

# DTI 516 Multimedia Processing

## Chapter: 6

### Colours

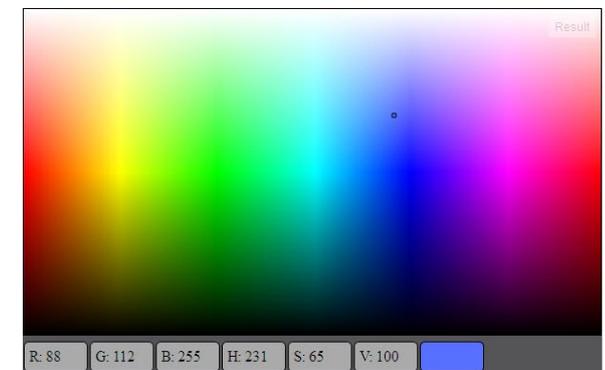
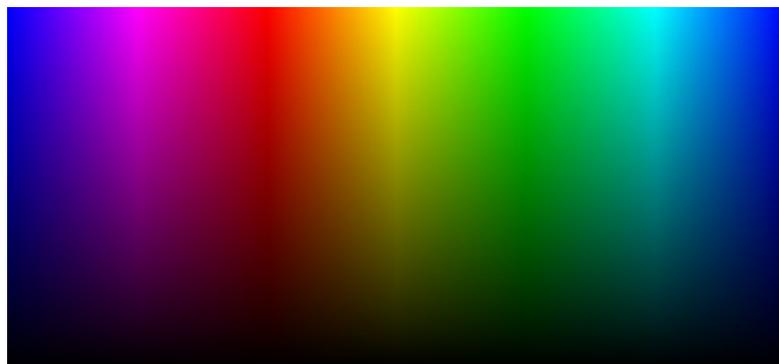
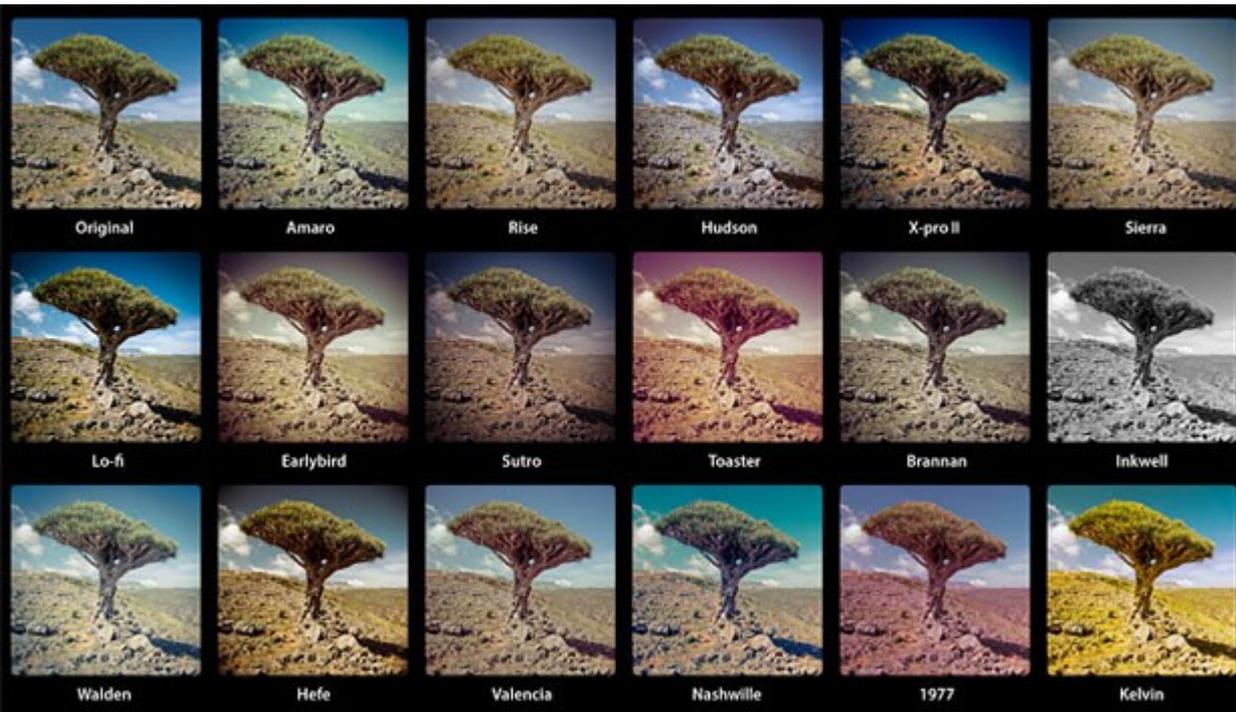
Dr. Paween Khoenkaw

Digital Technology Innovation : Maejo University

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# Color Processing



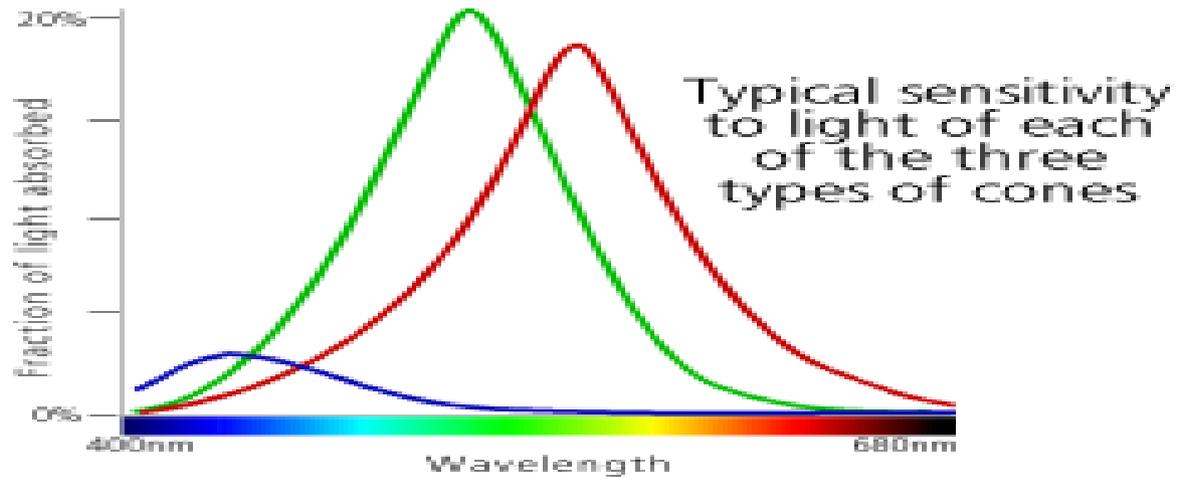
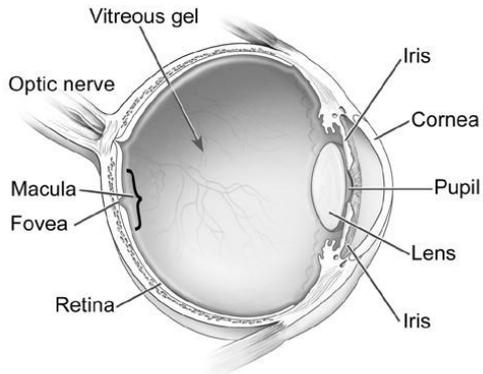
# What is color ?



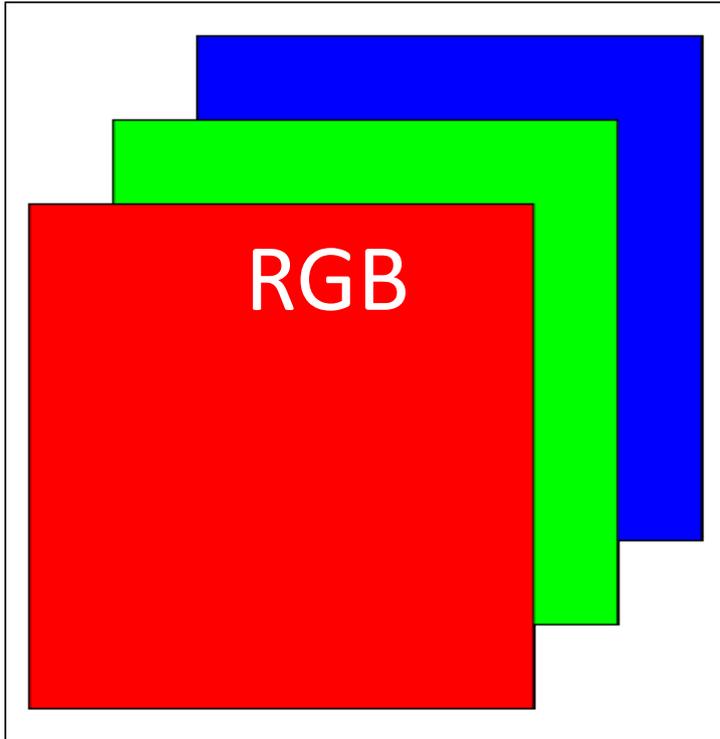
The colors of the visible light spectrum		
color	wavelength interval	frequency interval
<a href="#">red</a>	~ 700–635 nm	~ 430–480 THz
<a href="#">orange</a>	~ 635–590 nm	~ 480–510 THz
<a href="#">yellow</a>	~ 590–560 nm	~ 510–540 THz
<a href="#">green</a>	~ 560–520 nm	~ 540–580 THz
<a href="#">cyan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



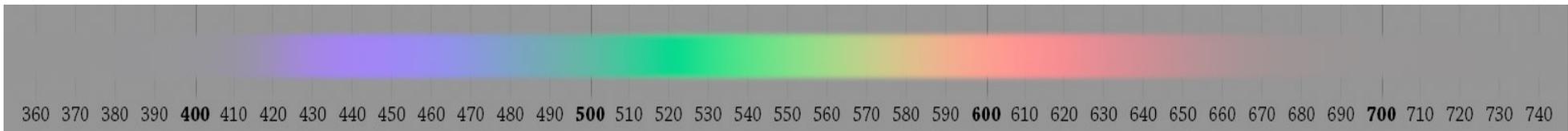
## Where is purple ?



# Colors

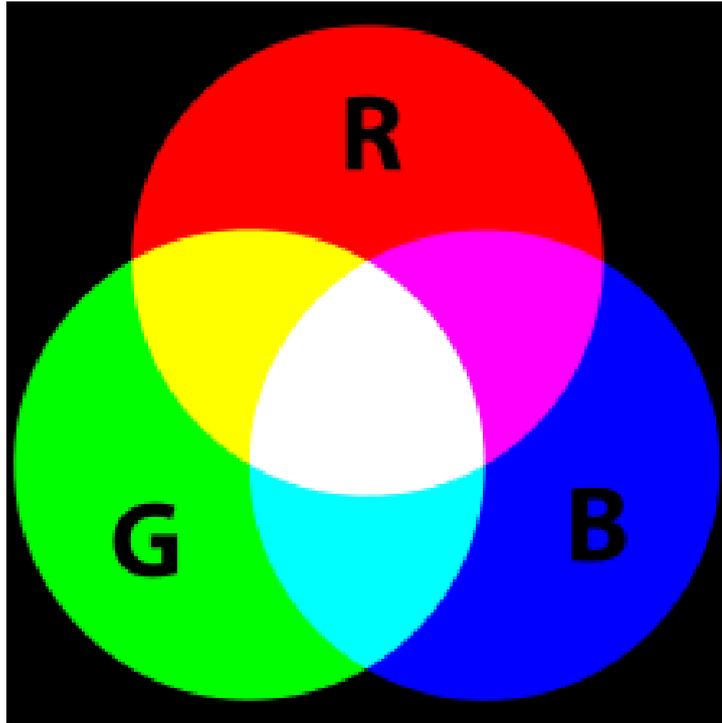


The colors of the visible light spectrum		
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<a href="#">red</a>	~ 700–635 nm	~ 430–480 THz
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<a href="#">blue</a>	~ 490–450 nm	~ 610–670 THz
<a href="#">violet</a>	~ 450–400 nm	~ 670–750 THz



# Colors

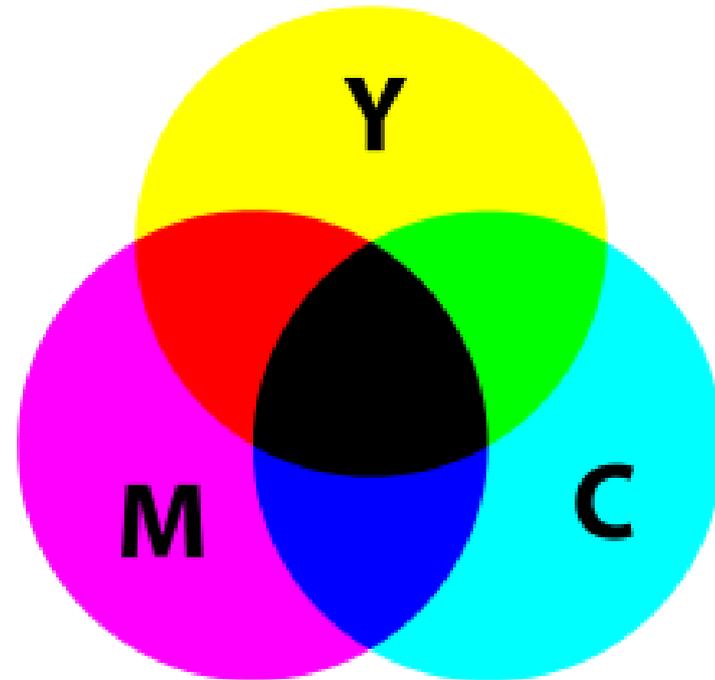
Additive



$$\text{Color} = R + G + B$$



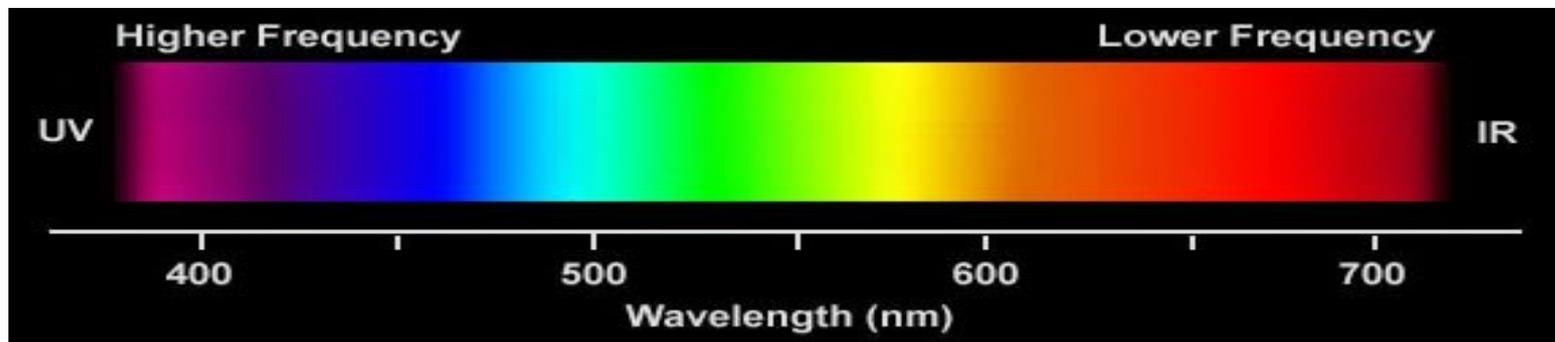
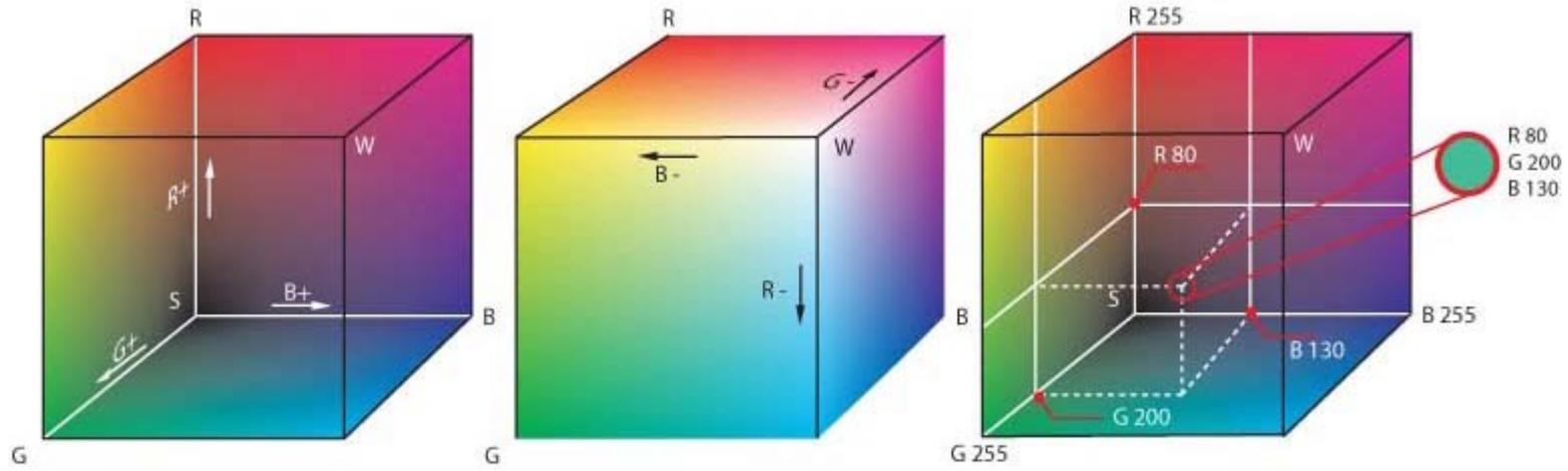
Subtractive



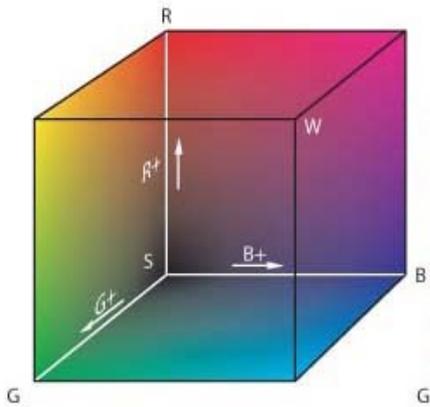
$$\text{Color} = 1 - C - M - Y$$



# RGB Color space



# RGB Colors Mixing



330000	333300	336600	339900	33CC00	33FF00	66FF00	66CC00	669900	666600	663300	660000	FF0000	FF3300	FF6600	FF9900	FFCC00	FFFF00
330033	333333	336633	339933	33CC33	33FF33	66FF33	66CC33	669933	666633	663333	660033	FF0033	FF3333	FF6633	FF9933	FFCC33	FFFF33
330066	333366	336666	339966	33CC66	33FF66	66FF66	66CC66	669966	666666	663366	660066	FF0066	FF3366	FF6666	FF9966	FFCC66	FFFF66
330099	333399	336699	339999	33CC99	33FF99	66FF99	66CC99	669999	666699	663399	660099	FF0099	FF3399	FF6699	FF9999	FFCC99	FFFF99
3300CC	3333CC	3366CC	3399CC	33CCCC	33FFCC	66FFCC	66CCCC	6699CC	6666CC	6633CC	6600CC	FF00CC	FF33CC	FF66CC	FF99CC	FFCCCC	FFFFCC
3300FF	3333FF	3366FF	3399FF	33CCFF	33FFFF	66FFFF	66CCFF	6699FF	6666FF	6633FF	6600FF	FF00FF	FF33FF	FF66FF	FF99FF	FFCCFF	FFFFFF
0000FF	0033FF	0066FF	0099FF	00CCFF	00FFFF	99FFFF	99CCFF	9999FF	9966FF	9933FF	9900FF	CC00FF	CC33FF	CC66FF	CC99FF	CCCCFF	CCFFFF
0000CC	0033CC	0066CC	0099CC	00CCCC	00FFCC	99FFCC	99CCCC	9999CC	9966CC	9933CC	9900CC	CC00CC	CC33CC	CC66CC	CC99CC	CCCCCC	CCFFCC
000099	003399	006699	009999	00CC99	00FF99	99FF99	99CC99	999999	996699	993399	990099	CC0099	CC3399	CC6699	CC9999	CCCC99	CCFF99
000066	003366	006666	009966	00CC66	00FF66	99FF66	99CC66	999966	996666	993366	990066	CC0066	CC3366	CC6666	CC9966	CCCC66	CCFF66
000033	003333	006633	009933	00CC33	00FF33	99FF33	99CC33	999933	996633	993333	990033	CC0033	CC3333	CC6633	CC9933	CCCC33	CCFF33
000000	003300	006600	009900	00CC00	00FF00	99FF00	99CC00	999900	996600	993300	990000	CC0000	CC3300	CC6600	CC9900	CCCC00	CCFF00
000000	333333	666666	999999	CCCCCC	FFFFFF												

© ColorTools.NET

RR GG BB

# RGB Colors Mixing



**-0**



**-60**



**-70**



# RGB Colors Mixing



$$.393R+.769G+.189B$$



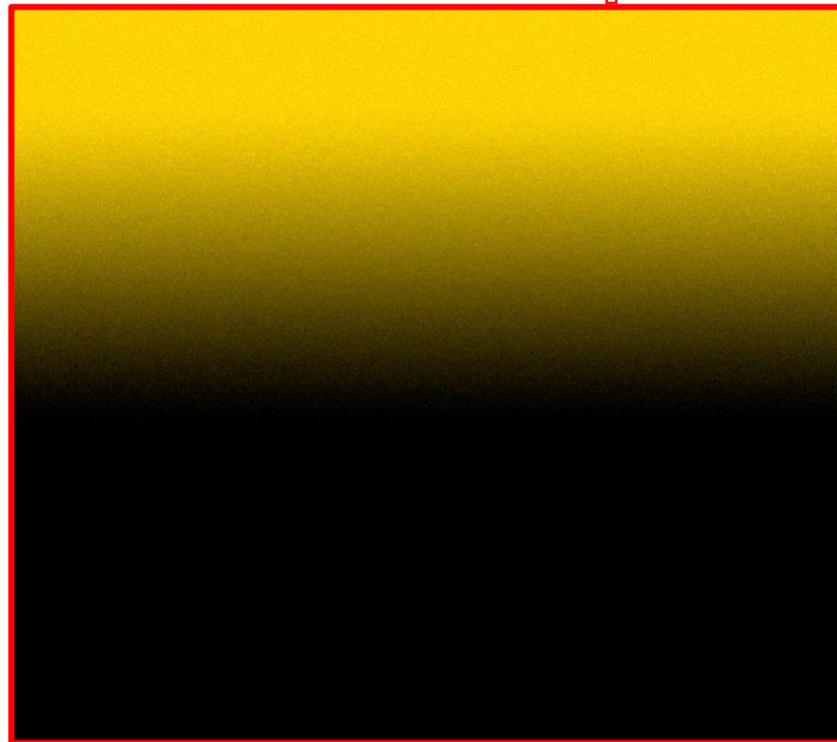
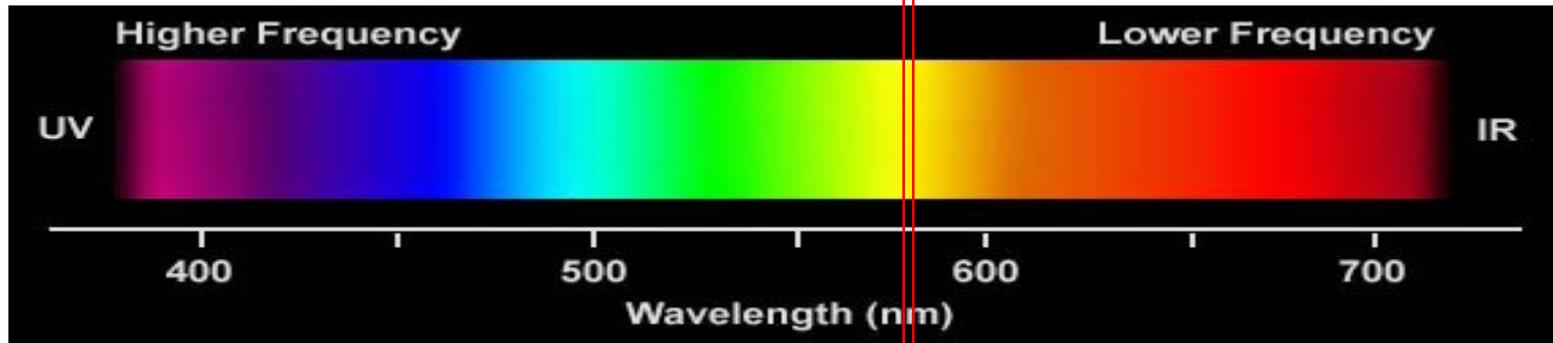
$$.349R+.686G+.168B$$



$$.272R+.534G+.131B$$



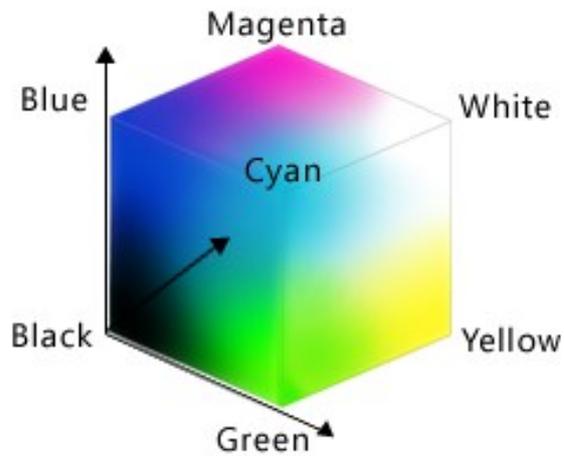
# RGB Color in difference brightness



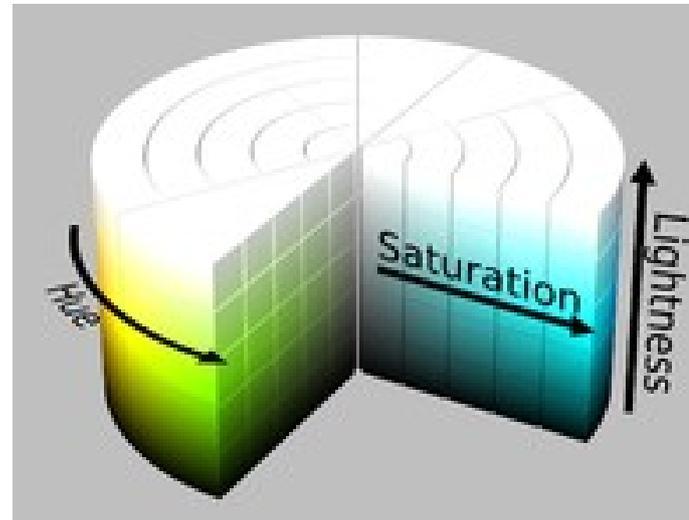
# HSL and HSV Color space

HSL stands for Hue, Saturation, and Lightness

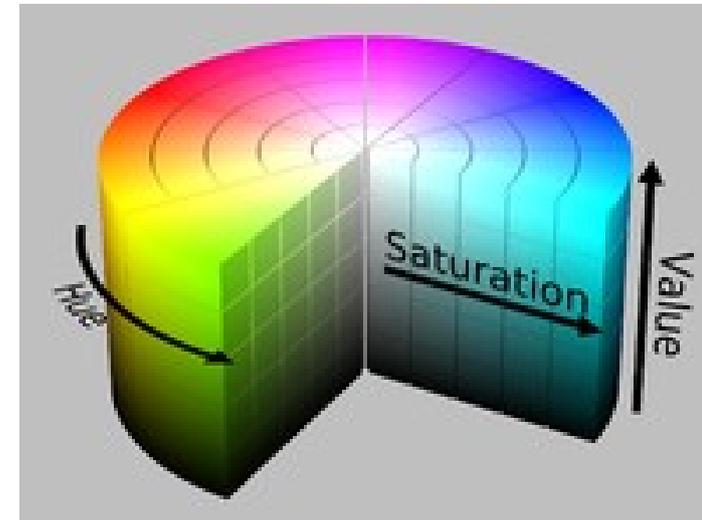
HSV stands for Hue, Saturation, and Value



RGB



HSL



HSV

# HSV Color space



**RED**



**GREEN**



**BLUE**



**HUE**



**SATURATION**



**Color VALUE**

# HSV Color space



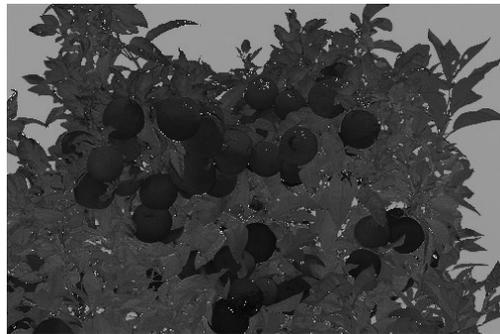
**RED**



**GREEN**



**BLUE**



**HUE**

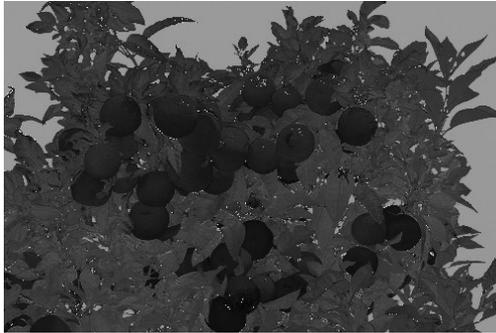


**SATURATION**



**Color VALUE**

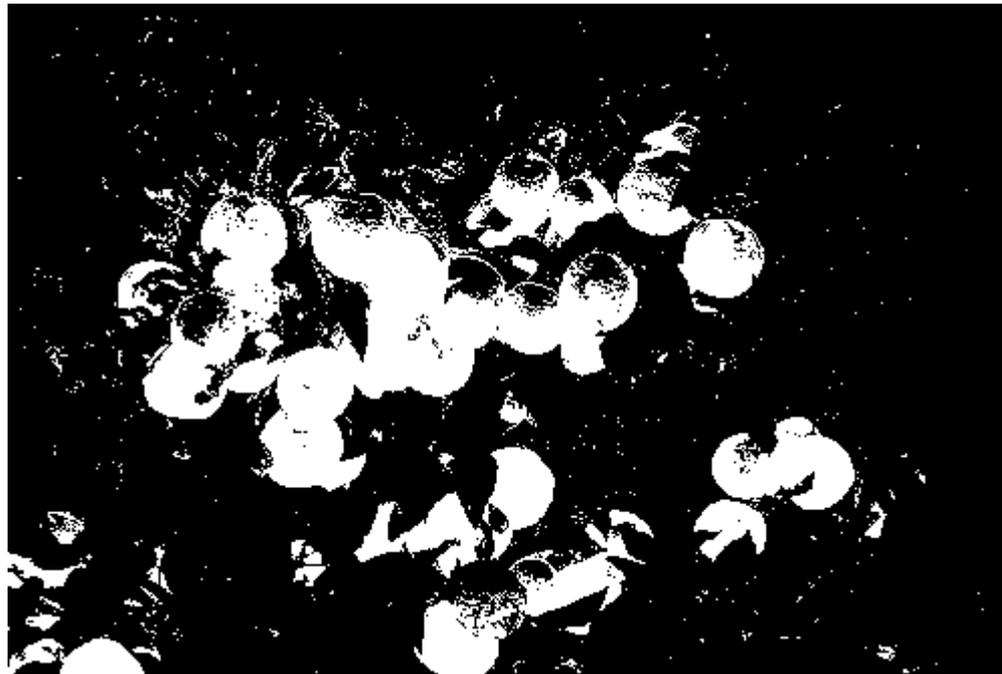
# HSV Color space



**HUE**

**SATURATION**

**Color VALUE**



$$Im_{binary} = (Hue < 0.15) \wedge (Saturation > 0.5)$$

# Convert RGB space to HSV space

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

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

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

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

# Convert RGB space to HSV space

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

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

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

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

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

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



**R=64, G=50, B=110**

**H=? , S=? , V=?**

# Convert RGB space to HSV space

**R=64,G=50,B=110**

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

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

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

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

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

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

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

$$C_{max} = 110$$

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

$$C_{min} = 50$$

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

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

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

$$H = 0.7055$$

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

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

# Convert HSV space to RGB space

$$C = V \times S$$

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

$$m = V - C$$

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

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

# Convert HSV space to RGB space

$$C = V \times S$$

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

$$m = V - C$$

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

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

H=0.7055, S=0.5454, V=0.4314



R=?, G=?, B=?

# Convert HSV space to RGB space

$$C = V \times S$$

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

$$m = V - C$$

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

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

$$H=0.7055, S=0.5454, V=0.4314$$

$$C = 0.4314 \times 0.5454$$

$$C = 0.2352$$

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

$$X = 0.0548$$

$$m = 0.4314 - 0.2352$$

$$m = 0.1962$$

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

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

$$R = 0.0548 + 0.1962 = 0.251$$

$$G = 0 + 0.1962 = 0.1962$$

$$B = 0.2352 + 0.1962 = 0.4314$$

# Convert HSV space to RGB space

$$C = V \times S$$

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

$$m = V - C$$

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

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

$$H=0.7055, S=0.5454, V=0.4314$$

$$C = 0.4314 \times 0.5454$$

$$C = 0.2352$$

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

$$X = 0.0548$$

$$m = 0.4314 - 0.2352$$

$$m = 0.1962$$

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

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

$$R = 0.251 \times 255 = 64.005$$

$$G = 0.1962 \times 255 = 50.031$$

$$B = 0.4314 \times 255 = 110.007$$

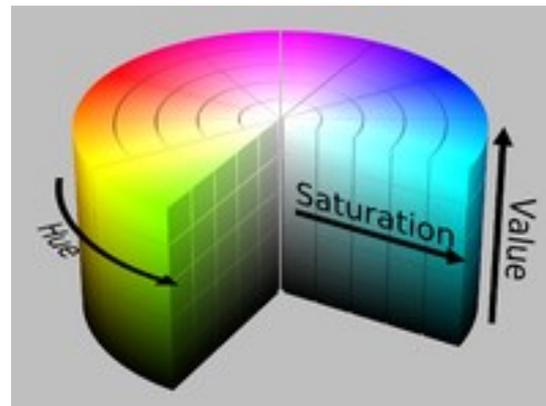
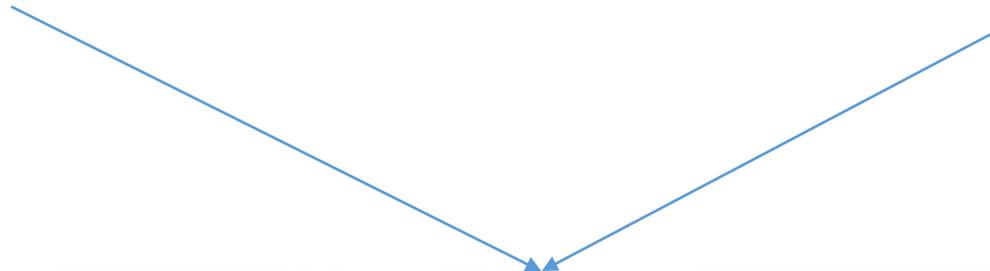
# HSV Color Mixing



**H**

**S**

**V**



# HSV Color Mixing

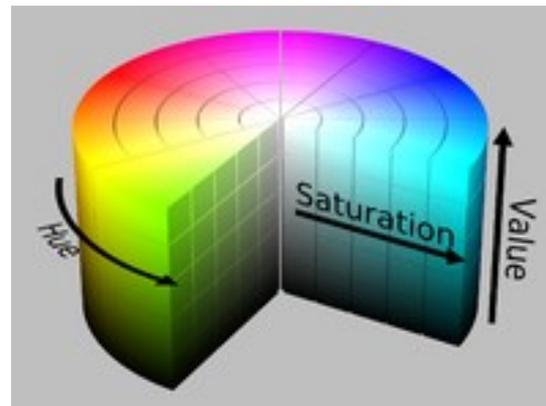


**H**

**S**

**V**

X 0.3



# HSV Color Mixing

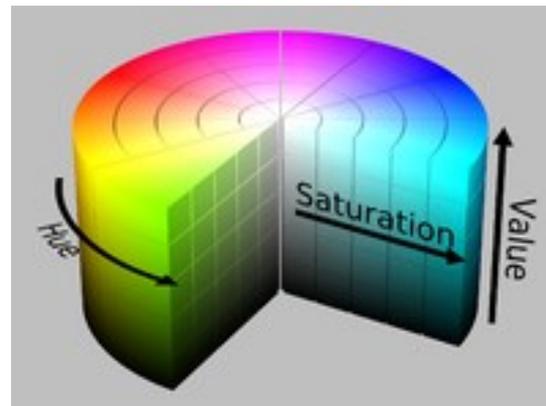


**H**

**S**

**V**

X 2



# HSV Color Mixing

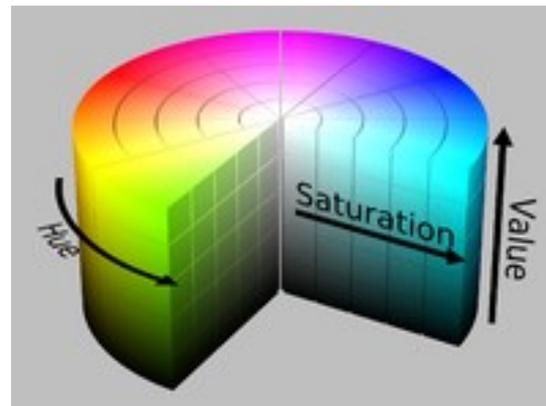


**H**

**S**

**V**

X 0.3



# HSV Color Mixing

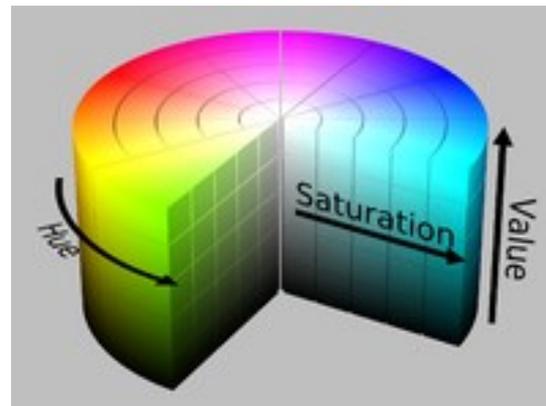


H

S

V

X 2



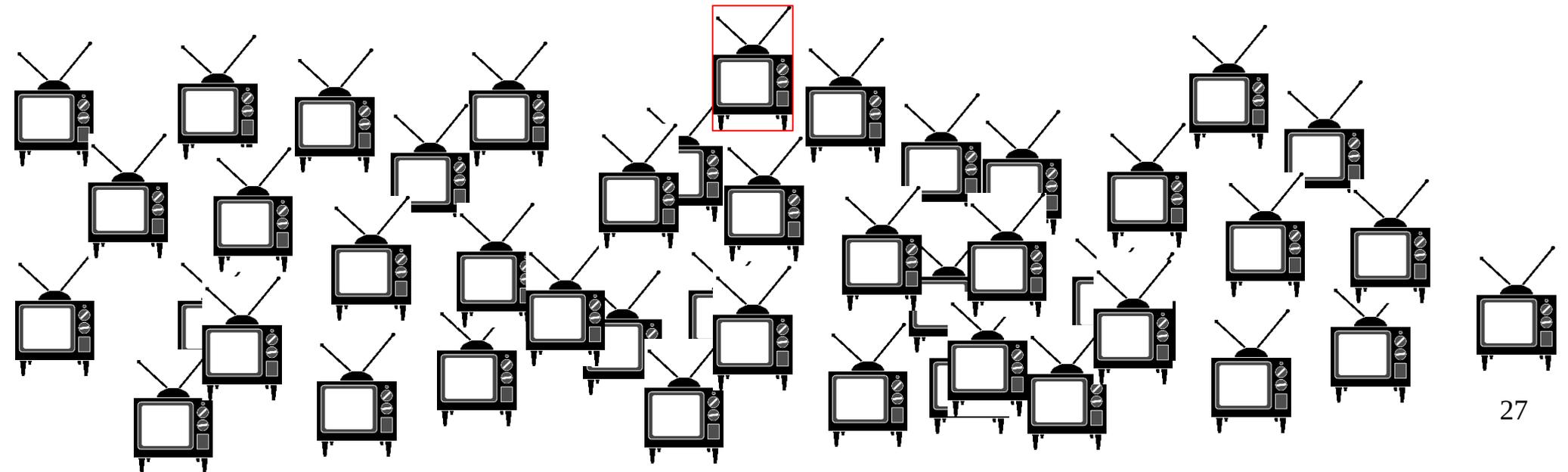
# YUV Color Space



Black and White Television



Color Television



# YUV Color Space



Gray



R



G



B



Original Image

Bandwidth x4



V



S



H



Original Image

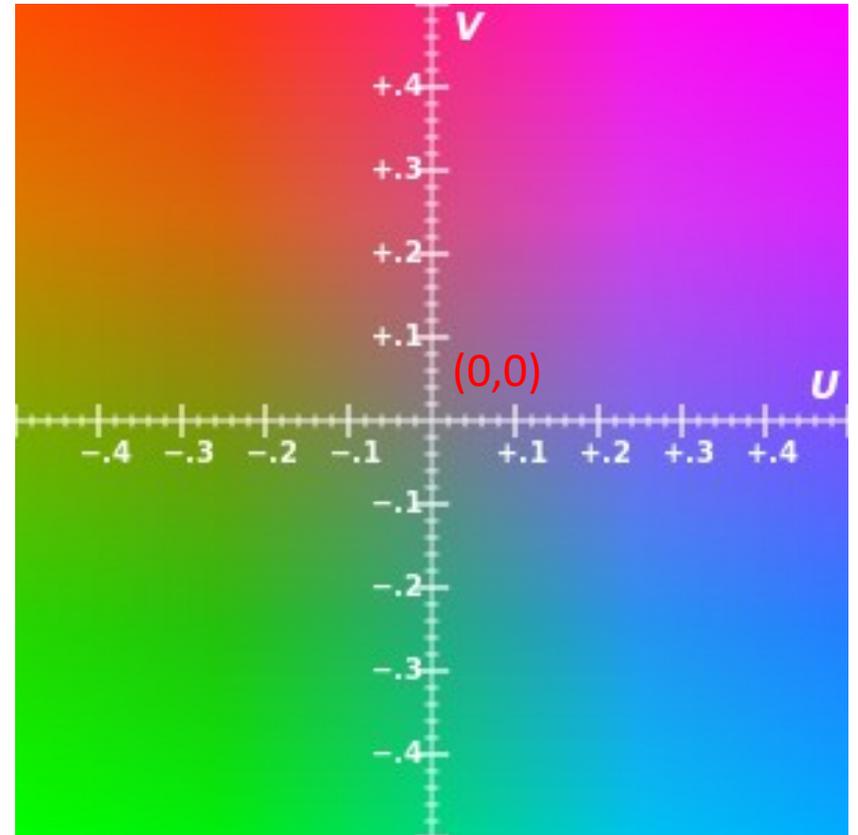
Bandwidth x3

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

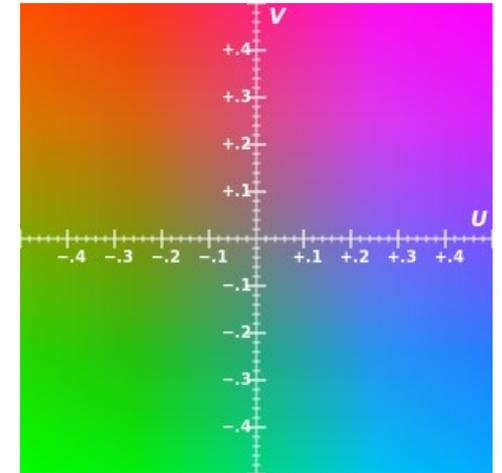


Y

U

V

$\times 0.5$



# YUV Color Mixing

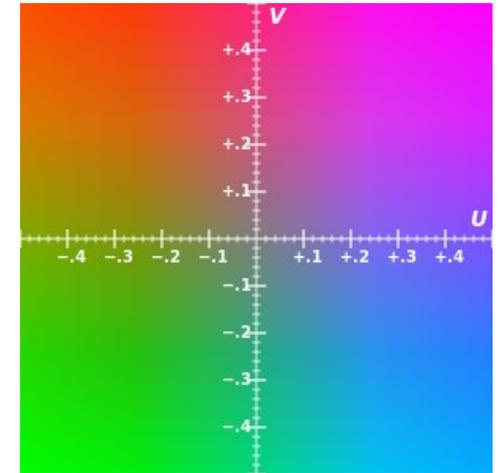


Y

U

V

X2



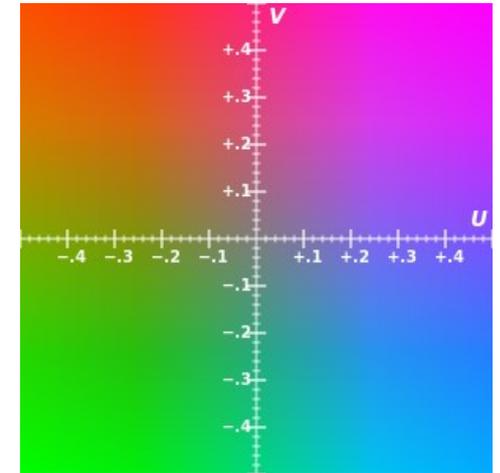
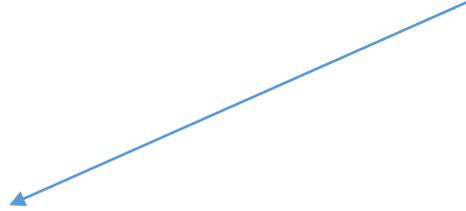
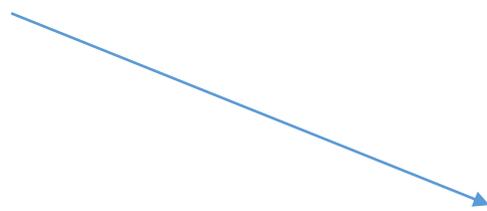
# YUV Color Mixing



Y

U

V



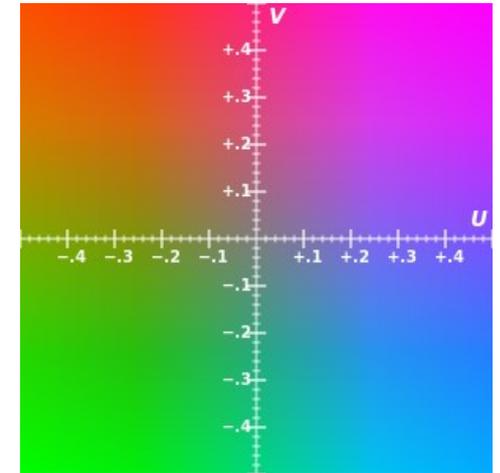
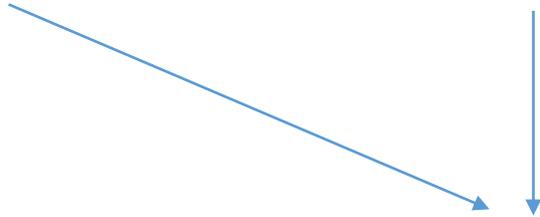
# YUV Color Mixing



Y

U

V



# YUV Color Mixing

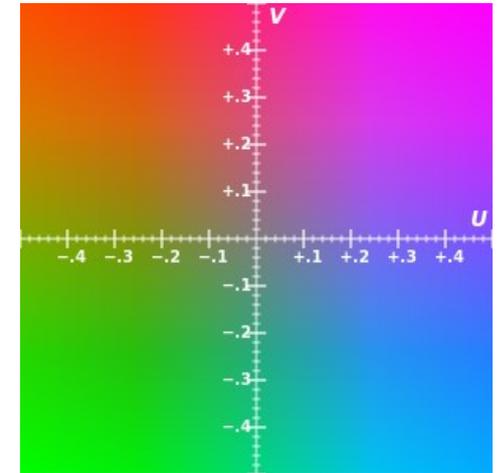


Y

U

V

-128



# YUV Color Mixing

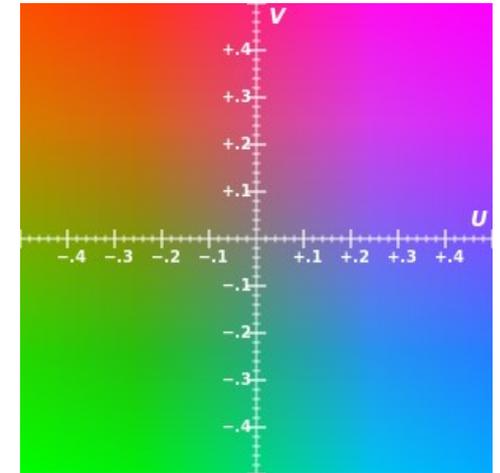


Y

U

V

-128



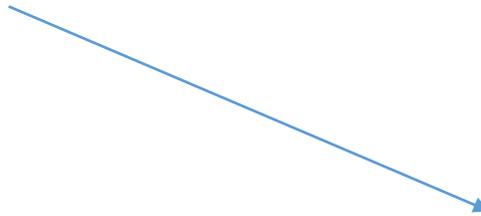
# YUV Color Mixing



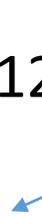
Y

U

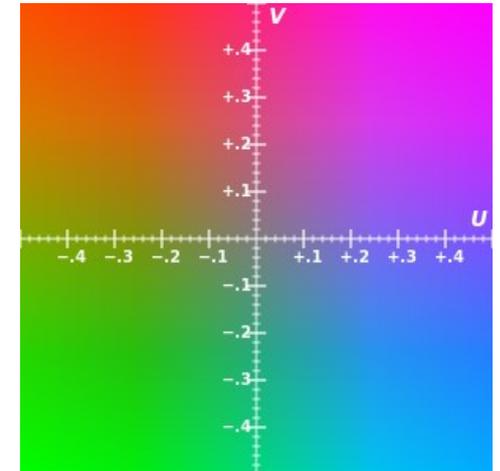
V



-128



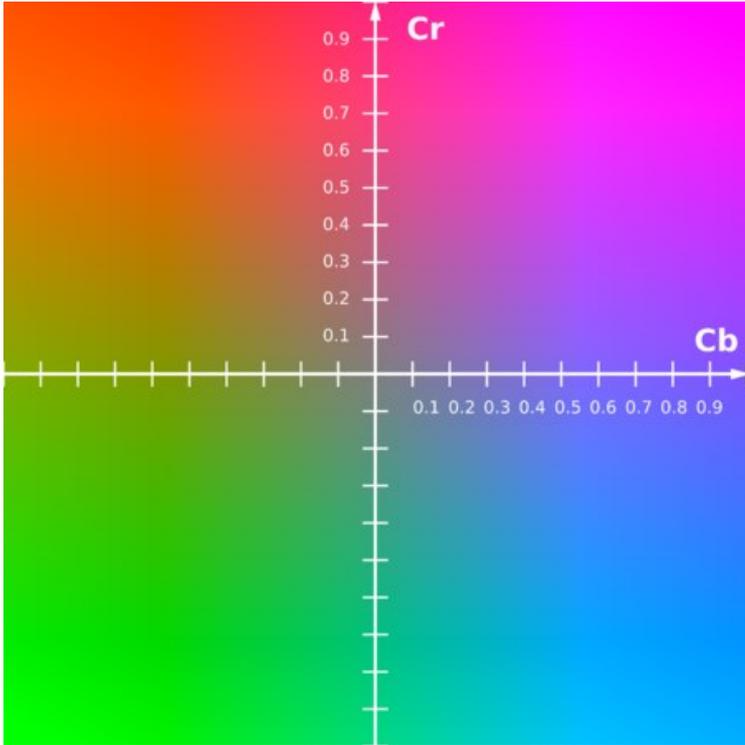
-128



# YCbCr Color Space



Y



Cb



Cr

# YCbCr Color Space

## JPEG conversion

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

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

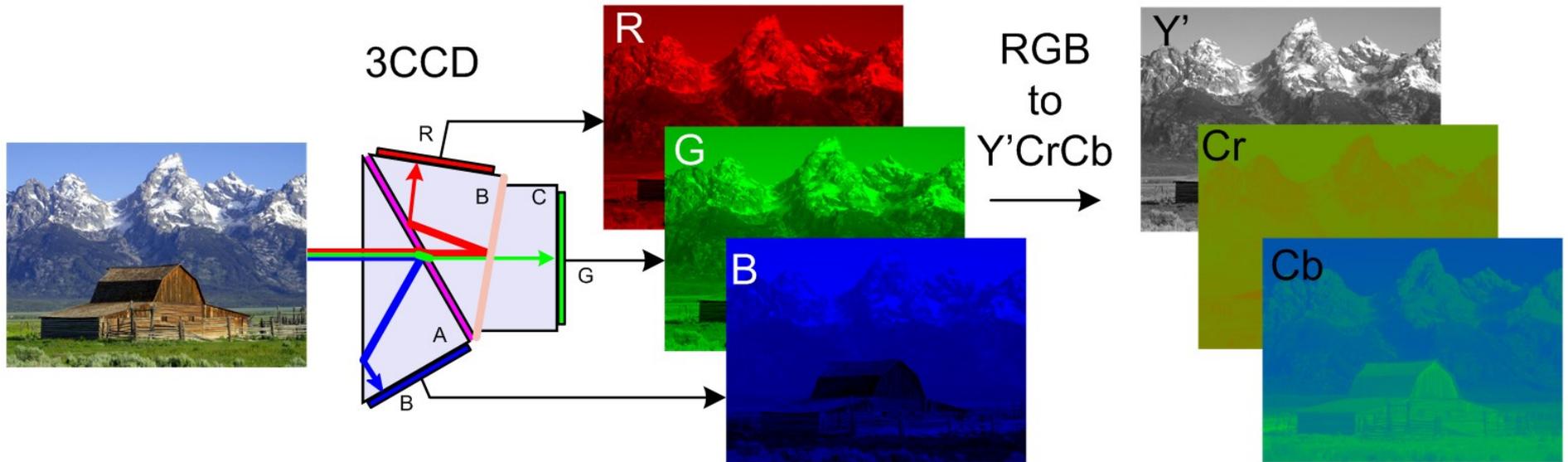
$$Cr = 128 + 0.5R - 0.418688G + 0.081312B$$

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

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

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

# YCbCr Color Space



Video camera

# Channel Subsampling



Y  
x0.5



Cb  
x0.5



Cr  
x0.5



# Channel Subsampling



Y  
x1



Cb  
x0.5



Cr  
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  
x0.05



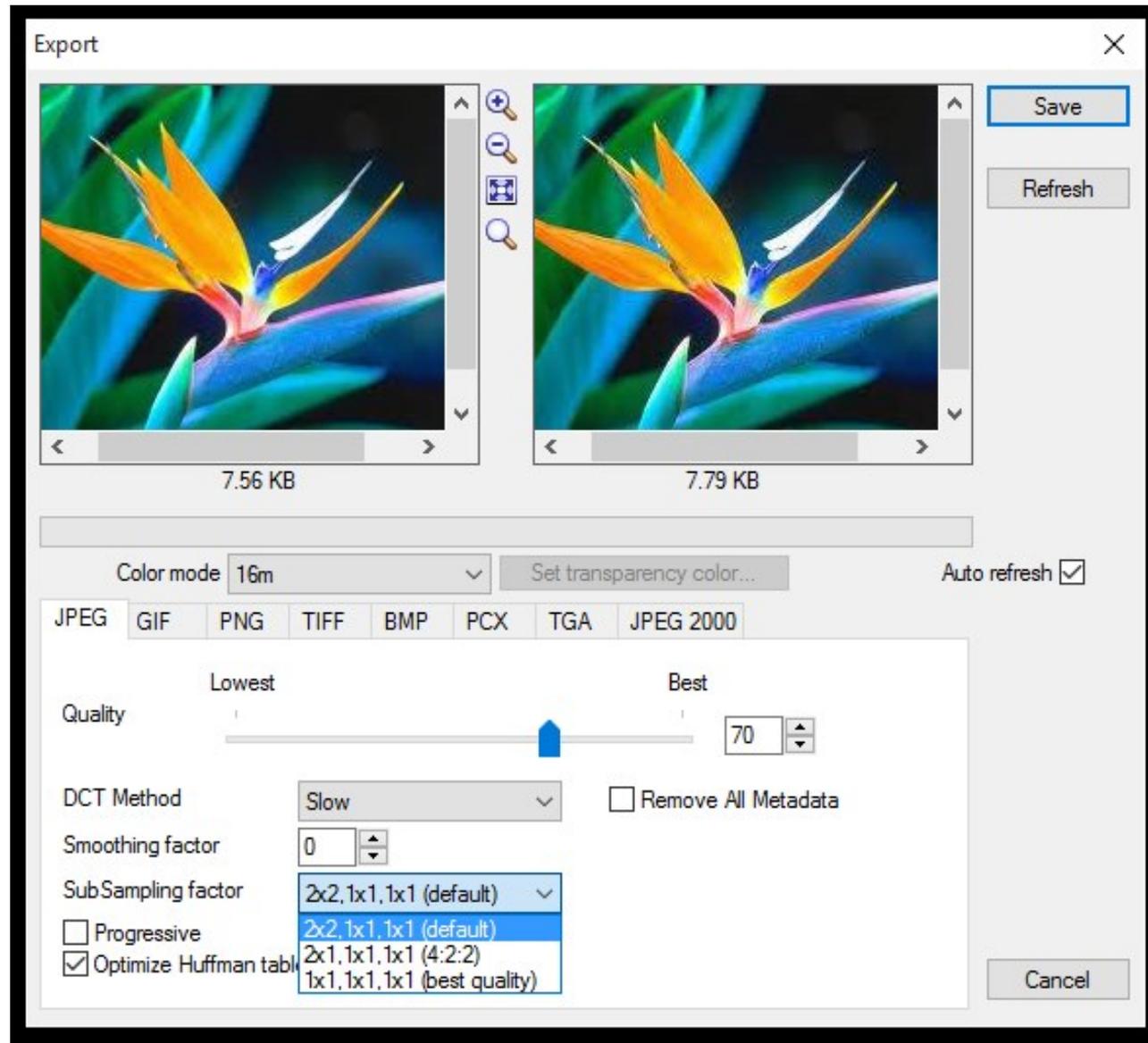
Cb  
x1



Cr  
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

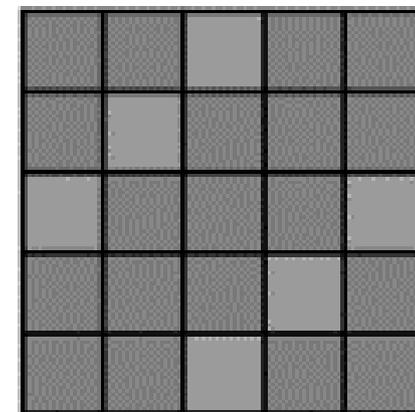
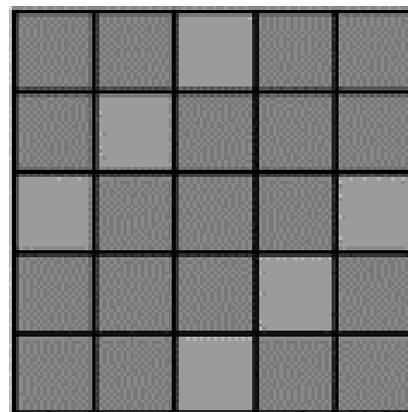
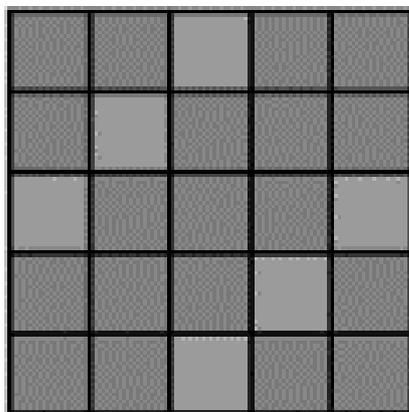
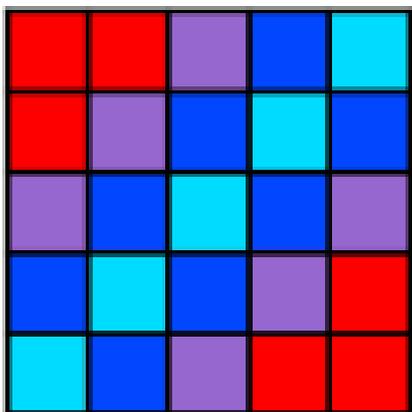


# Indexed color

Bitmap

Bitmap

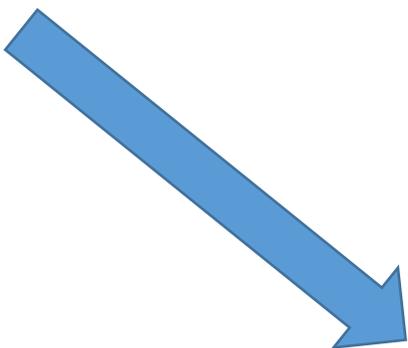
Bitmap



A

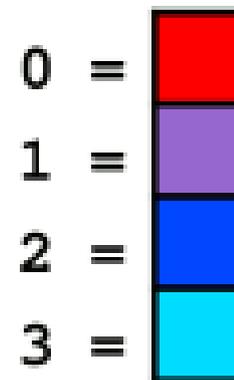
B

C



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

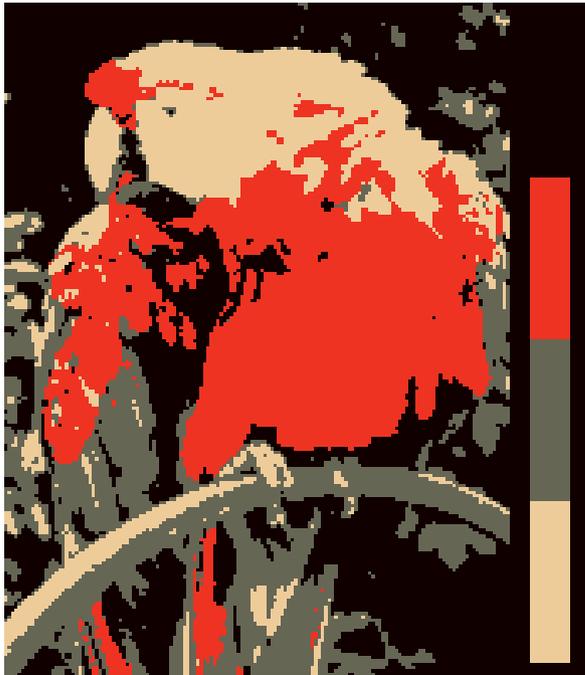


Palettes/ color map

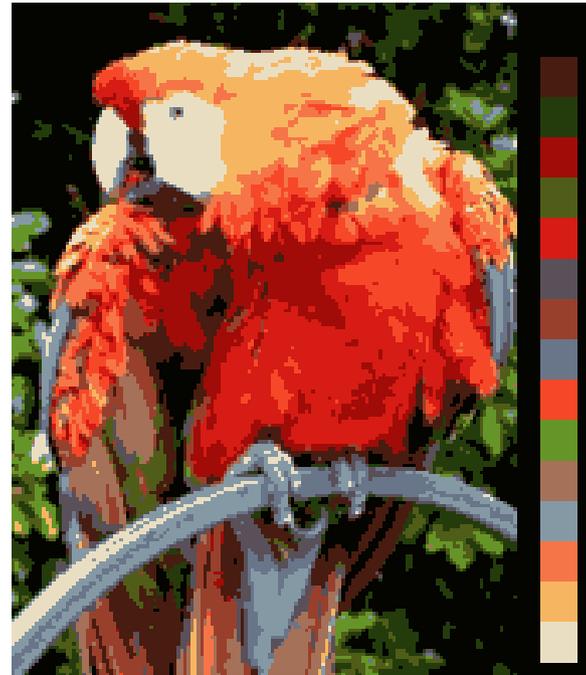
# Indexed color



**24-Bit**



**2-Bit**



**4-Bit**



**8-Bit**

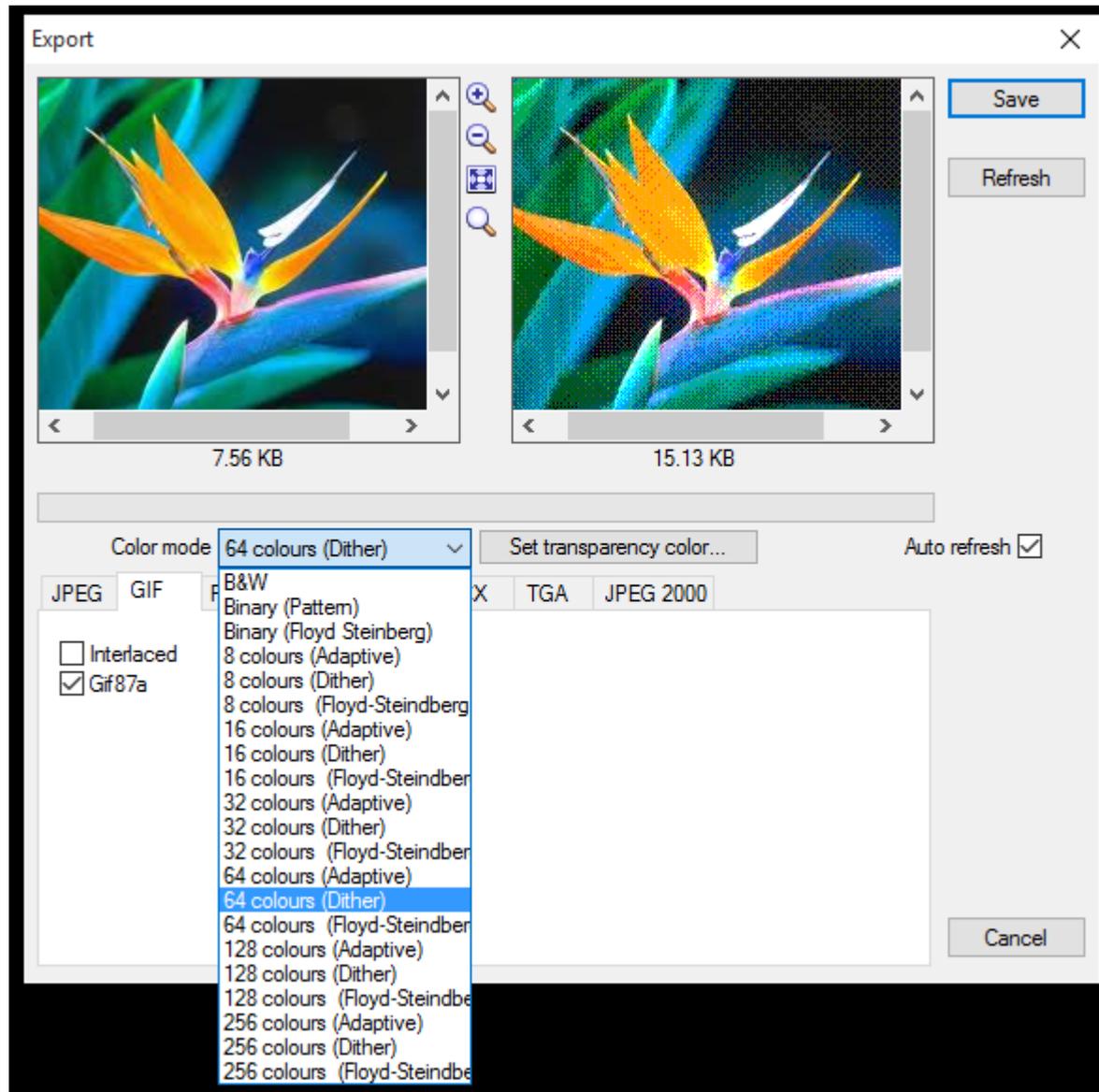
# Indexed color

## Image file formats supporting indexed color

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

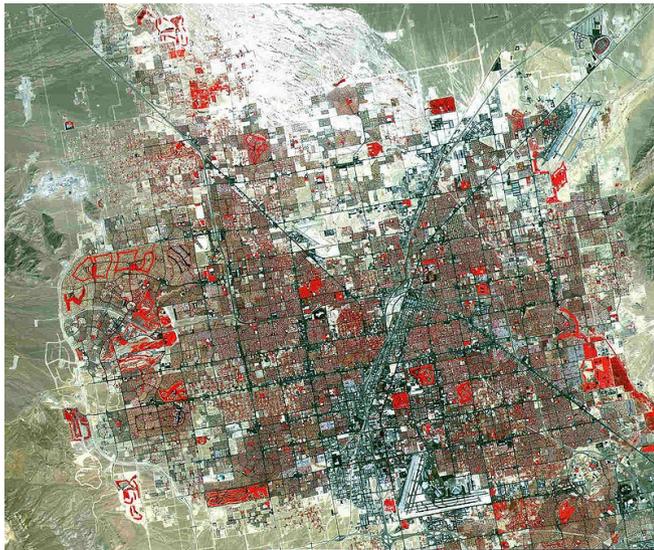
# Indexed color

## Color mode in GIF image format

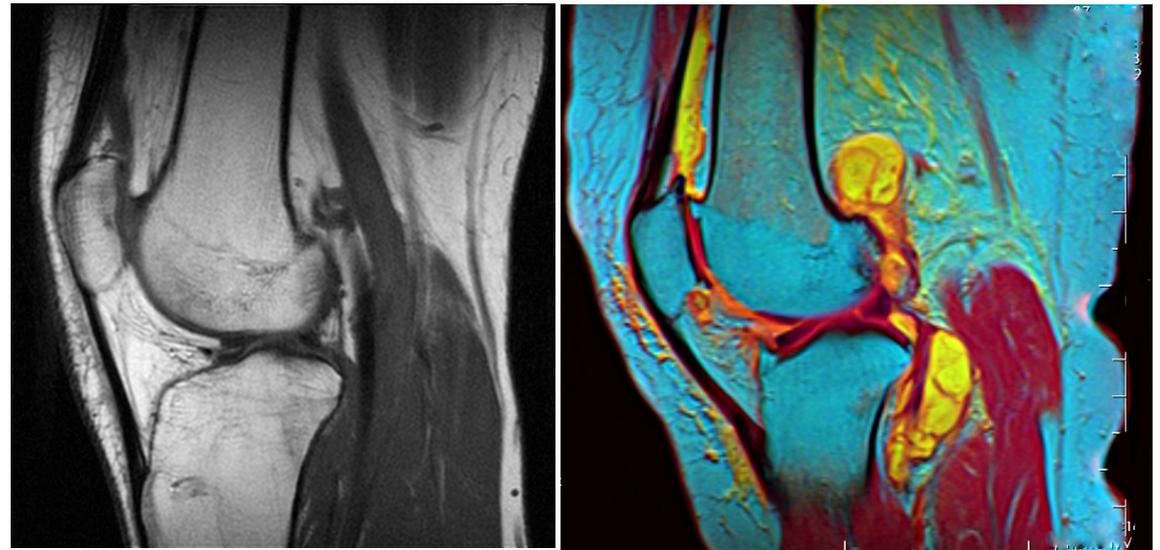


**A false-color** image sacrifices natural color rendition in order to ease the detection of features that are not readily discernible

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



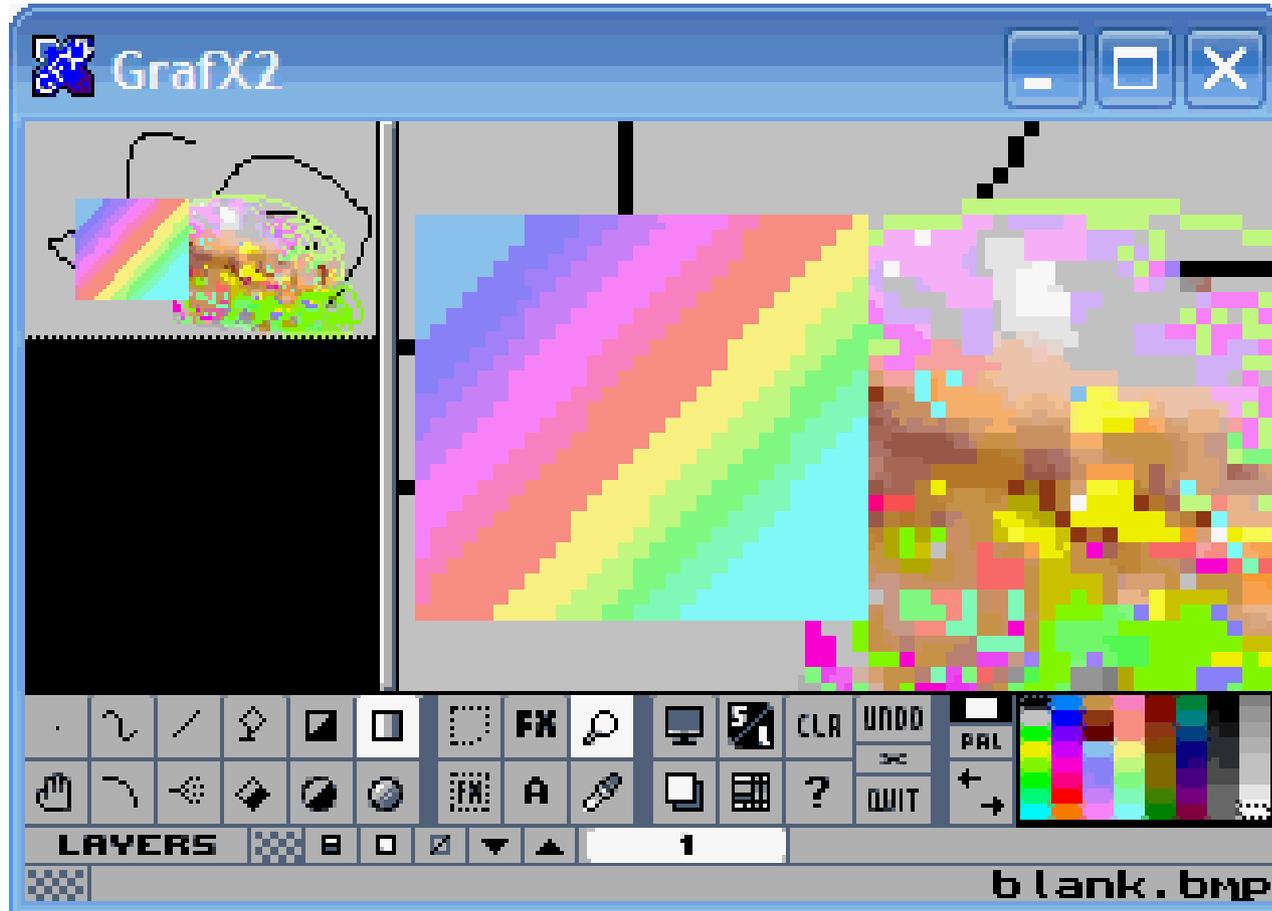
False color



Pseudo color

# Indexed color

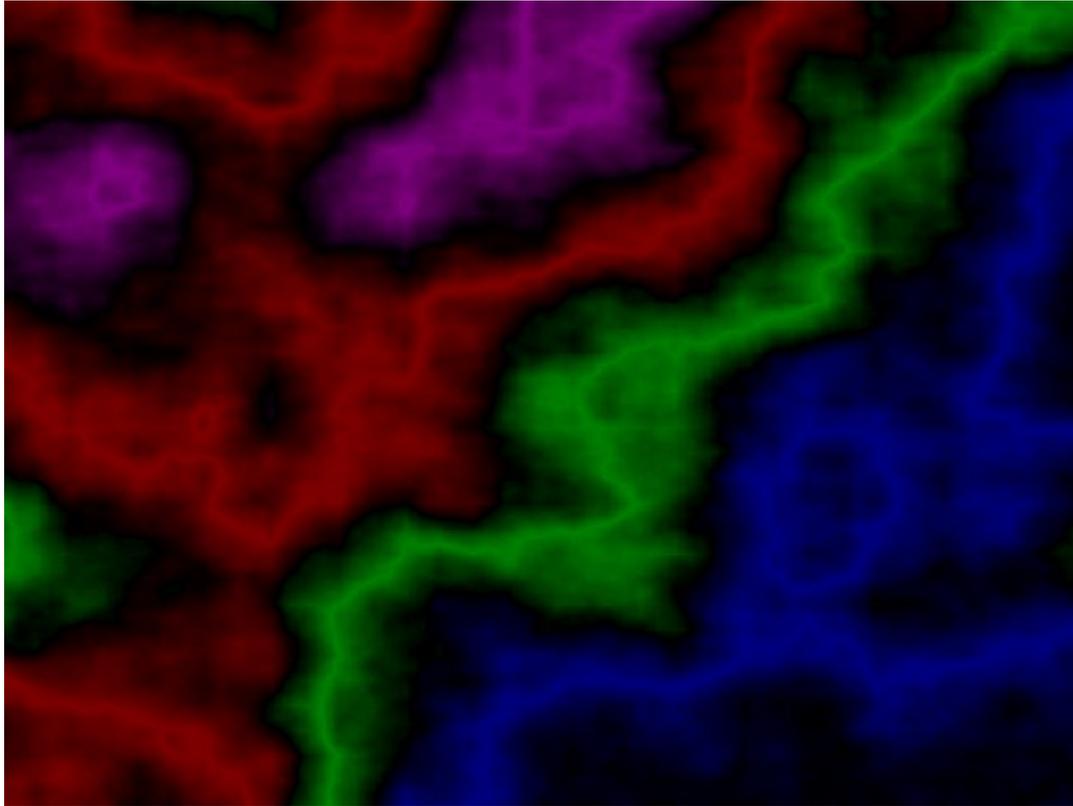
## palette shifting



**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/canvacycle/?sound=1>



# Matlab image processing function

RGB to HSV conversion:

```
lHSV=rgb2hsv(im);
```

HSV to RGB conversion:

```
im=hsv2rgb(lHSV);
```

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](https://en.wikipedia.org/wiki/List_of_color_spaces_and_their_uses)

