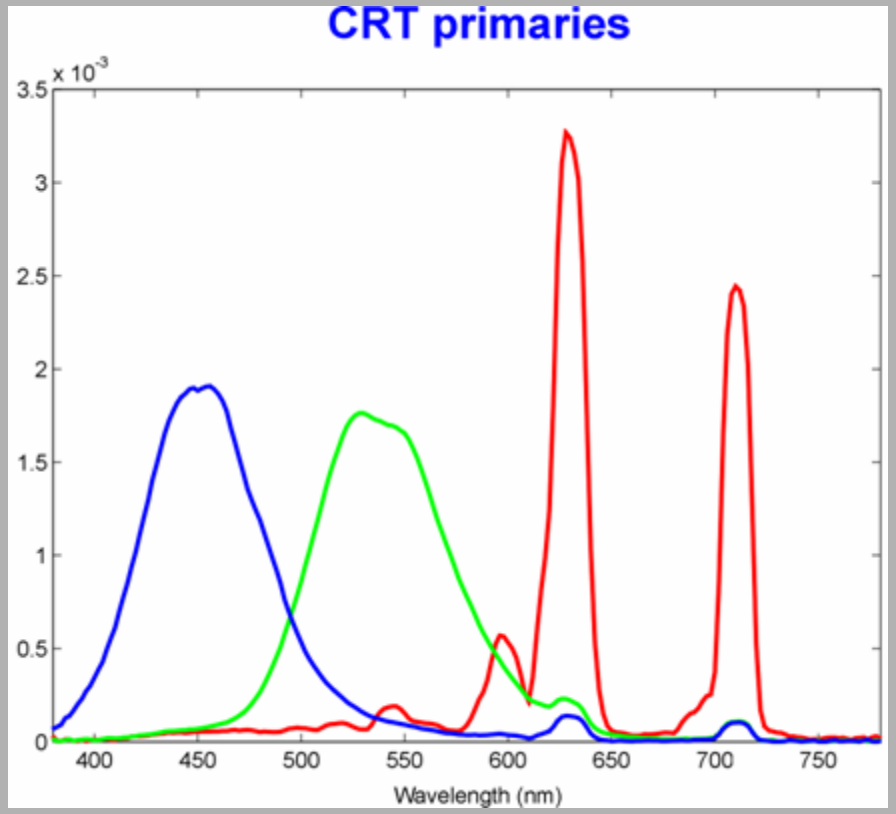
# Simulation of Illuminant Change

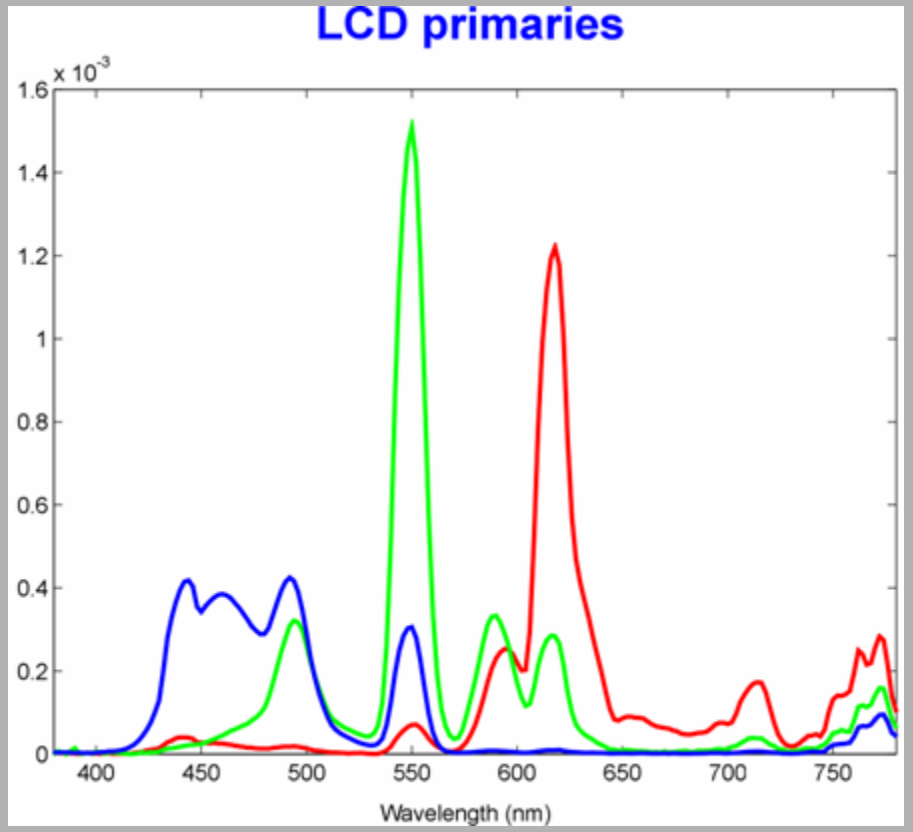
# Reproduction of color images on displays



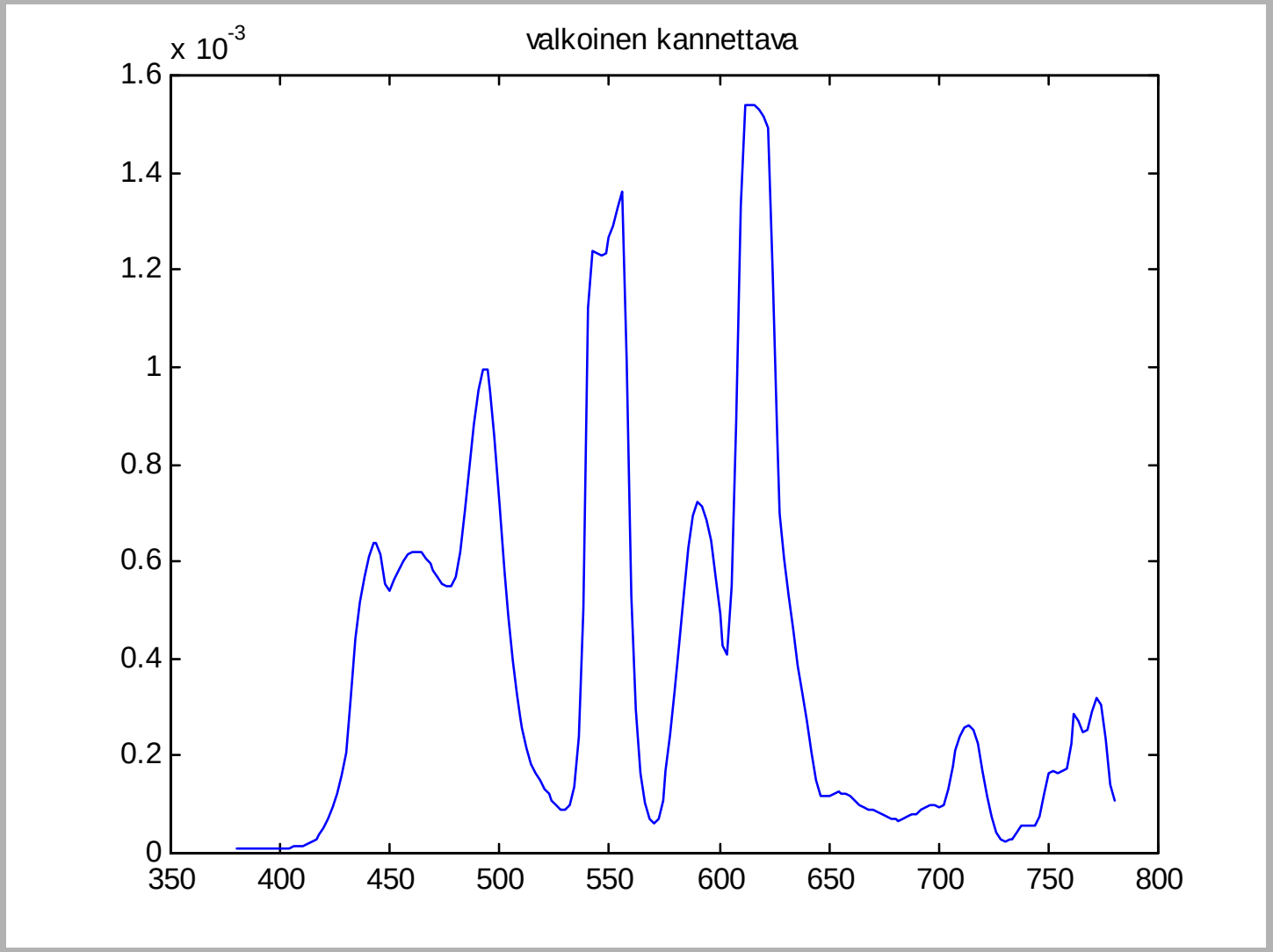

birch – yellow leaf
Relative transmittance
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
450
500
550
600
650
700
Wavelength (nm)

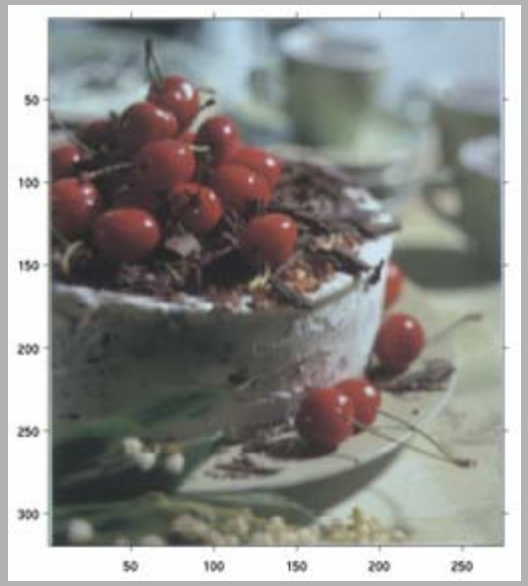
# Display characterictics

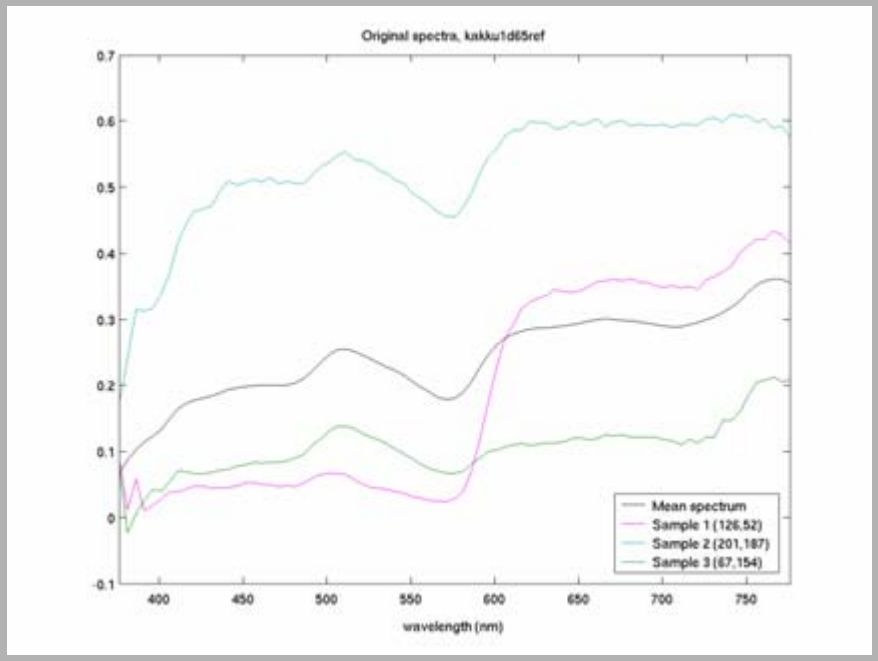


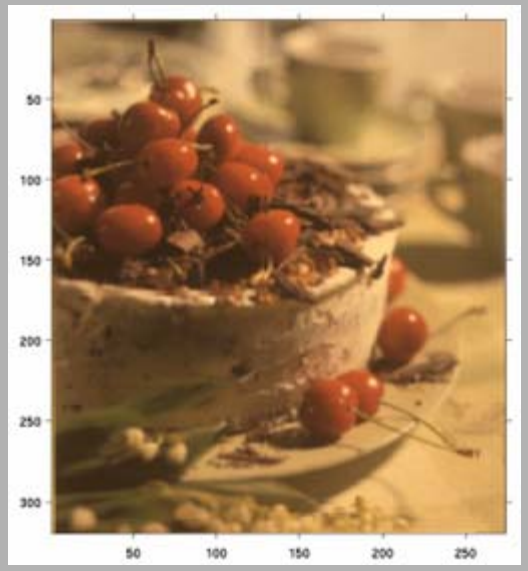



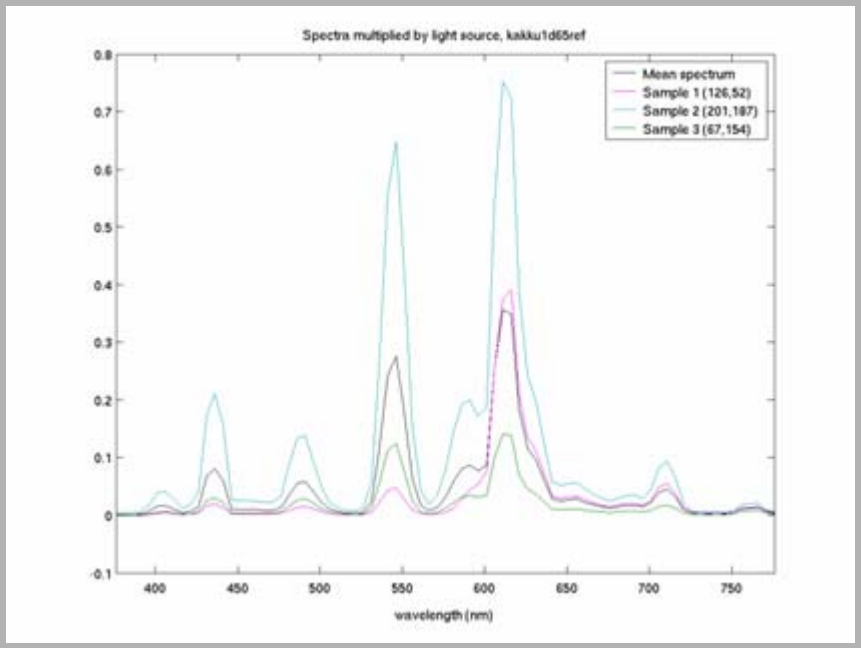
# Laptop, white color on display






Original spectra, kakku1d65ref
wavelength (nm)
Mean spectrum
Sample 1 (126,52)
Sample 2 (201,187)
Sample 3 (67,154)




Spectra multiplied by light source, kakku1d65ref
wavelength (nm)
Mean spectrum
Sample 1 (126,52)
Sample 2 (201,187)
Sample 3 (67,154)

# Examples for CRT and LCD displays

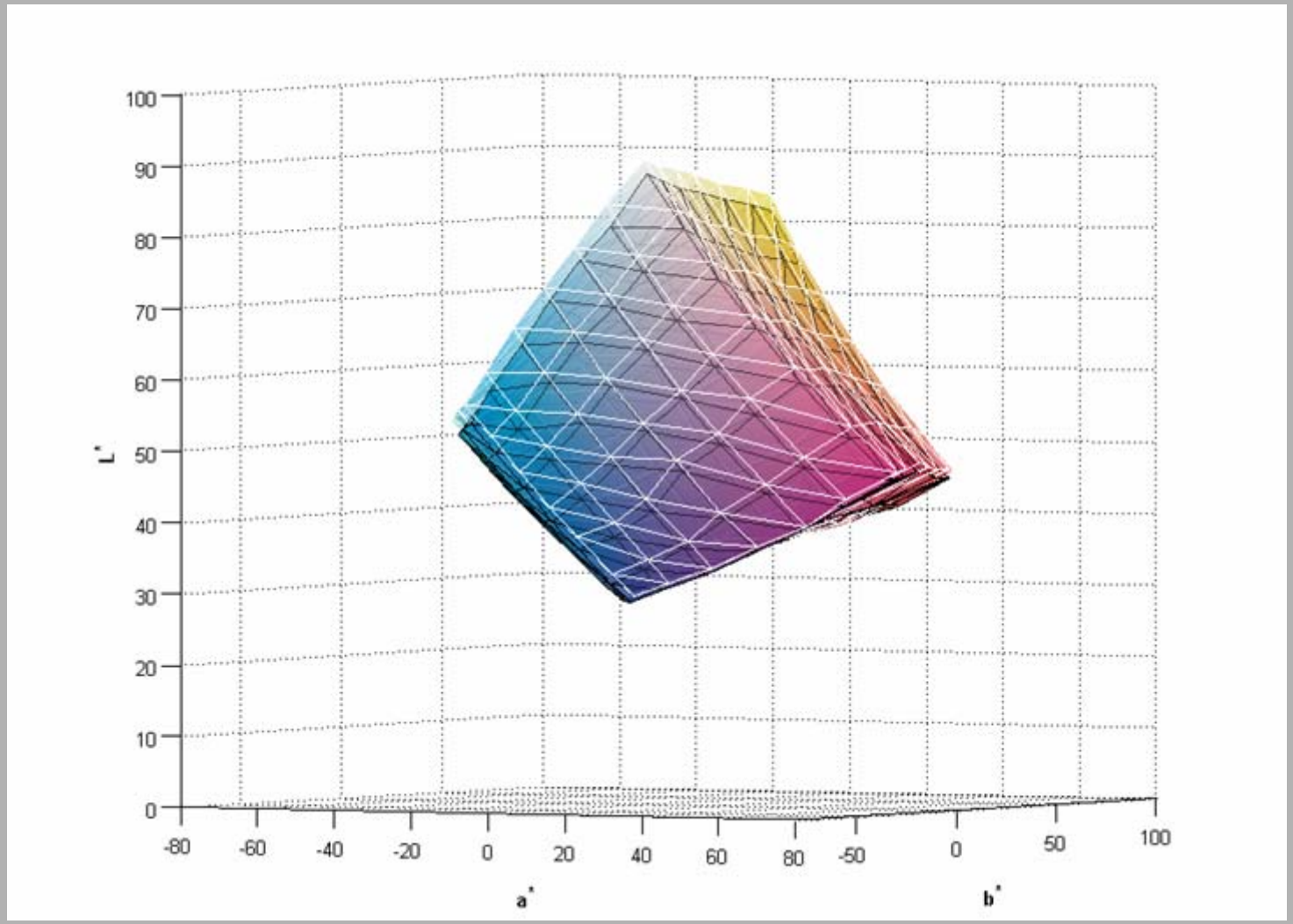
IMAGE OF SRGB-REPRODUCTION ON CRT DISPLAY

IMAGE OF ORIGINAL SAMPLE

IMAGE OF METAMERIC COLOR REPRODUCTION ON CRT DISPLAY

# Examples: color characterization

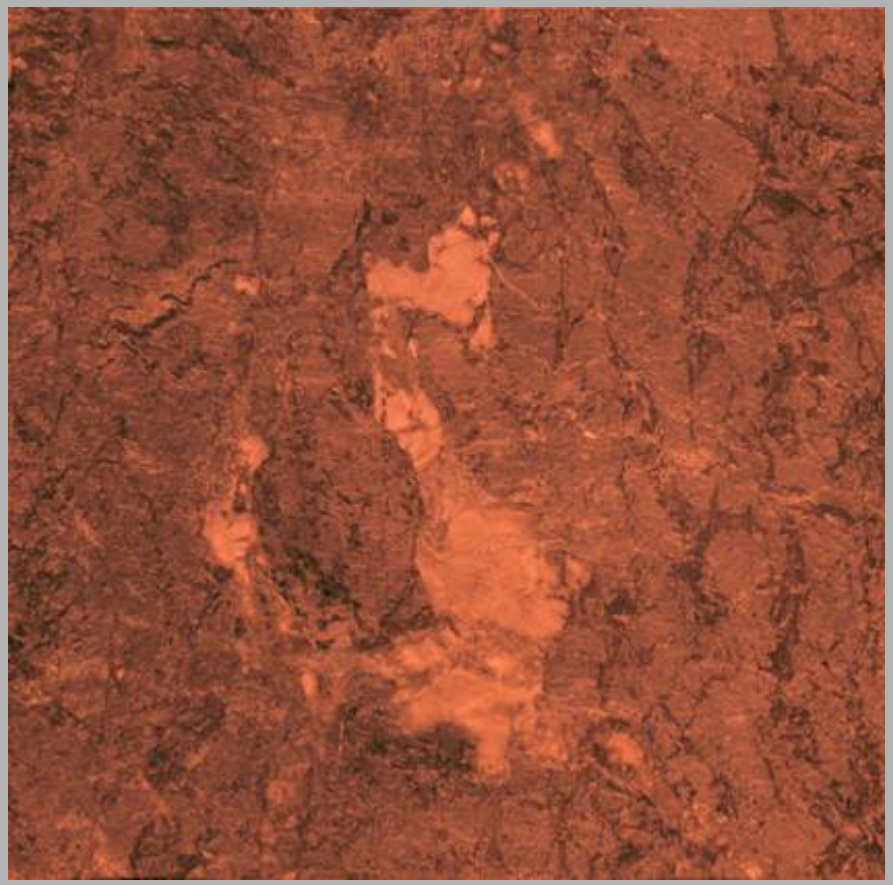
# Visualization of color gamuts: same paper, different ink set used

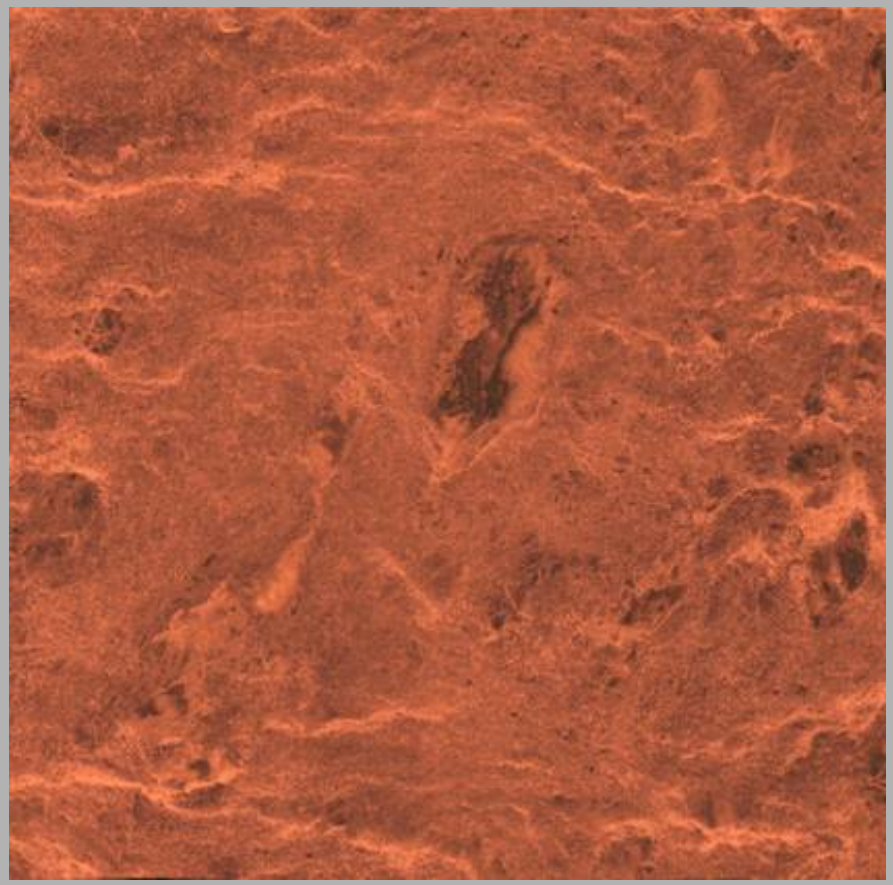


# Spectral imaging of soap stones

**The spectral imaging system and examples of soap stones**

# Optimized soapstone images





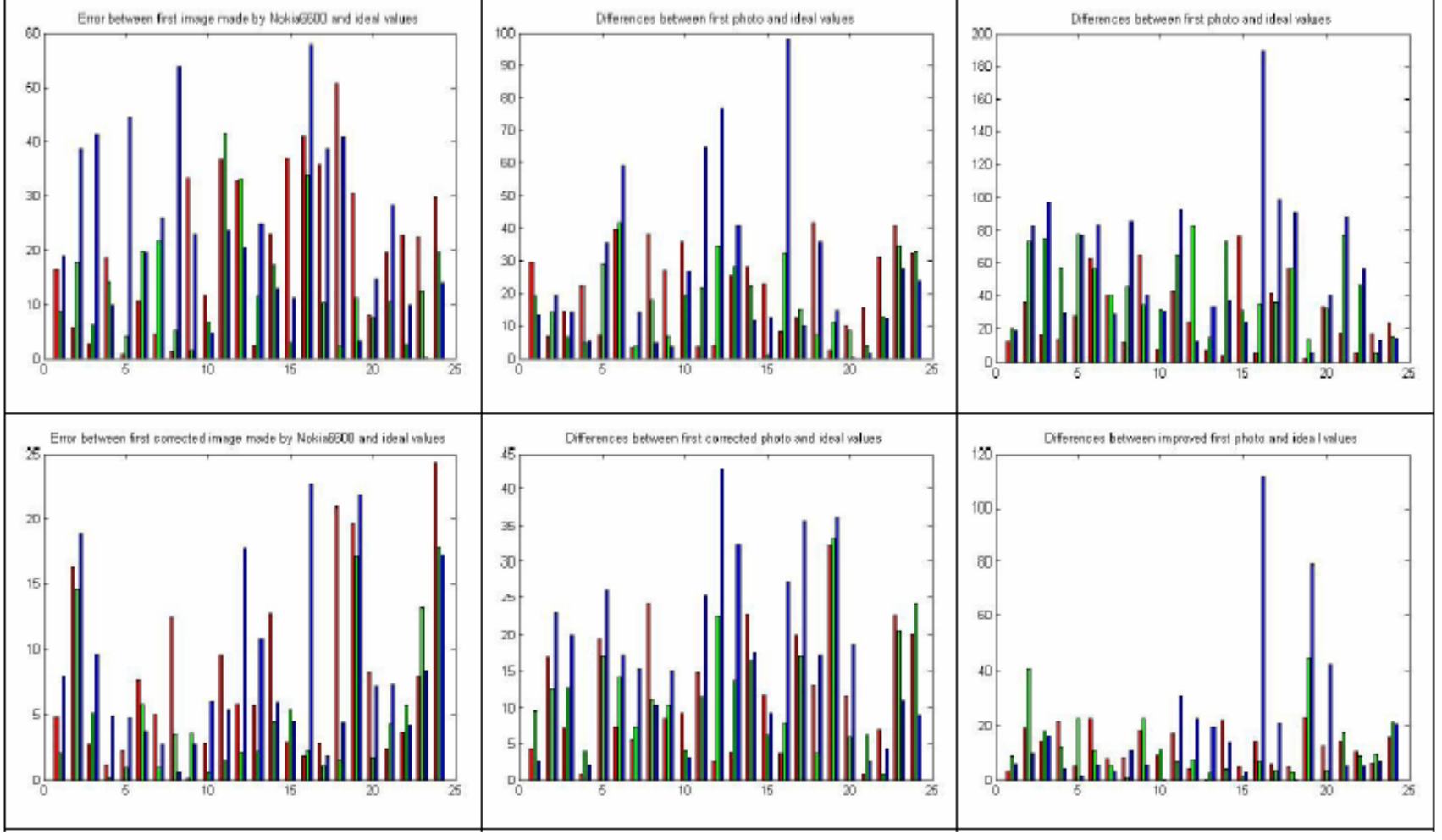
# Some tests with mobile phones cameras

| *Nokia 6600* | *Siemens S65* | *Samsung SGH-D500* |
|---|---|---|
| Original mobile phone images | | |
|  |  |  |
| Images improved using 2nd order polynomial model | | |
|  |  |  |

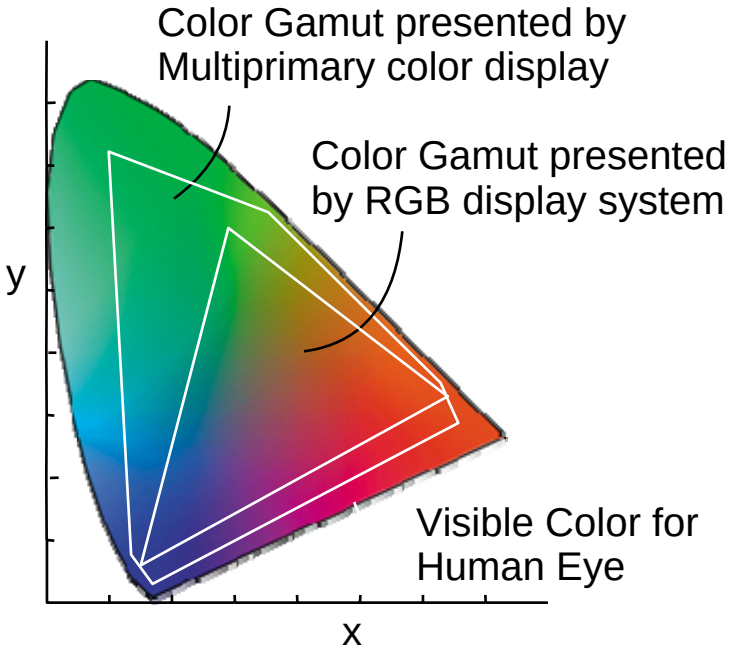
# Some preliminary tests with mobile phones cameras

Error between RGB values of camera image and ideal sRGB values calculated from spectra.

First row: error between the original image and ideal values.
Second row: error between the corrected image and ideal values.
Note that the scale of y-axis of diagrams varies between images.



# Multiprimary color displays

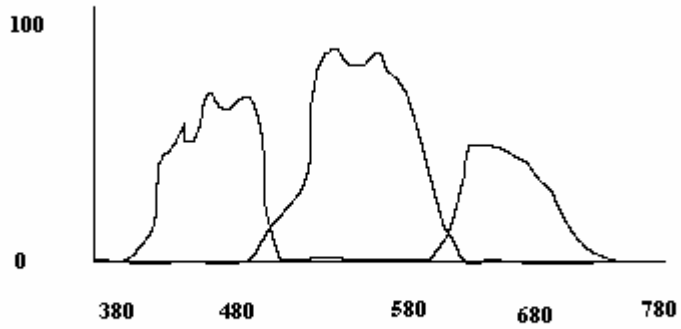



Stacked front-projection 6-primary DLP display

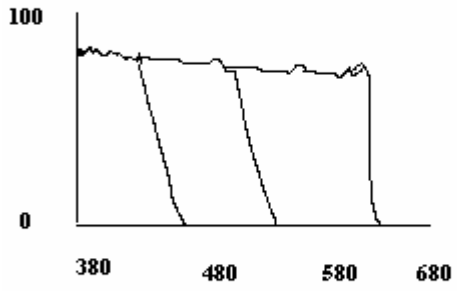
2x2-tiled, 2000x2000pixels rear-projection
6-primary display

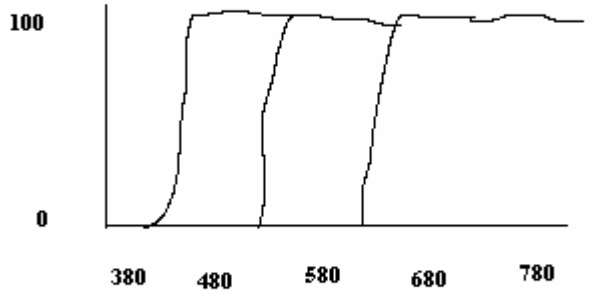
Conventional LCD  4-primary Flat-panel LCD

RGB-filters



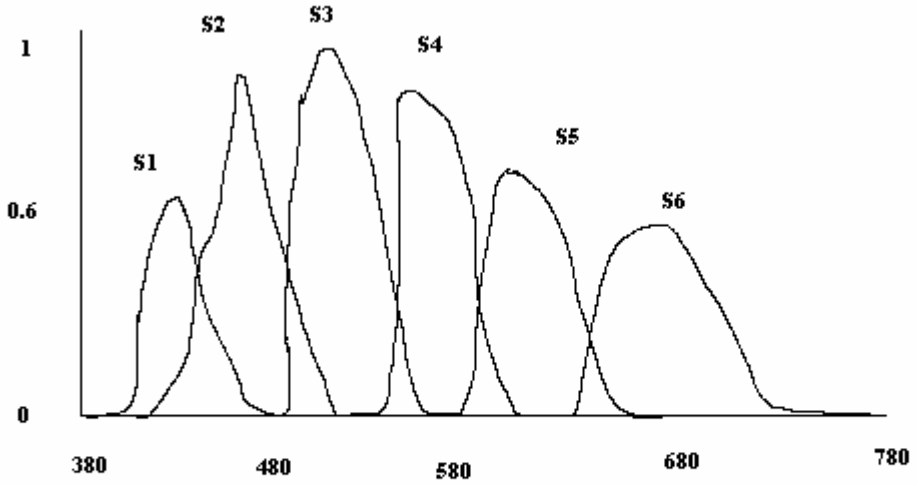

High and low pass filters

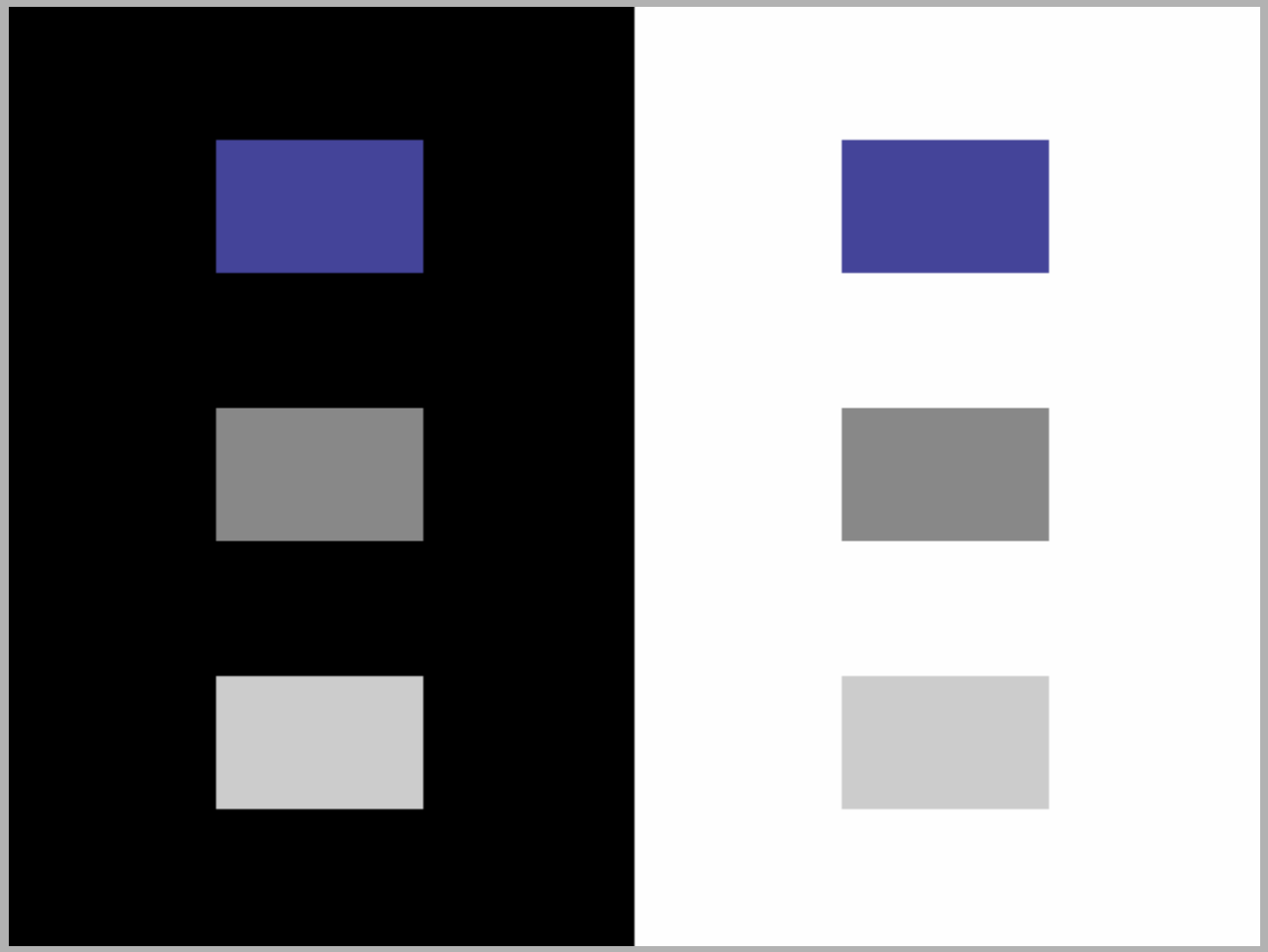



6 filters for

Multiprimary displ





# surround ciecam