CS462 Image Processing

Chapter 6

Colours

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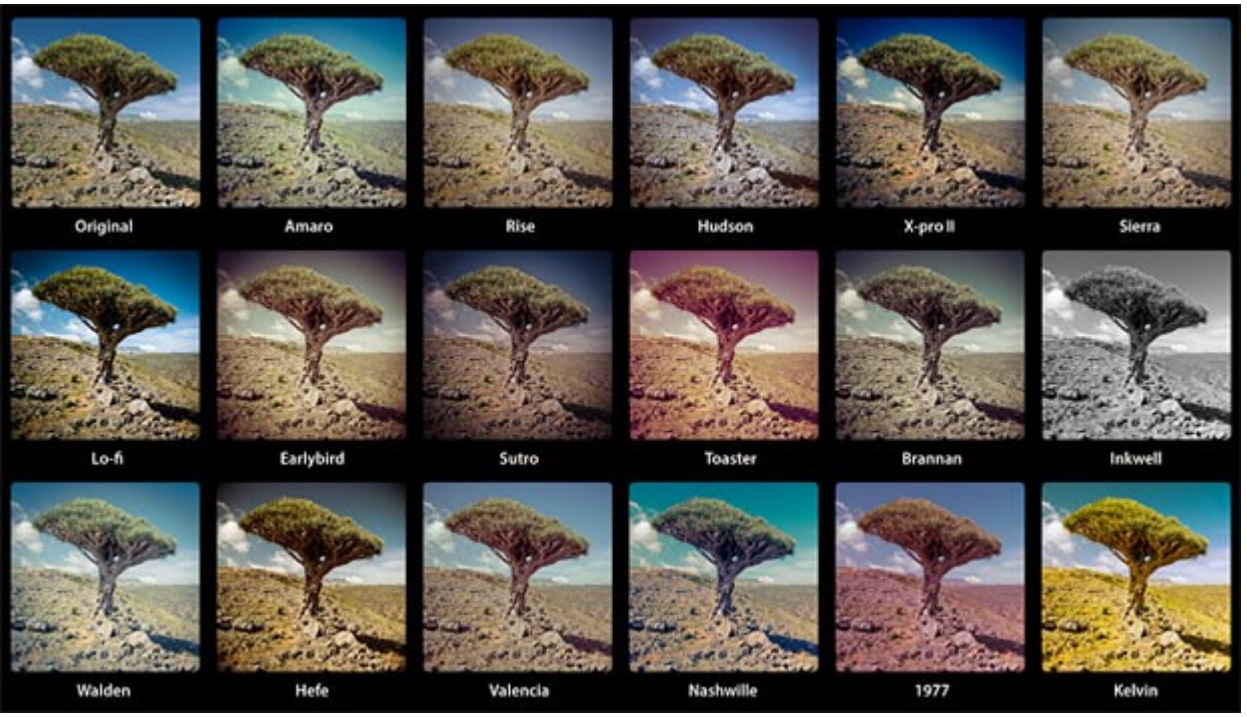
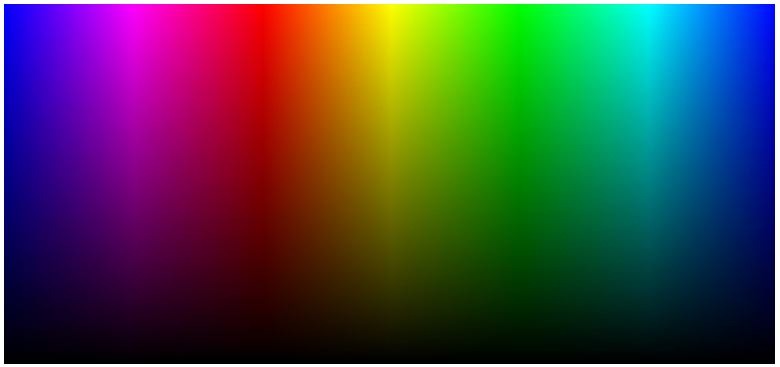
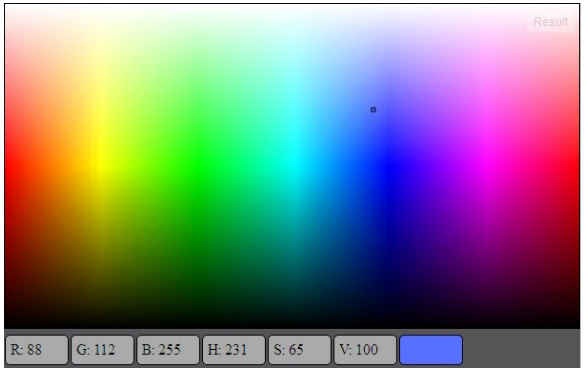
Computer Science MJU

Color Processing



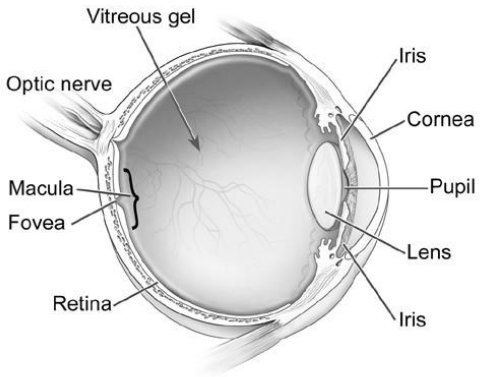


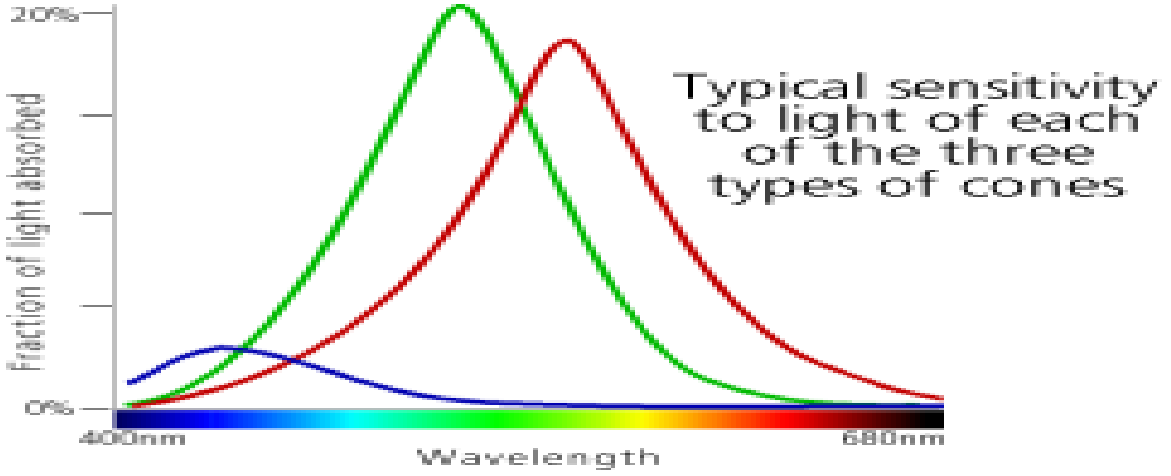


What is color ?

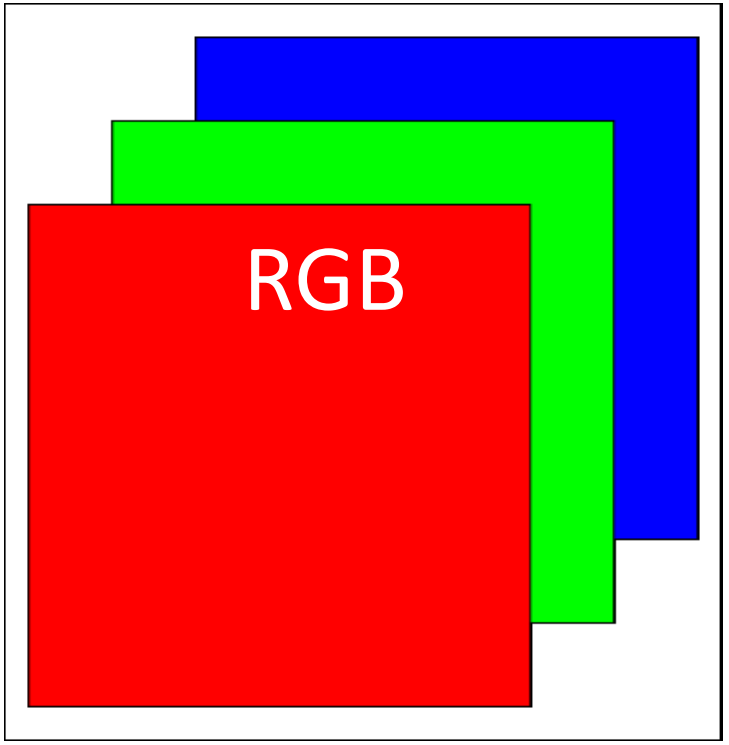
The colors of the visible light spectrum		
color	wavelength interval	frequency interval
red	~ 700–635 nm	~ 430–480 THz
orange	~ 635–590 nm	~ 480–510 THz
yellow	~ 590–560 nm	~ 510–540 THz
green	~ 560–520 nm	~ 540–580 THz
cyan	~ 520–490 nm	~ 580–610 THz
blue	~ 490–450 nm	~ 610–670 THz
violet	~ 450–400 nm	~ 670–750 THz

Where is purple ?





Colors



The colors of the visible light spectrum		
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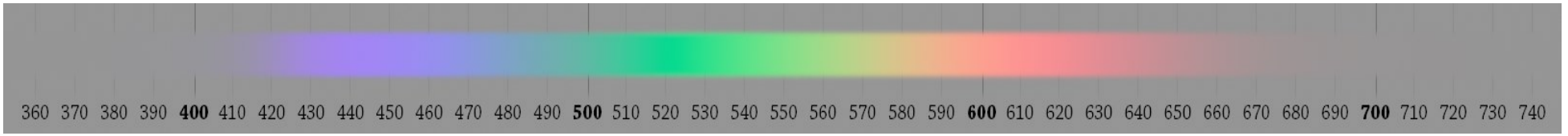
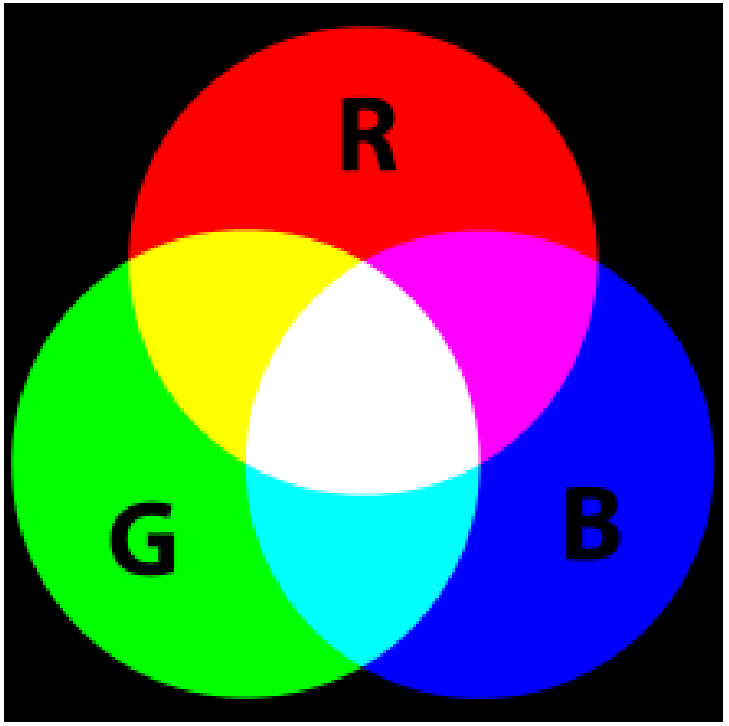


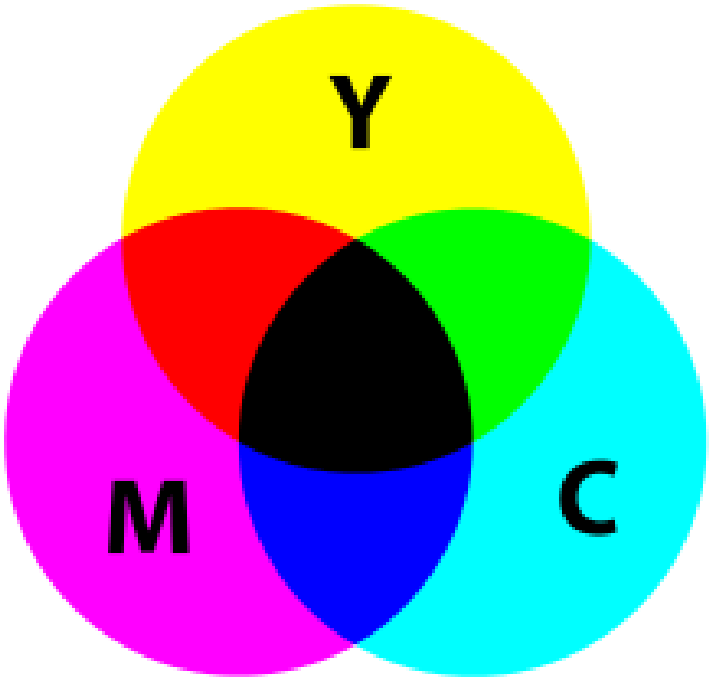
Colors

Additive

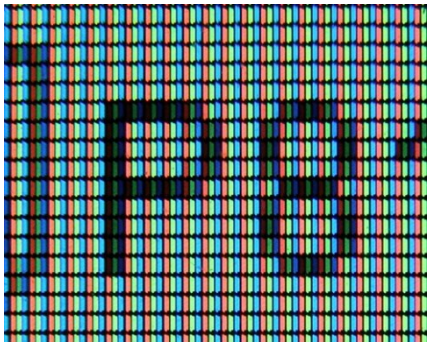


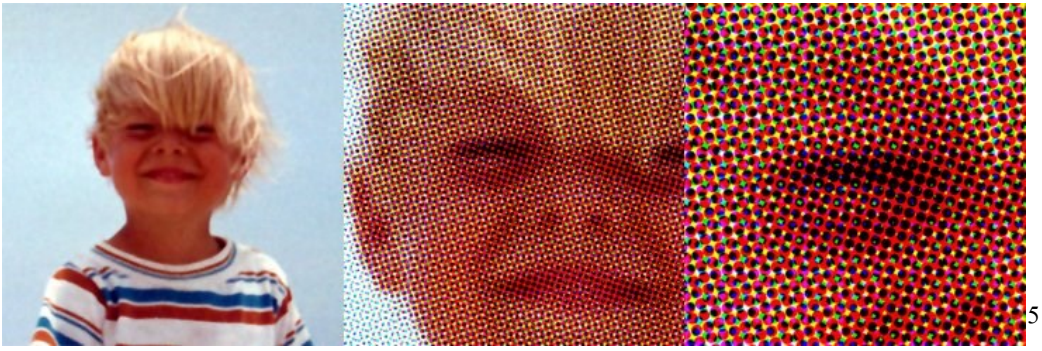
Color = R + G + B

Subtractive

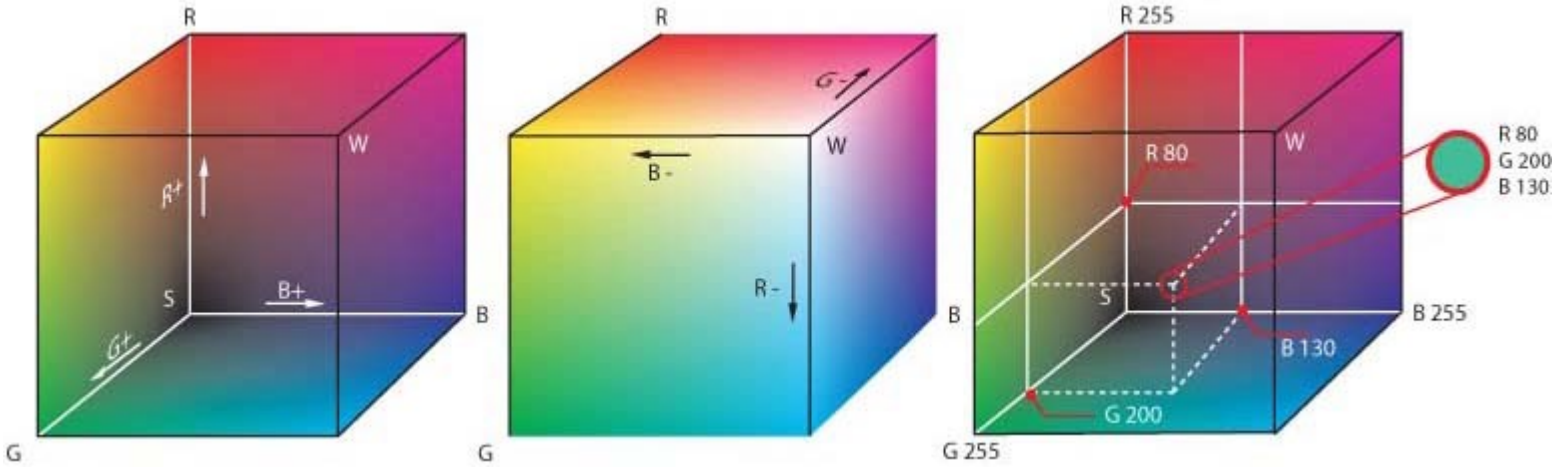


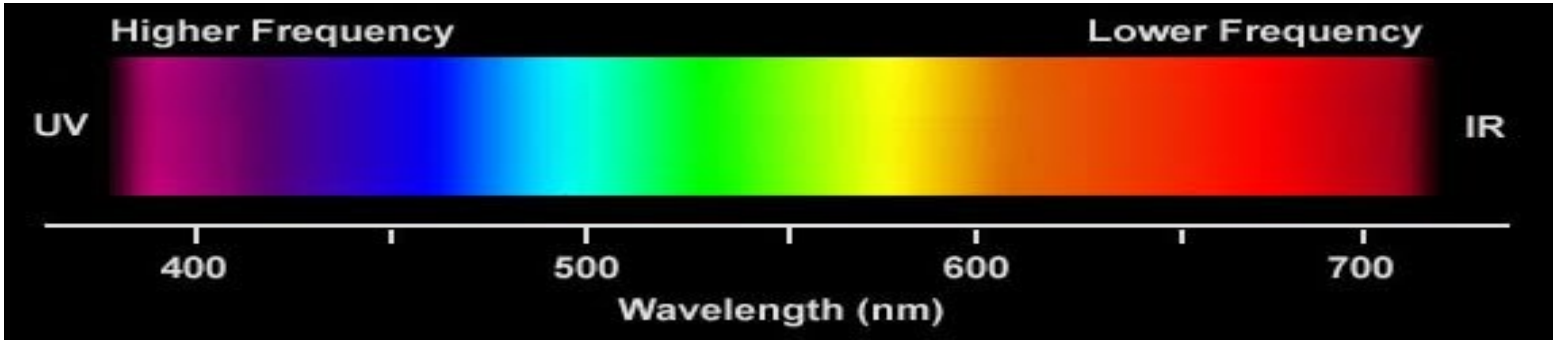
Color = 1 - C – M - Y



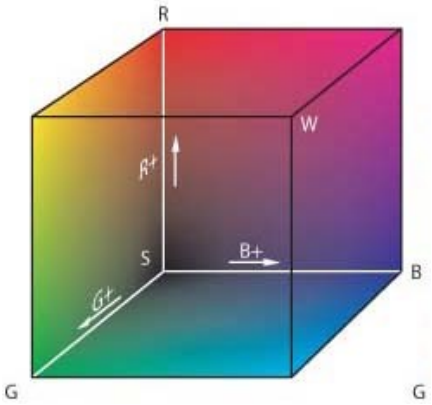


RGB Color space





RGB Colors Mixing



RR GG BB

RGB Colors Mixing

-0 **-60** **-70**

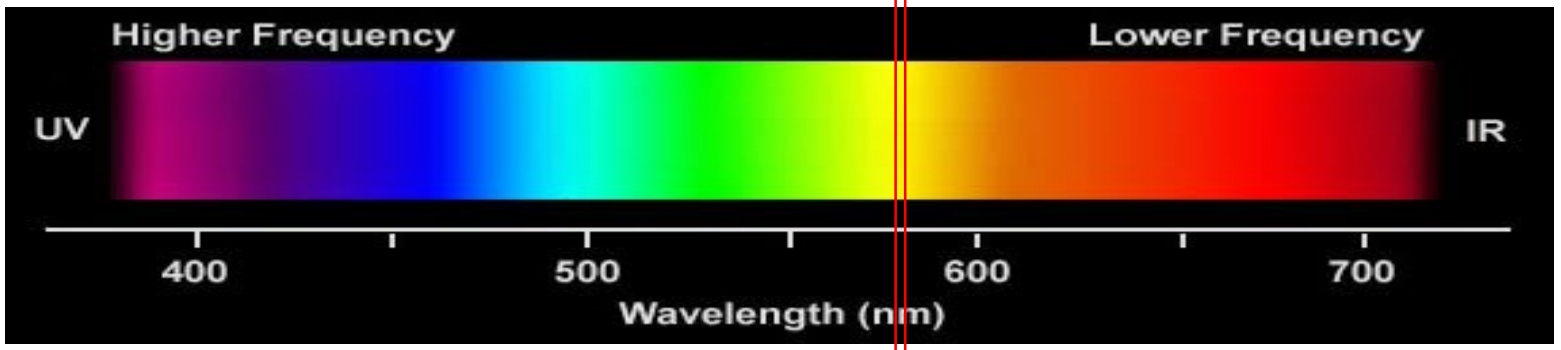
RGB Colors Mixing

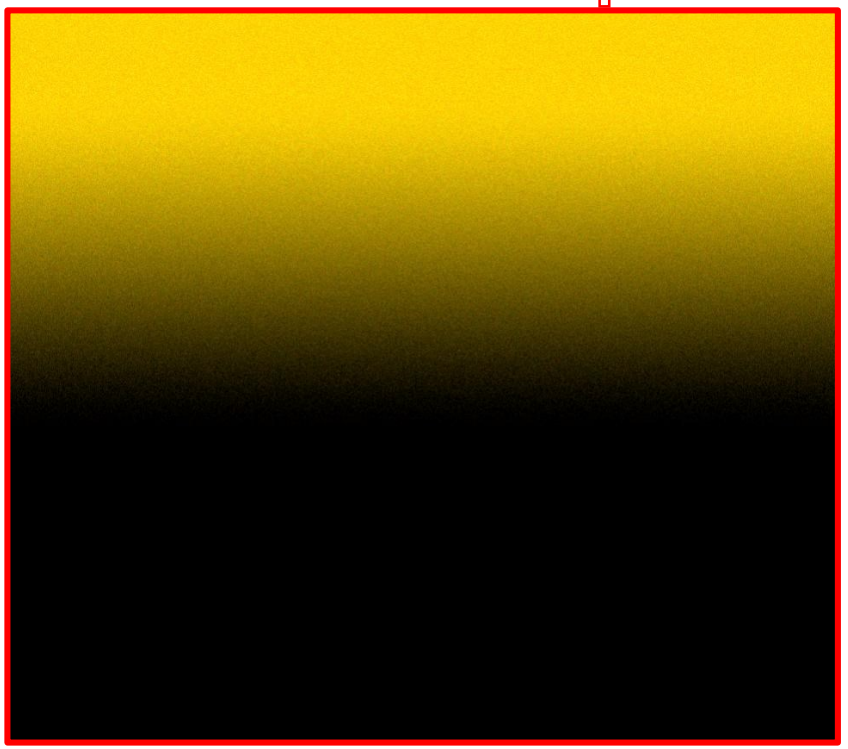
.393R+.769G+.189B

.349R+.686G+.168B

.272R+.534G+.131B

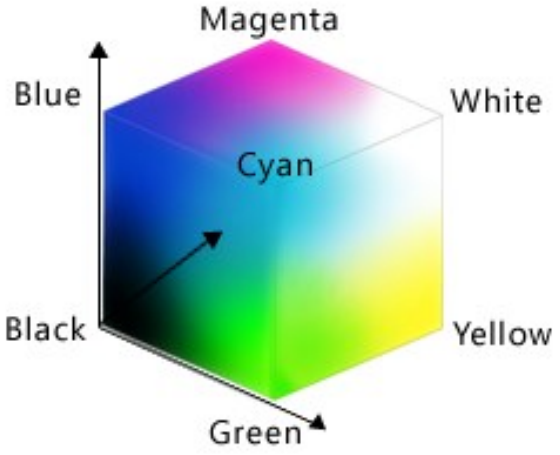
RGB Color in difference brightness



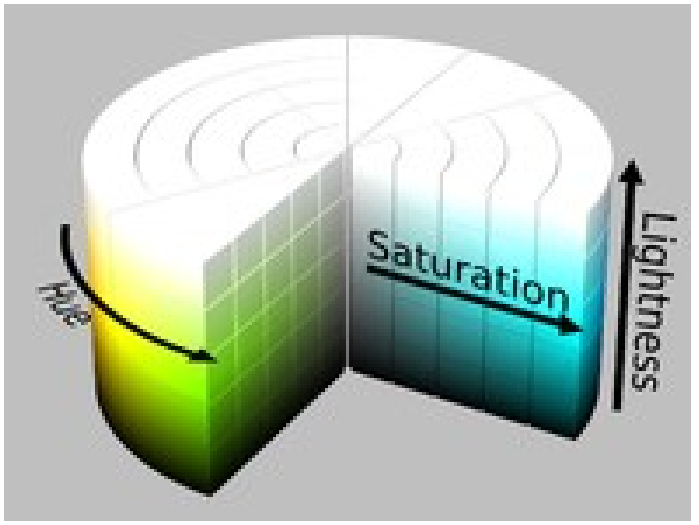


HSL and HSV Color space

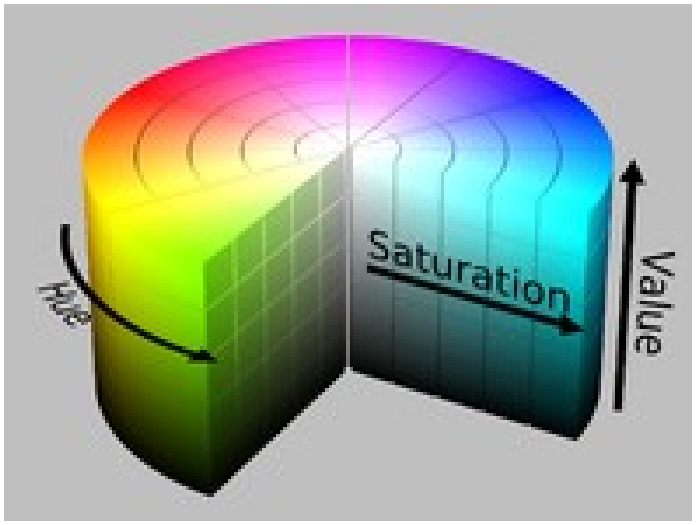
HSL stands for Hue, Saturation, and Lightness
HSV stands for Hue, Saturation, and Value



RGB



HSL



HSV

HSV Color space

RED

GREEN

BLUE

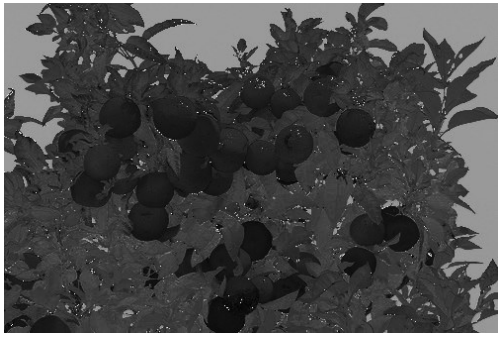
HUE

SATURATION

Color VALUE

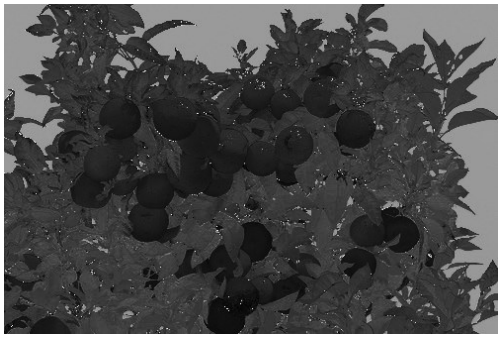
HSV Color space

RED **GREEN** **BLUE**

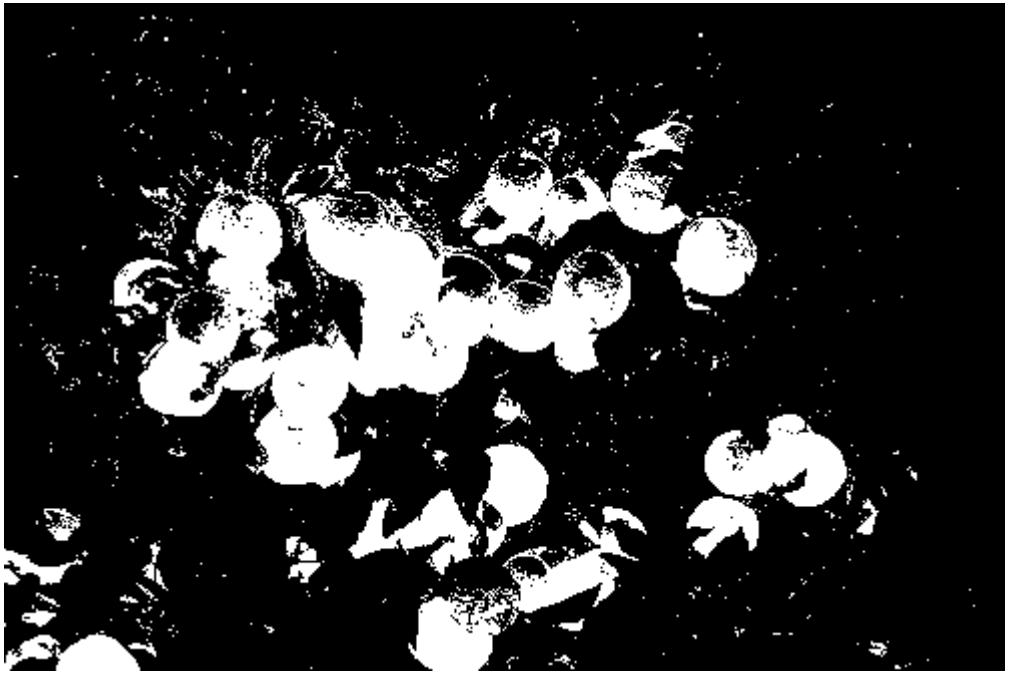


HUE **SATURATION** **Color VALUE**

HSV Color space

HUE **SATURATION** **Color VALUE**



$$\boldsymbol{Im}_{binary} = (\boldsymbol{Hue} < 0.15) \wedge (\boldsymbol{Saturation} > 0.5)$$

Convert RGB space to HSV space

$$C_{max} = \max\{r, g, b\} \qquad C_{min} = \min\{r, g, b\}$$

$$\Delta = C_{max} - C_{min}$$

$$H = \begin{cases} 0° & , \Delta = 0 \\ 60° \times \left(\frac{g-b}{\Delta} mod 6\right) \times \frac{1}{360} & , C_{max} = r \\ 60° \times \left(\frac{b-r}{\Delta} + 2\right) \times \frac{1}{360} & , C_{max} = g \\ 60° \times \left(\frac{r-g}{\Delta} + 4\right) \times \frac{1}{360} & , C_{max} = b \end{cases}$$

$$S = \begin{cases} 0 & , C_{max} = 0 \\ \frac{\Delta}{C_{max}} & , C_{max} \neq 0 \end{cases} \qquad V = \frac{C_{max}}{255}$$

Convert RGB space to HSV space

$$C_{max} = \max\{r, g, b\}$$

$$C_{min} = \min\{r, g, b\}$$

$$\Delta = C_{max} - C_{min}$$

$$H = \begin{cases} 0° & ,\Delta = 0 \\ 60° \times \left(\frac{g-b}{\Delta} mod 6\right) \times \frac{1}{360} & ,C_{max} = r \\ 60° \times \left(\frac{b-r}{\Delta} + 2\right) \times \frac{1}{360} & ,C_{max} = g \\ 60° \times \left(\frac{r-g}{\Delta} + 4\right) \times \frac{1}{360} & ,C_{max} = b \end{cases}$$

$$S = \begin{cases} 0 & ,C_{max} = 0 \\ \frac{\Delta}{C_{max}} & ,C_{max} \neq 0 \end{cases}$$

$$V = \frac{C_{max}}{255}$$

R=64,G=50,B=110

H=? ,S=? ,V=?

Convert RGB space to HSV space

$$C_{max} = \max\{r, g, b\}$$

$$C_{min} = \min\{r, g, b\}$$

$$\Delta = C_{max} - C_{min}$$

$$H = \begin{cases} 0° & , \Delta = 0 \\ 60° \times \left(\frac{g-b}{\Delta} mod 6\right) \times \frac{1}{360} & , C_{max} = r \\ 60° \times \left(\frac{b-r}{\Delta} + 2\right) \times \frac{1}{360} & , C_{max} = g \\ 60° \times \left(\frac{r-g}{\Delta} + 4\right) \times \frac{1}{360} & , C_{max} = b \end{cases}$$

$$S = \begin{cases} 0 & , C_{max} = 0 \\ \frac{\Delta}{C_{max}} & , C_{max} \neq 0 \end{cases}$$

$$V = \frac{C_{max}}{255}$$

R=64,G=50,B=110

$$C_{max} = \max\{64,50,110\}$$
$$C_{max} = 110$$

$$C_{min} = \min\{64,50,110\}$$
$$C_{min} = 50$$

$$\Delta = 110 - 50 = 60$$

$$H = \begin{cases} 0° & , \Delta = 0 \\ 60° \times \left(\frac{g-b}{\Delta} mod 6\right) \times \frac{1}{360} & , C_{max} = r \\ 60° \times \left(\frac{b-r}{\Delta} + 2\right) \times \frac{1}{360} & , C_{max} = g \\ 60° \times \left(\frac{r-g}{\Delta} + 4\right) \times \frac{1}{360} & , C_{max} = b \end{cases}$$

$$H = 60° \times \left(\frac{64-50}{60} + 4\right) \times \frac{1}{360}$$

$$H = 0.7055$$

$$S = \frac{60}{110} = 0.5454$$

$$V = \frac{110}{255} = 0.4314$$

Convert HSV space to RGB space

$$C = V \times S$$

$$X = C \times \left(1 - \left|1 - \left(\frac{H \times 60}{360}\right) mod\ 2 - 1\right|\right)$$

$$m = V - C$$

$$\{R', G', B'\} = \begin{cases} (C, X, 0) & , 0 \leq H < 0.1667 \\ (X, C, 0) & , 0.1667 \leq H < 0.3333 \\ (0, C, X) & , 0.3 \leq H < 0.5 \\ (0, X, C) & , 0.5 \leq H < 0.6667 \\ (X, 0, C) & , 0.6667 \leq H < 0.8333 \\ (C, 0, X) & , 0.8333 \leq H < 1 \end{cases}$$

$$\{R, G, B\} = \{(R' + m), (G' + m), (B' + m)\}$$

Convert HSV space to RGB space

$$C = V \times S$$

$$X = C \times \left(1 - \left|1 - \left(\frac{H \times 60}{360}\right) mod\ 2 - 1\right|\right)$$

$$m = V - C$$

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$$\{R, G, B\} = \{(R' + m), (G' + m), (B' + m)\}$$

H=0.7055, S=0.5454, V=0.4314

R=?,G=?,B=?

Convert HSV space to RGB space

$$C = V \times S$$

$$X = C \times (1 - \left|1 - \left(\frac{H \times 60}{360}\right) mod\ 2 - 1\right|)$$

$$m = V - C$$

$$\{R', G', B'\} = \begin{cases} (C, X, 0) & , 0 \le H < 0.1667 \\ (X, C, 0) & , 0.1667 \le H < 0.3333 \\ (0, C, X) & , 0.3 \le H < 0.5 \\ (0, X, C) & , 0.5 \le H < 0.6667 \\ (X, 0, C) & , 0.6667 \le H < 0.8333 \\ (C, 0, X) & , 0.8333 \le H < 1 \end{cases}$$

$$\{R, G, B\} = \{(R' + m), (G' + m), (B' + m)\}$$

H=0.7055, S=0.5454, V=0.4314

$$C = 0.4314 \times 0.5454$$

$$C = 0.2352$$

$$X = 0.2352 \times (1 - \left|1 - \left(\frac{0.7055 \times 60}{360}\right) mod\ 2 - 1\right|)$$

$$X = 0.0548$$

$$m = 0.4314 - 0.2352$$

$$m = 0.1962$$

$$\{R', G', B'\} = \begin{cases} (C, X, 0) & , 0 \le H < 0.1667 \\ (X, C, 0) & , 0.1667 \le H < 0.3333 \\ (0, C, X) & , 0.3 \le H < 0.5 \\ (0, X, C) & , 0.5 \le H < 0.6667 \\ (X, 0, C) & , 0.6667 \le H < 0.8333 \\ (C, 0, X) & , 0.8333 \le H < 1 \end{cases}$$

$\{R', G', B'\}$={0.0548, 0,0.2352}

$$R = 0.0548 + 0.1962 = 0.251$$

$$G = 0 + 0.1962 = 0.1962$$

$$B = 0.2352 + 0.1962 = 0.4314$$

Convert HSV space to RGB space

$$C = V \times S$$

$$X = C \times (1 - \left|1 - \left(\frac{H \times 60}{360}\right) mod\ 2 - 1\right|)$$

$$m = V - C$$

$$\{R', G', B'\} = \begin{cases} (C, X, 0) & , 0 \le H < 0.1667 \\ (X, C, 0) & , 0.1667 \le H < 0.3333 \\ (0, C, X) & , 0.3 \le H < 0.5 \\ (0, X, C) & , 0.5 \le H < 0.6667 \\ (X, 0, C) & , 0.6667 \le H < 0.8333 \\ (C, 0, X) & , 0.8333 \le H < 1 \end{cases}$$

$$\{R, G, B\} = \{(R' + m), (G' + m), (B' + m)\}$$

H=0.7055, S=0.5454, V=0.4314

$$C = 0.4314 \times 0.5454$$

$$C = 0.2352$$

$$X = 0.2352 \times (1 - \left|1 - \left(\frac{0.7055 \times 60}{360}\right) mod\ 2 - 1\right|)$$

$$X = 0.0548$$

$$m = 0.4314 - 0.2352$$

$$m = 0.1962$$

$$\{R', G', B'\} = \begin{cases} (C, X, 0) & , 0 \le H < 0.1667 \\ (X, C, 0) & , 0.1667 \le H < 0.3333 \\ (0, C, X) & , 0.3 \le H < 0.5 \\ (0, X, C) & , 0.5 \le H < 0.6667 \\ (X, 0, C) & , 0.6667 \le H < 0.8333 \\ (C, 0, X) & , 0.8333 \le H < 1 \end{cases}$$

$\{R', G', B'\}$={0.0548, 0,0.2352}

$R = 0.251$ x 255=64.005

$G = 0.1962$ x 255=50.031

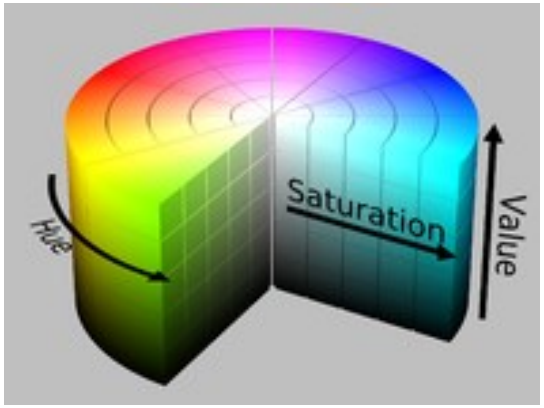
$B = 0.4314$ x 255 =110.007

HSV Color Mixing

H

S

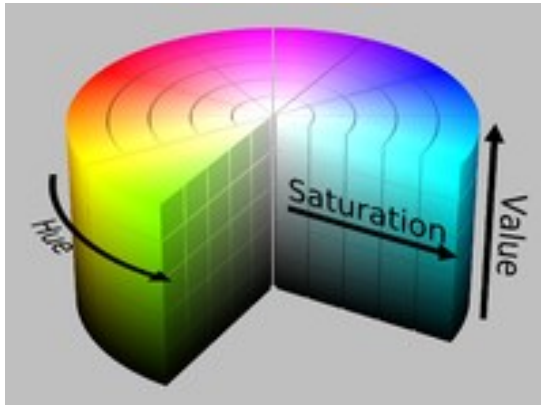
V



HSV Color Mixing

H **S** **V**

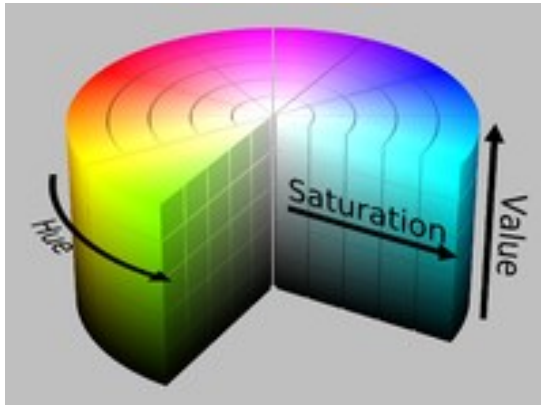
X 0.3



HSV Color Mixing

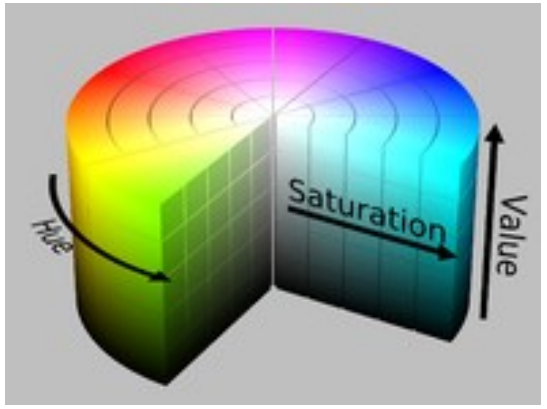
H **S** **V**

X 2



HSV Color Mixing

H **S** **V**

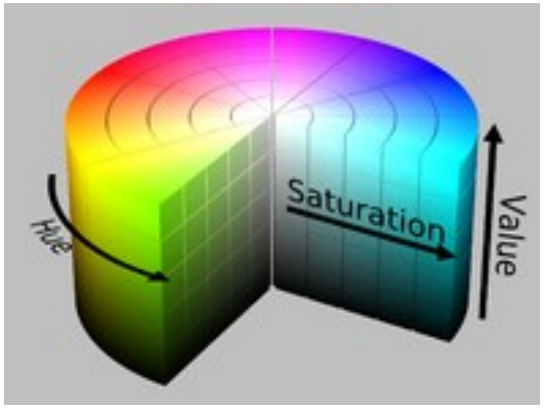


X 0.3

HSV Color Mixing

H **S** **V**

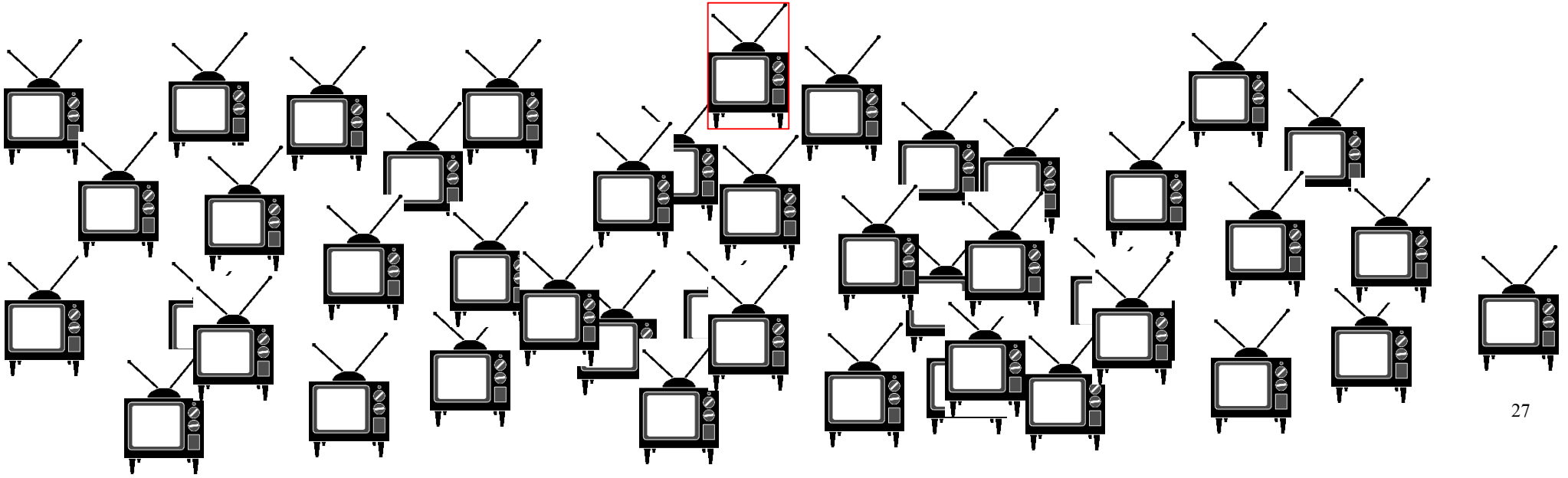
X 2



YUV Color Space

Black and White Television

Color Television



YUV Color Space

Gray

R

G

B

Original Image

Bandwidth x4

V

S

H

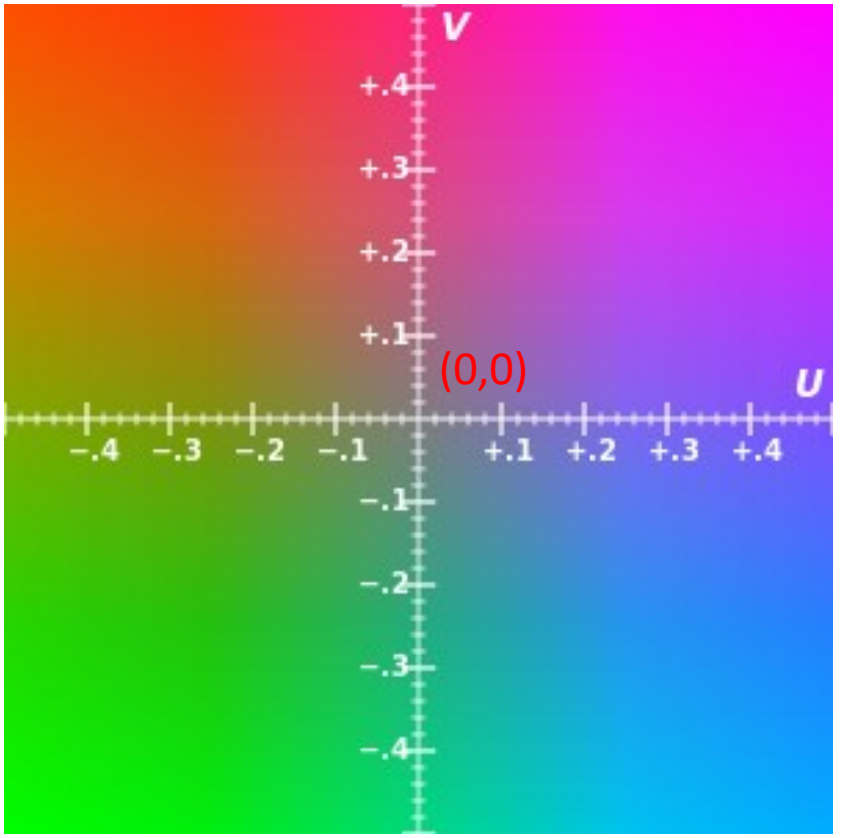
Original Image

Bandwidth x3

Shades are wrong

YUV Color Space

Gray (Y)



U-V color plane

U

V

Y + U + V

YUV Color Space

SDTV with BT.601

$$Y = 0.299R + 0.587G + 0.114B$$
$$U = (-0.14713R - 0.28886G + 0.436B)$$
$$V = (0.615R - 0.51499G - 0.10001B)$$

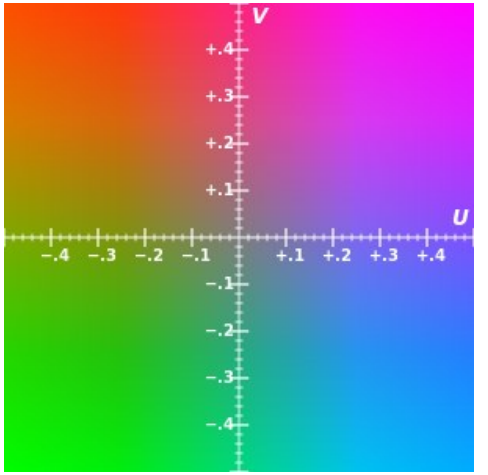
$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.14713 & -0.28886 & 0.436 \\ 0.615 & -0.51499 & -0.10001 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1.13983 \\ 1 & -0.39465 & -0.58060 \\ 1 & 2.03211 & 0 \end{bmatrix} \begin{bmatrix} Y \\ U \\ V \end{bmatrix}$$

YUV Color Mixing

Y U V

X0.5



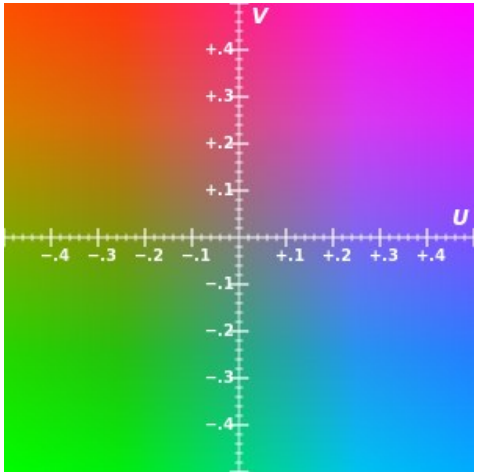
YUV Color Mixing

Y

U

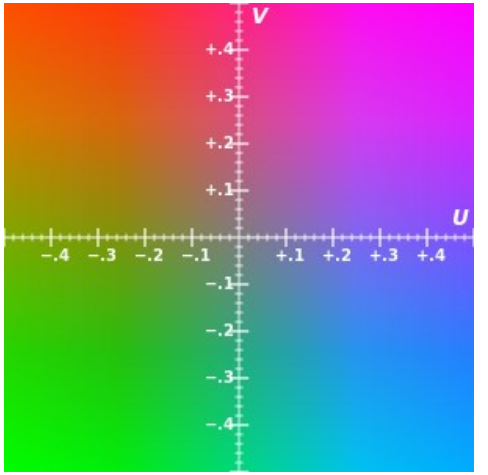
V

X2



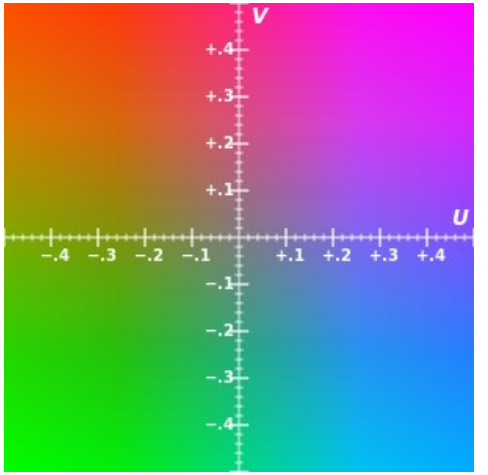
YUV Color Mixing

Y U V



YUV Color Mixing

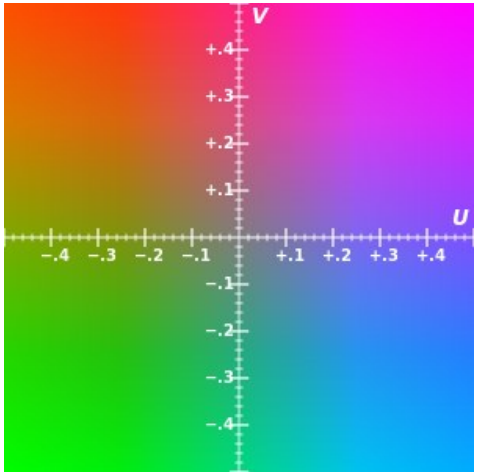
Y U V



YUV Color Mixing

Y U V

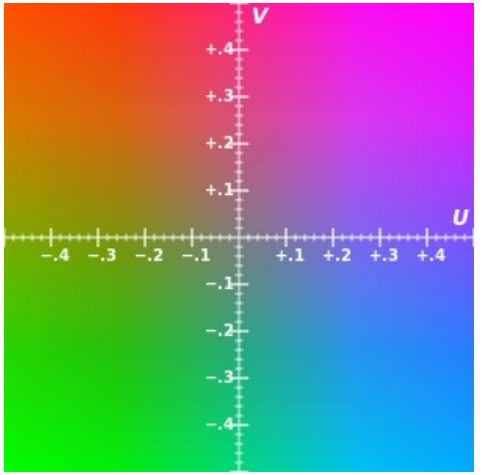
-128



YUV Color Mixing

Y U V

-128



YUV Color Mixing

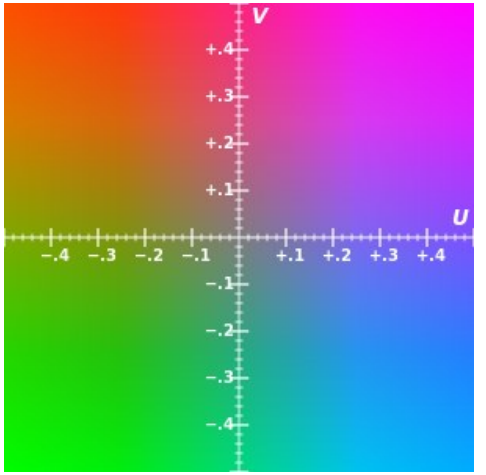
Y

U

V

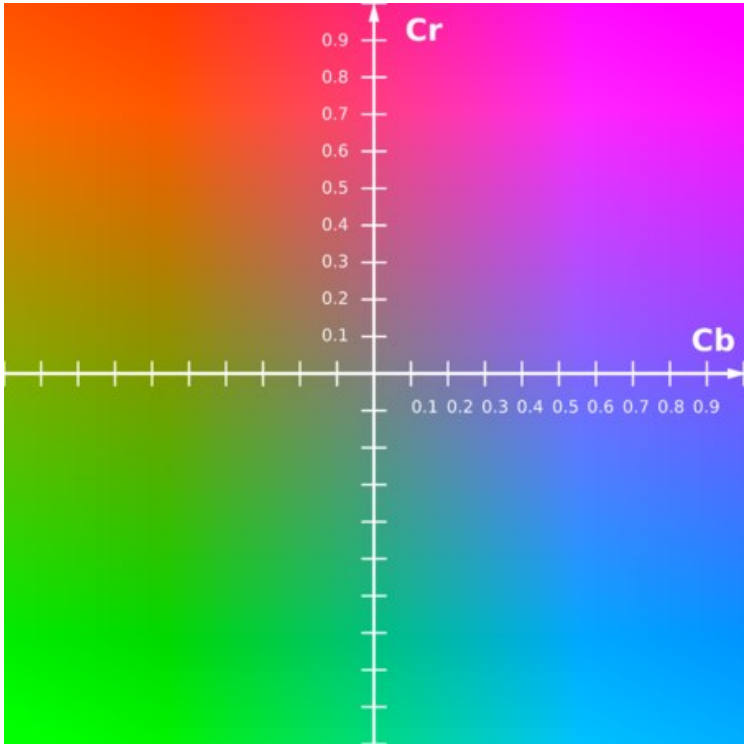
-128

-128



YCbCr Color Space

Y



Cb

Cr

YCbCr Color Space

JPEG conversion

$$Y = 0.299R + 0.587G + 0.114B$$

$$Cb = 128 - 0.168736R - 0.331264G + 0.5B$$

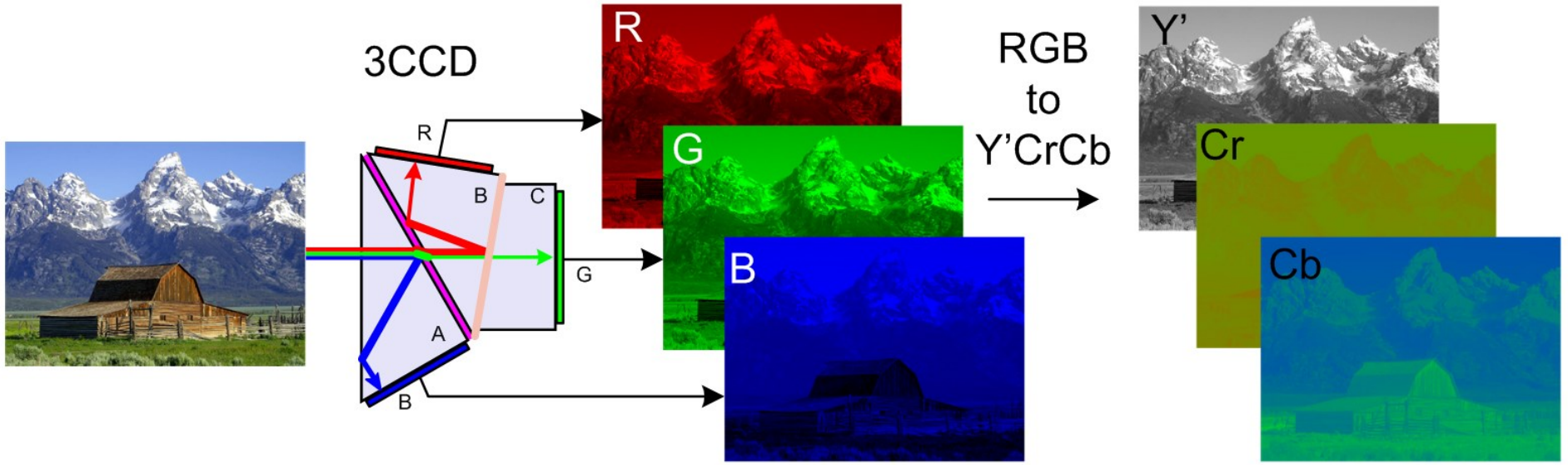
$$Cr = 128 + 0.5R - 0.418688G + 0.081312B$$

$$R = Y + 1.402(Cr - 128)$$

$$G = Y - 0.34414(Cb - 128) - 0.71414(Cr - 128)$$

$$B = Y + 1.772(Cb - 128)$$

YCbCr Color Space



Video camera

Channel Subsampling

Y
x0.5

Cb
x0.5

Cr
x0.5

Channel Subsampling

Y	Cb	Cr
x1	x0.5	x0.5

Channel Subsampling

Y
x1

Cb
x0.1

Cr
x0.1

Channel Subsampling

Y
x1

Cb
x0.05

Cr
x0.05

Channel Subsampling

Y
x1

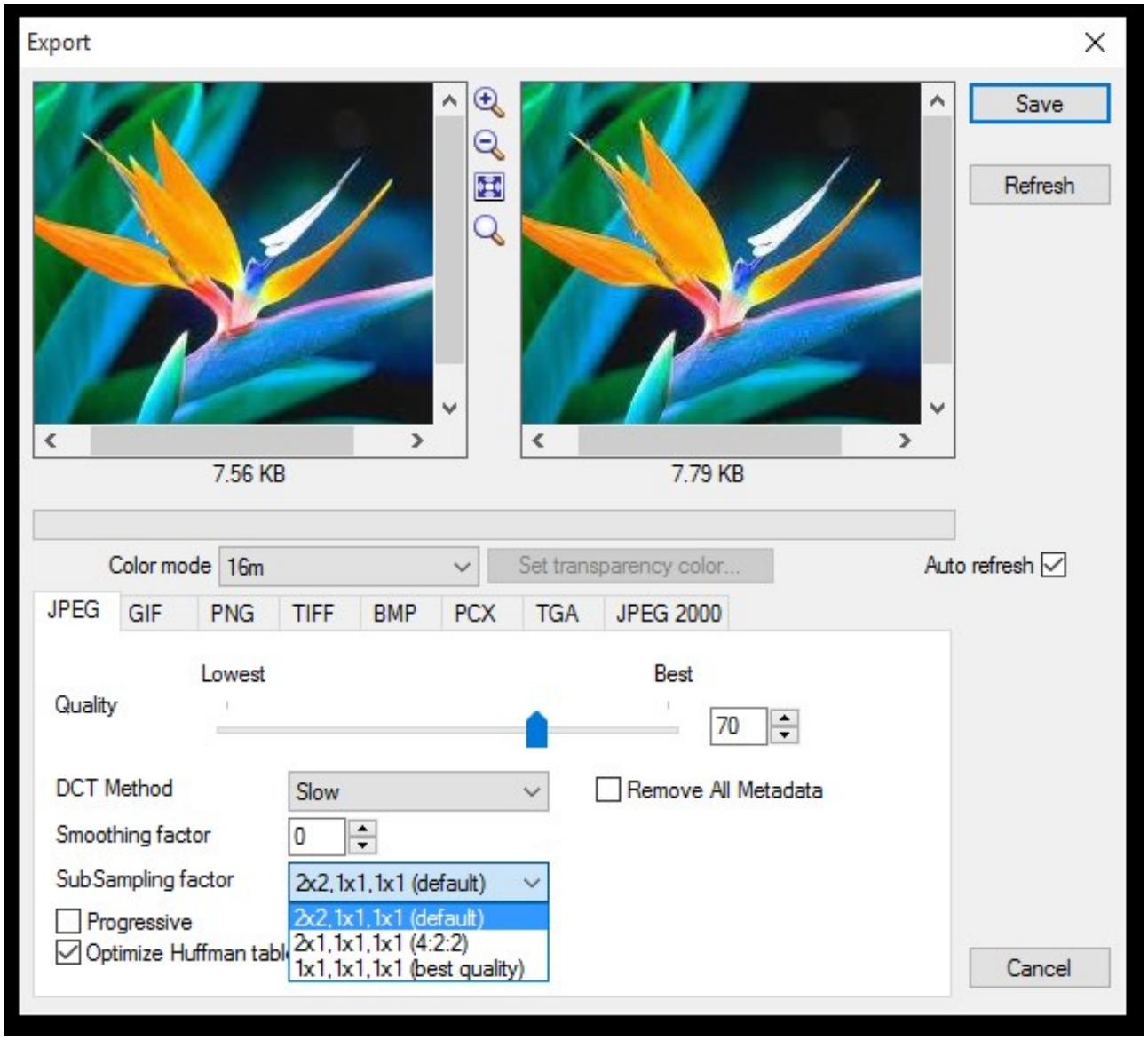
Cb
x0.01

Cr
x0.01

Channel Subsampling

Y	Cb	Cr
X0.05	x1	x1

Channel Subsampling



Channel Subsampling in JPEG image format

Channel re-quantization

Y
4bit

Cb
4bit

Cr
4bit

Channel re-quantization

Y
8bit

Cb
7bit

Cr
7bit

Channel re-quantization

Y
8bit

Cb
6bit

Cr
6bit

Channel re-quantization

Y
8bit

Cb
5bit

Cr
5bit

Channel re-quantization

Y
8bit

Cb
4bit

Cr
4bit

Channel re-quantization

Y
8bit

Cb
3bit

Cr
3bit

Channel re-quantization

Y
8bit

Cb
2bit

Cr
2bit

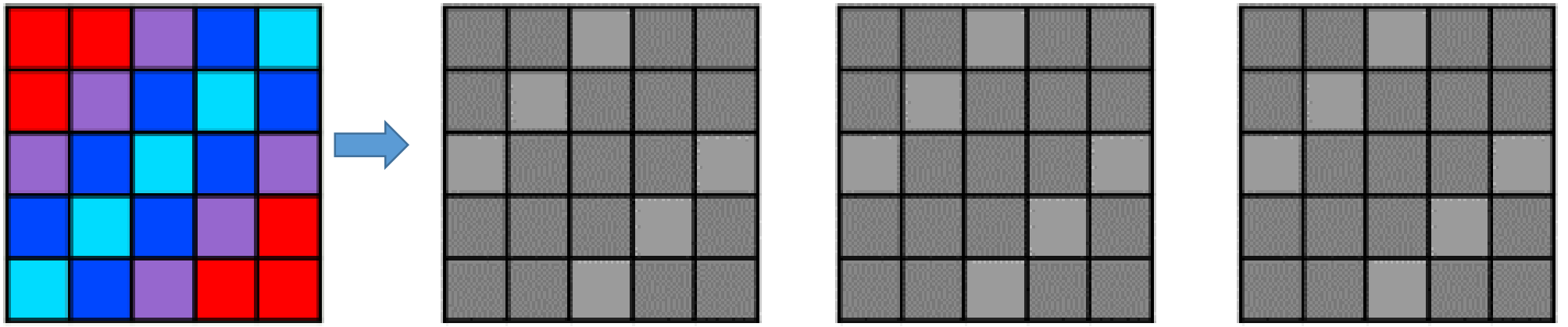
Channel re-quantization

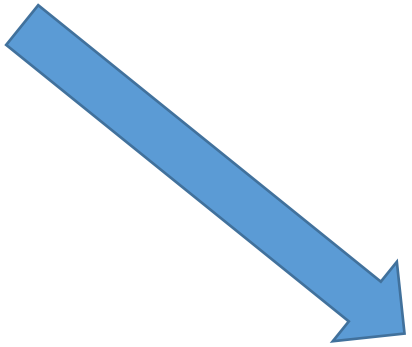
Y
4bit

Cb
8bit

Cr
8bit

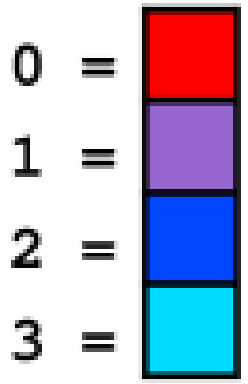
Indexed color





0	0	1	2	3
0	1	2	3	2
1	2	3	2	1
2	3	2	1	0
3	2	1	0	0

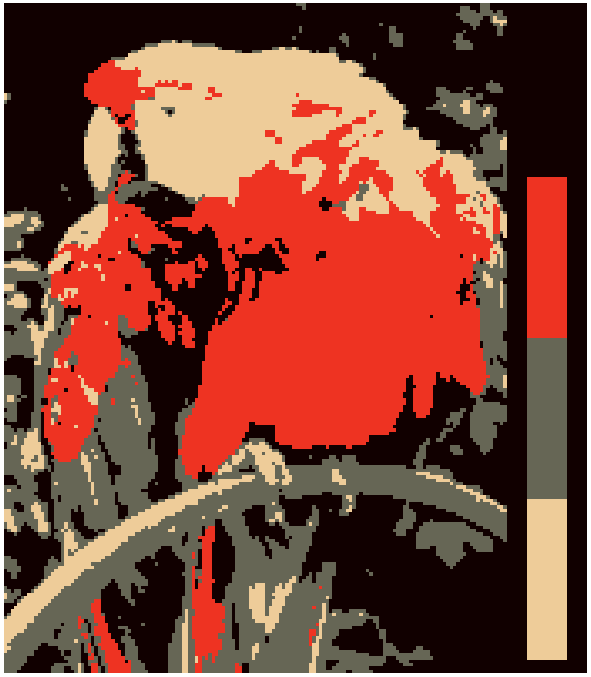
Bitmap



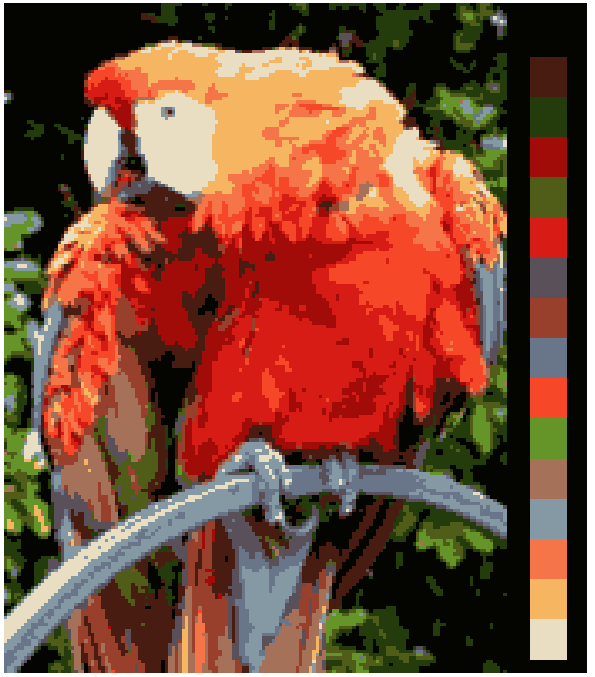
Palettes/ color map

Indexed color

24-Bit



2-Bit



4-Bit

8-Bit

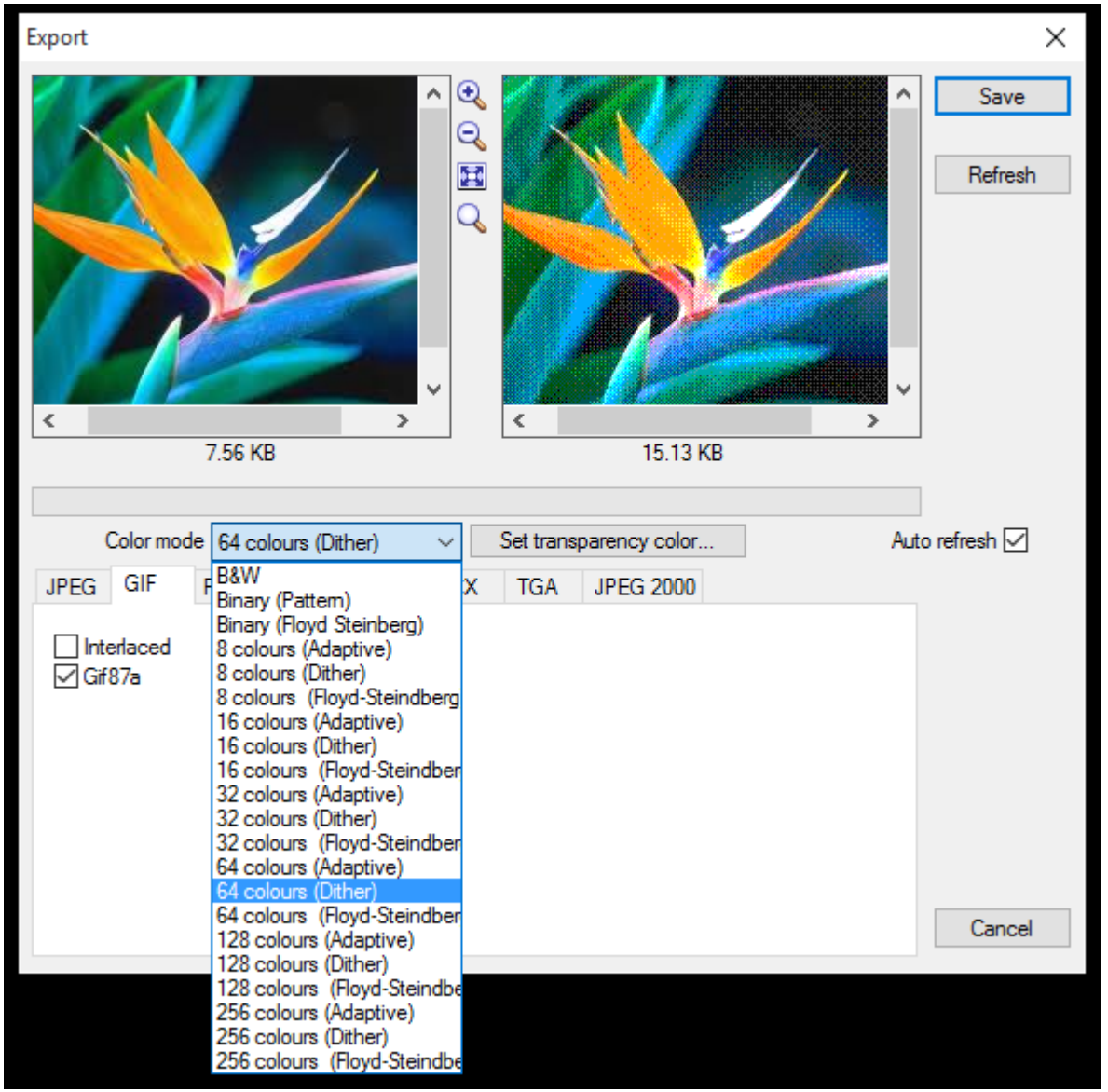
Indexed color

Image file formats supporting indexed color

Acronym	Full name	Creator	DOS extension	1-bit (2)	2-bit (4)	3-bit (8)	4-bit (16)	5-bit (32)	6-bit (64)	7-bit (128)	8-bit (256)	Compression
PCX	PC Paintbrush Image File	ZSoft Corporation	.pcx	Yes	Yes	No	Yes	No	No	No	Yes	RLE
ILBM	InterLeaved BitMap	Electronic Arts	.lbm, .iff	Yes	Yes	Yes	Yes	Yes	Yes* (EHB mode, 64-color)	Yes*	Yes*	Uncompressed, RLE
GIF	Graphics Interchange Format	Compuserve	.gif	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	LZW
TGA	TARGA File format	Truevision	.tga, .vda, .icb, .vst	No	No	No	No	No	No	No	Yes	RLE
TIFF	Tagged Image File Format	Aldus	.tif	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Uncompressed, DEFLATE, LZW, PackBits, CCITT Group 3 fax, CCITT Group 4 fax, JPEG, others less common (**)
BMP	Device-independent Bitmap	Microsoft	.bmp, .dib,.rle	Yes	No	No	Yes	No	No	No	Yes	Uncompressed, RLE (***)
PSD	Photoshop Document	Adobe Systems	.psd	No	No	No	No	No	No	No	Yes	PackBits
PNG	Portable Network Graphics	PNG Development Group	.png	Yes	Yes	No	Yes	No	No	No	Yes	DEFLATE

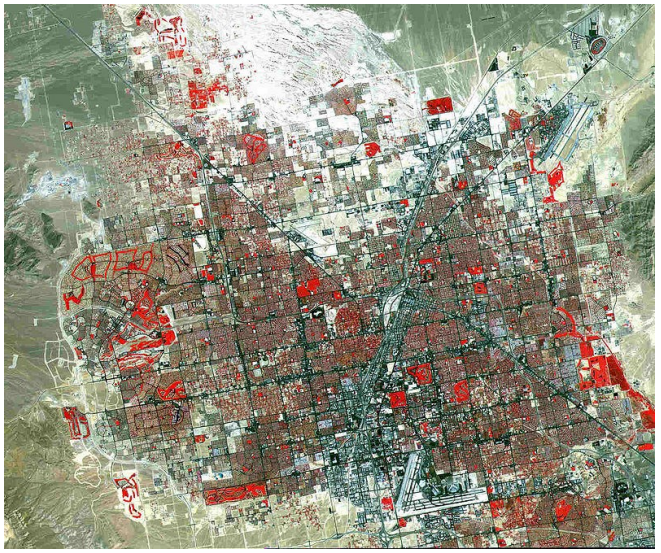
Indexed color

Color mode in GIF image format

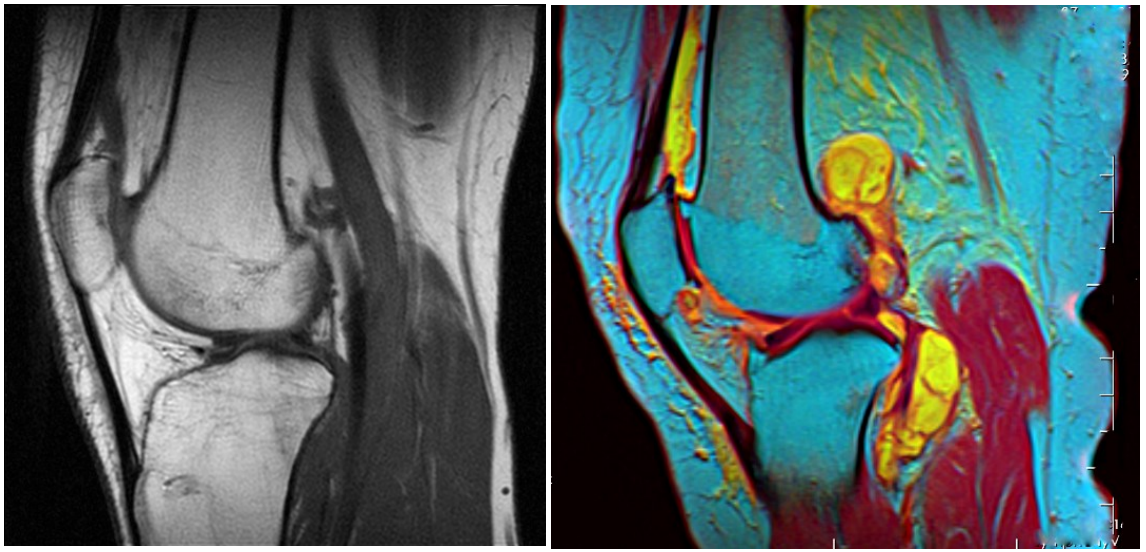


A false-color image sacrifices natural color rendition in order to ease the detection of features that are not readily discernible

A pseudo color image is derived from a grayscale image by mapping each intensity value to a color according to a table or function



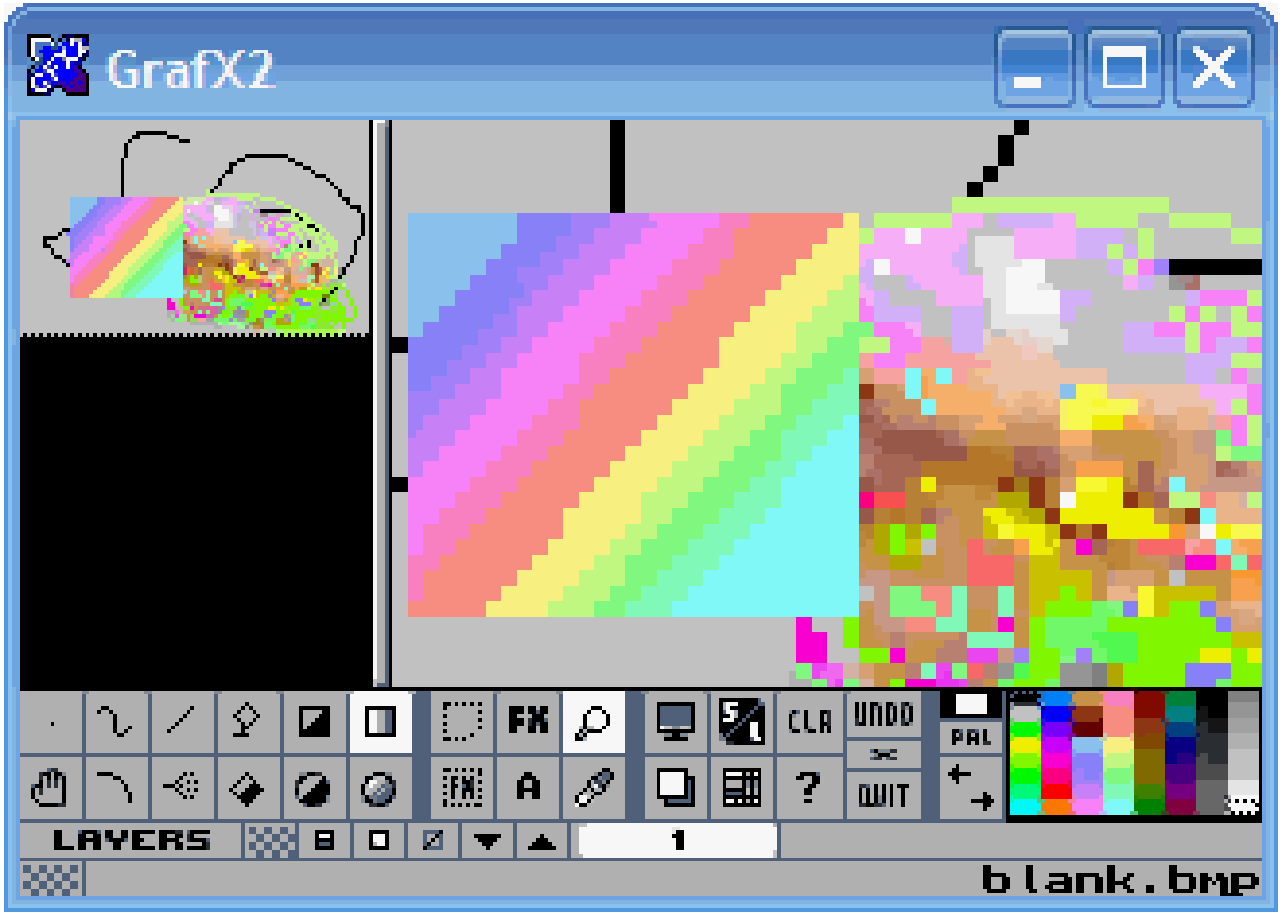
False color



Pseudo color

Indexed color

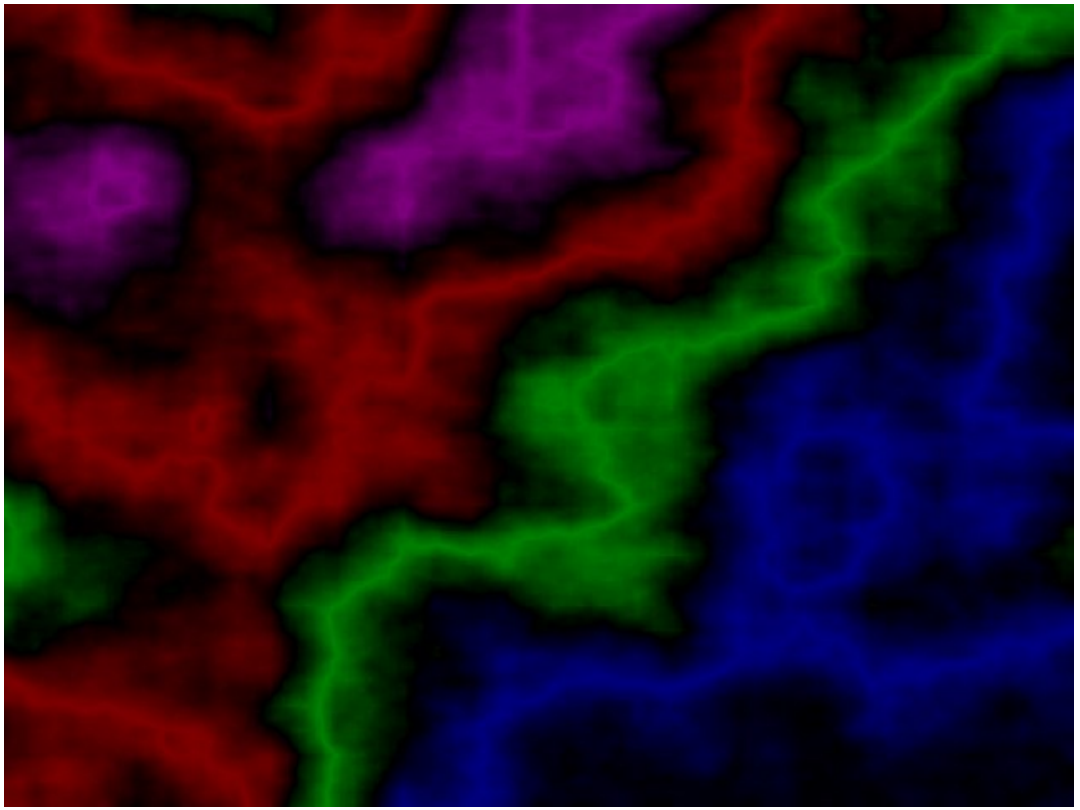
palette shifting



SimCity 2000 made extensive use of this technique: every building with animation had its animation provided by color cycling

Indexed color

palette shifting



http://www.effectgames.com/demos/canvascycle/?sound=1

Matlab image processing function

RGB to HSV conversion:

Ihsv=rgb2hsv(im);

HSV to RGB conversion:

im=hsv2rgb(**Ihsv**);

RGB to YCrCb conversion:

im=rgb2ycrcb(**rgb**);

YCrCb to RGB conversion:

im=ycrcb2rgb(**ycrcb**);

Change color map:

im=ind2rgb(**im,colormap(‘map type’)**);

List of color spaces and their uses

https://en.wikipedia.org/wiki/List_of_color_spaces_and_their_uses