Color & Compression

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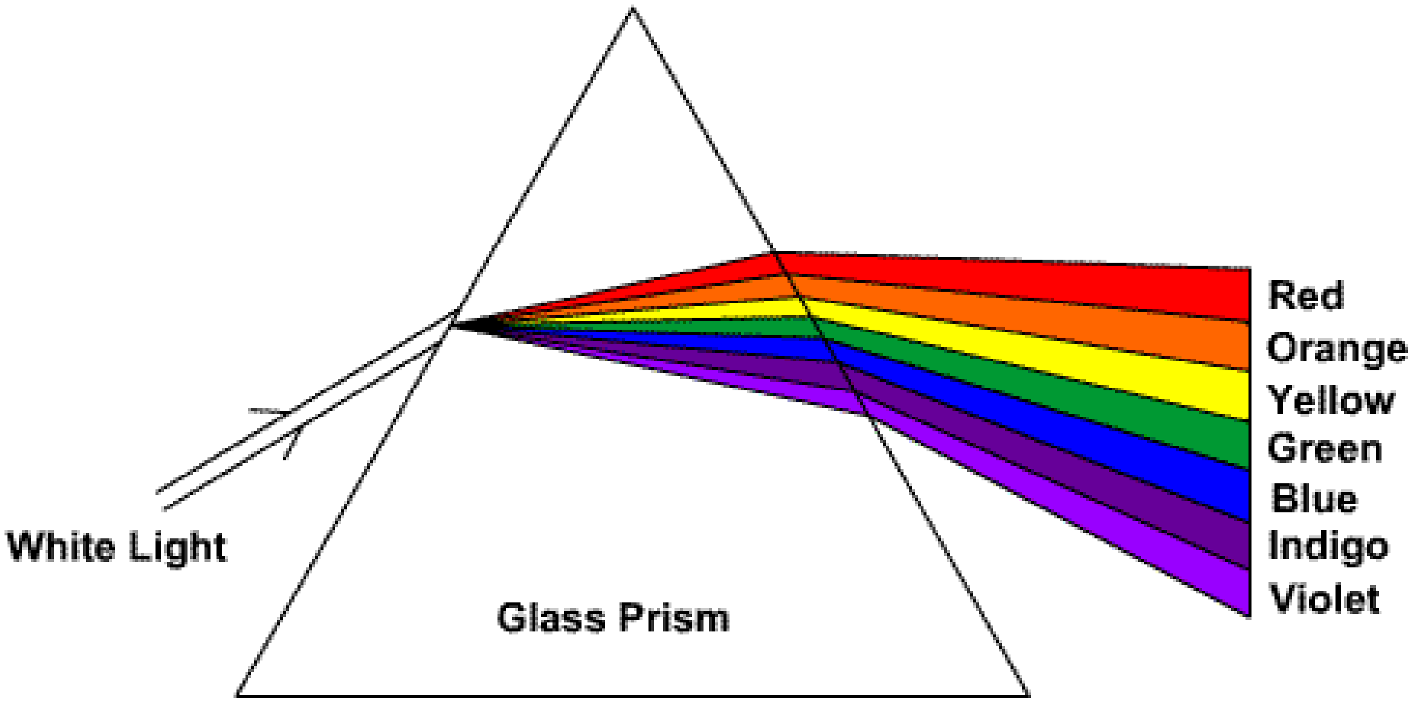
Outline

Color
- Color spaces
- Multispectral images
- Pseudocoloring
- Color image processing

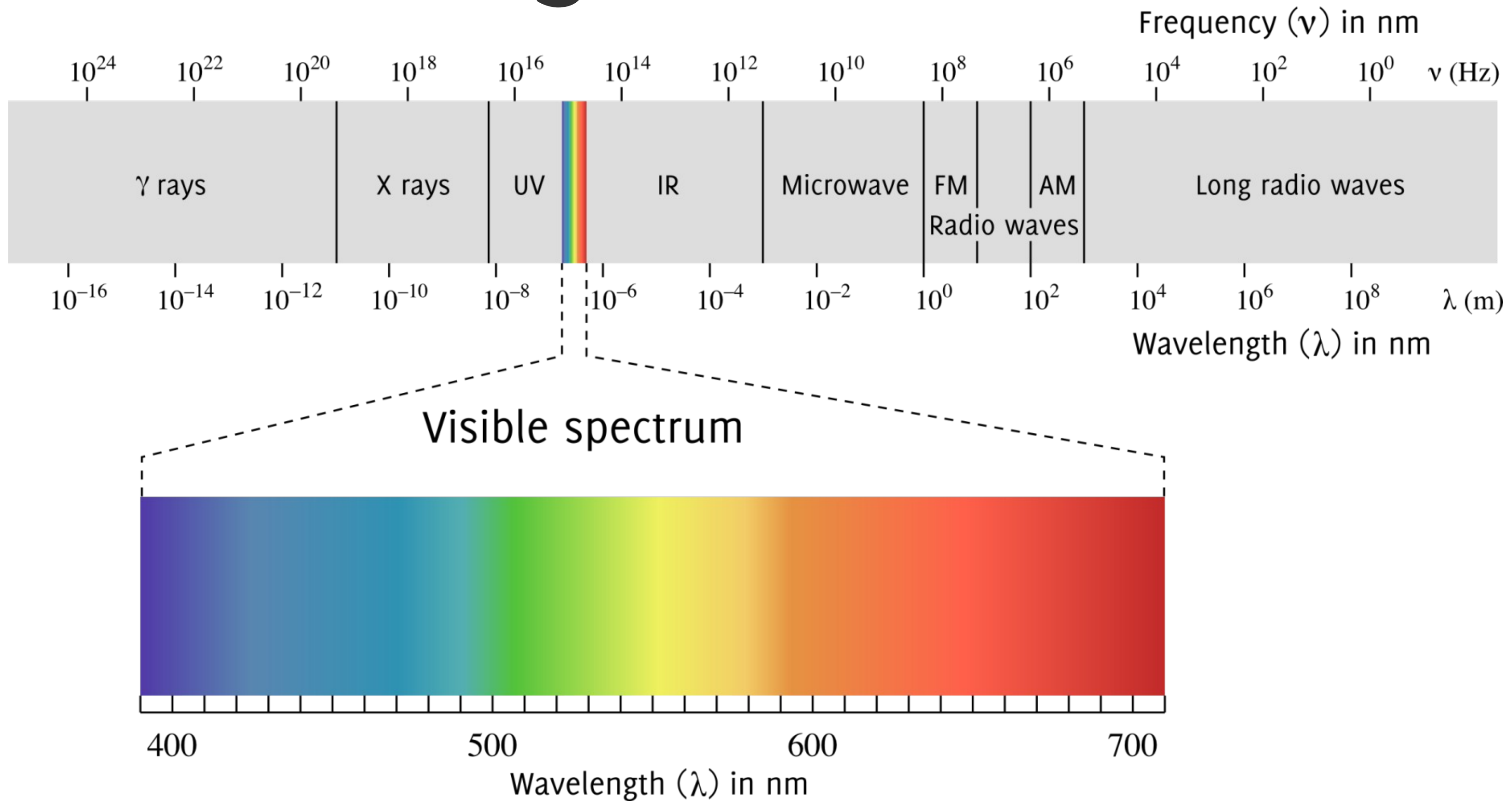
Coding/Compression
- Information and Data
- Redundancy
- Coding
- Compression
- File formats

Color fundamentals

- White light consists of seven visible colors:
  red, orange, yellow, green, blue, indigo and violet



Electromagnetic Radiation

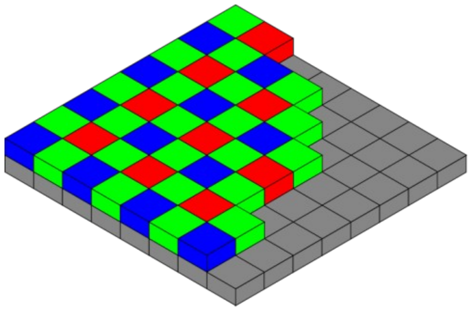


- Imaging systems typically selects one or several spectral windows.
- For grayscale image we have a single window.

Digital Camera as Detector

- Much like the human eye a digital camera has sensors sensitive to three colors. In a CCD chip they are differentiated by a Bayer filter pattern.

- Values are then interpolated to a full RGB image.


Bayer mosaic

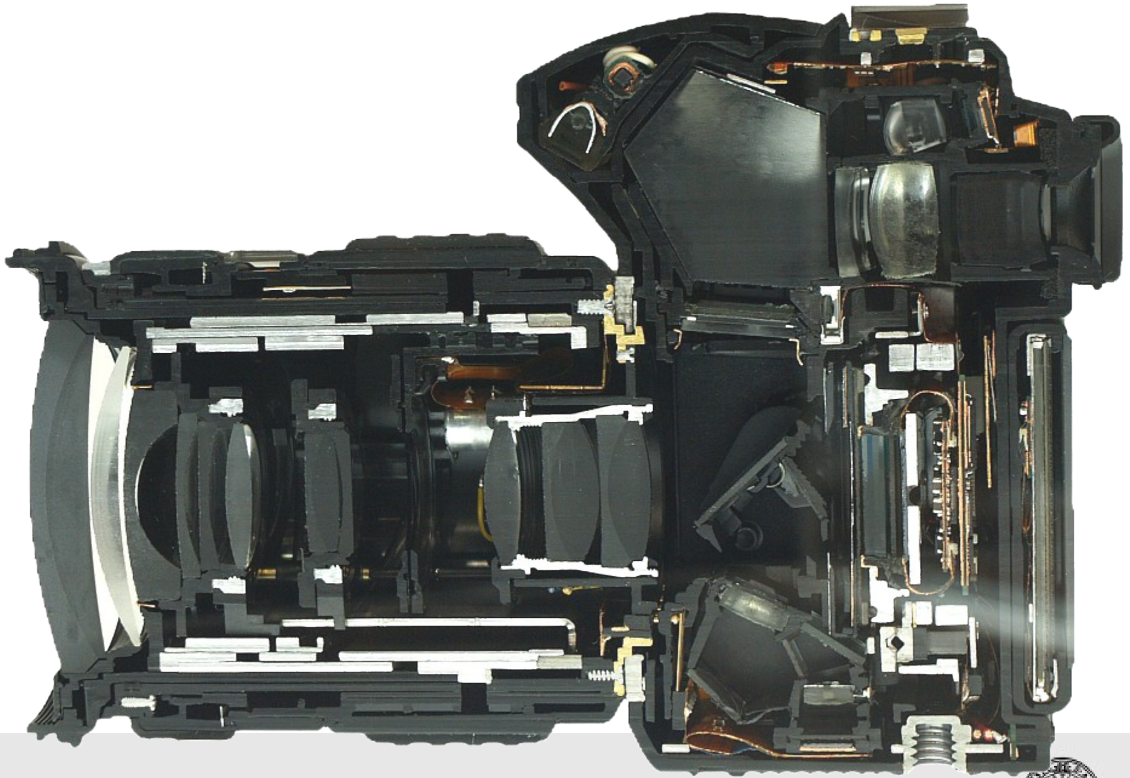
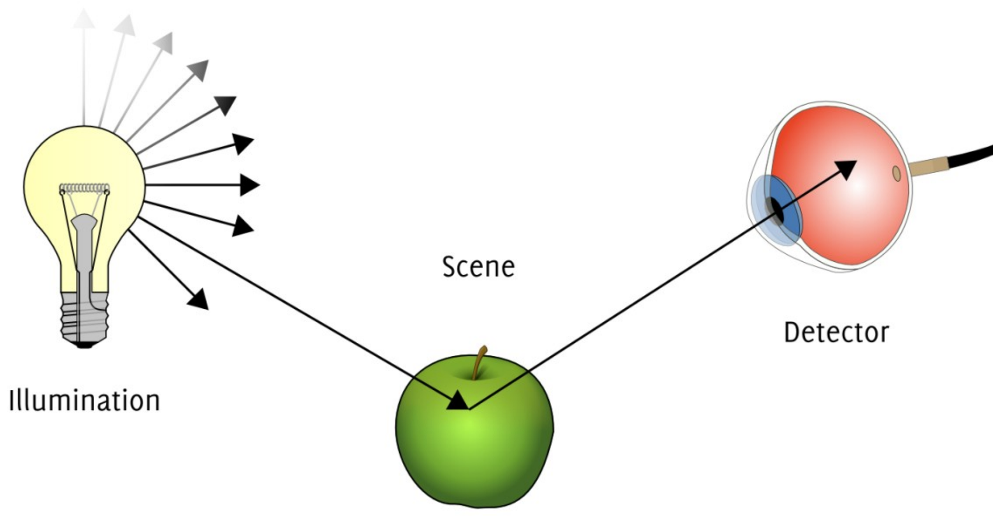


Image Formation



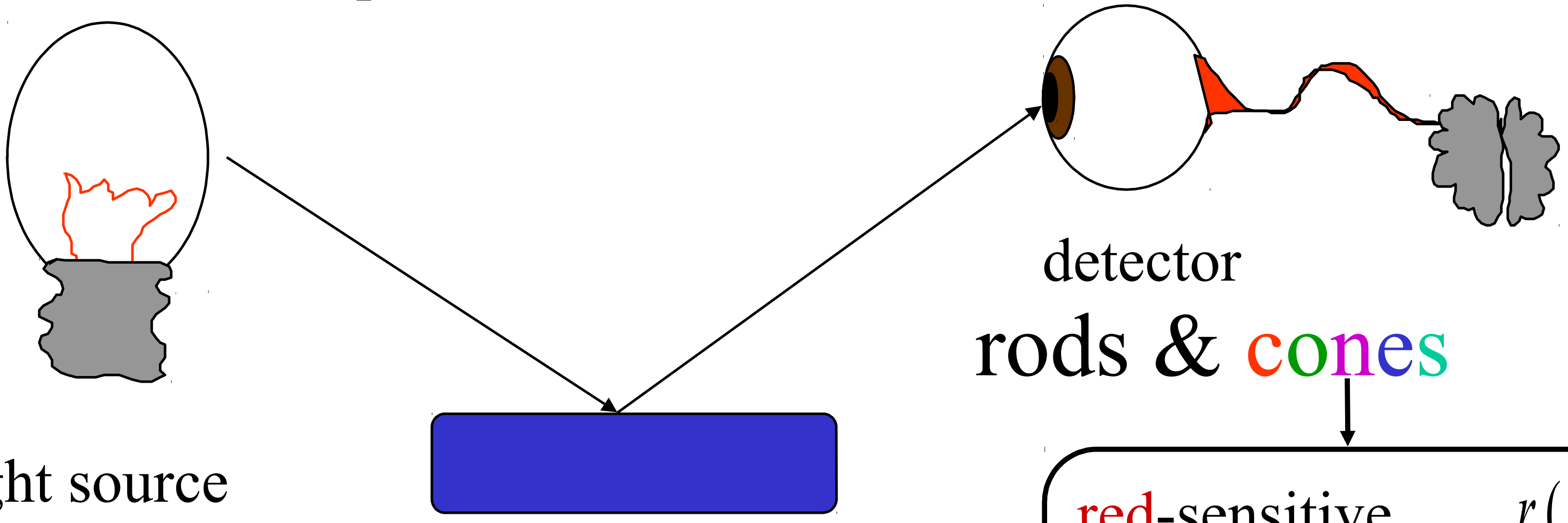
The acquired image depends on the spectral properties of:

- The illumination - light from, e.g., the sun or a lamp
- The object or scene - light can be reflected, absorbed or transmitted
- The detector - can be, e.g., a camera or the human eye

Color perception

Color = The eye's and the brain's impression of electromagnetic radiation in the visual spectrum

How is color perceived?



rods & cones

red-sensitive	$r(\lambda)$
green-sensitive	$g(\lambda)$
blue-sensitive	$b(\lambda)$

light source $s(\lambda)$

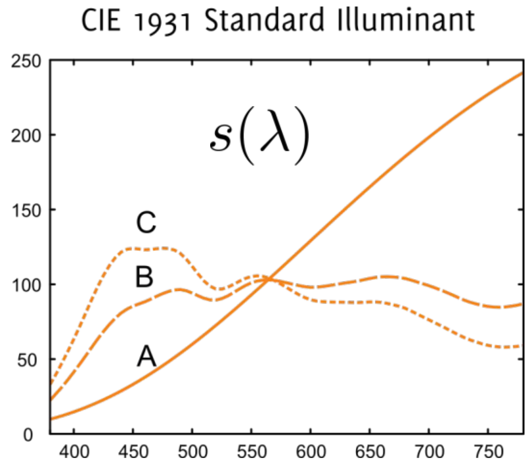
reflecting object $r(\lambda)$

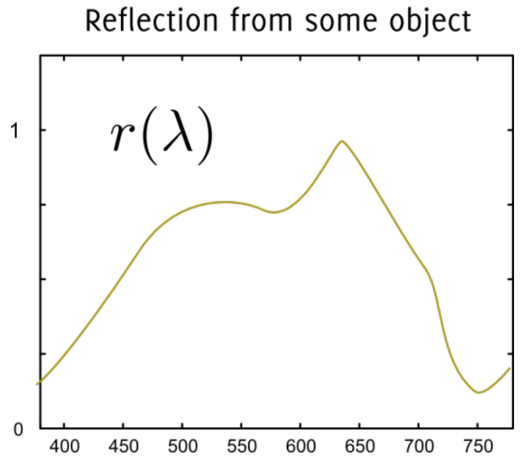
Light Properties

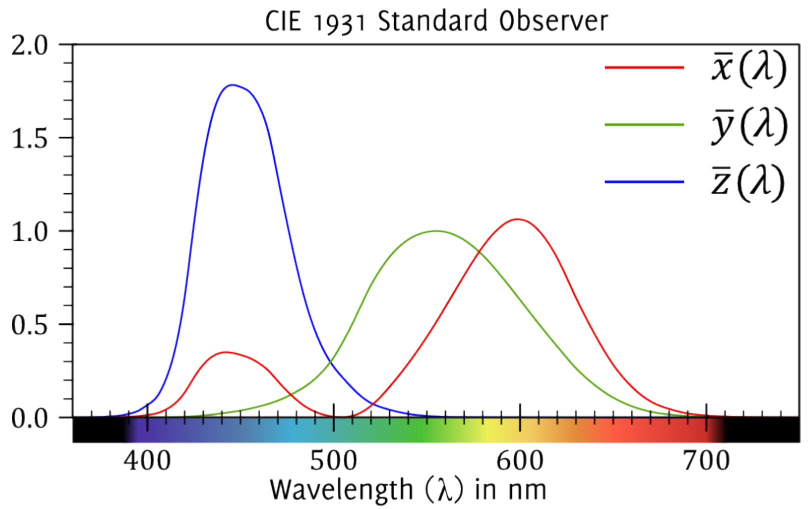
- Illumination
  - **Achromatic light -** *White* or uncolored light that contains all visual wavelengths in a *complete mix.*
  - **Chromatic light -** Colored light.
  - **Monochromatic light –** Light with a single wavelength, e.g., a laser.
- Reflection
  - Colors we see are typically a mix of wavelengths.
  - The dominant wavelength reflected by an object decides the "color tone" or hue.
  - If many wavelengths are reflected in equal amounts, an object appears to be grey.

Illumination - Reflection - Detection

The spectral measurement process





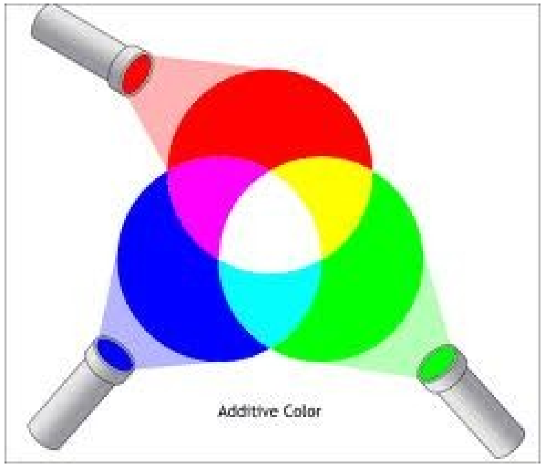


A-average incandencent light,
B-direct daylight, C-sunlight

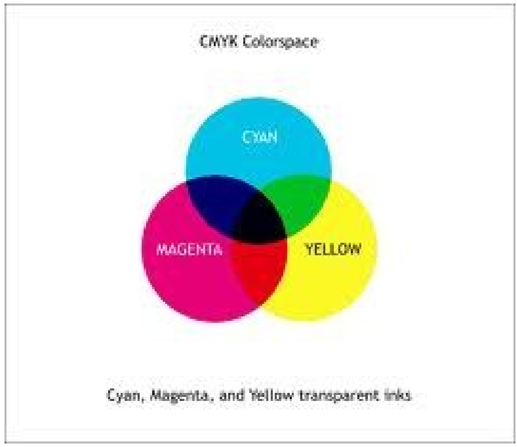
Color space representations

Color information can be described in a 'color space'

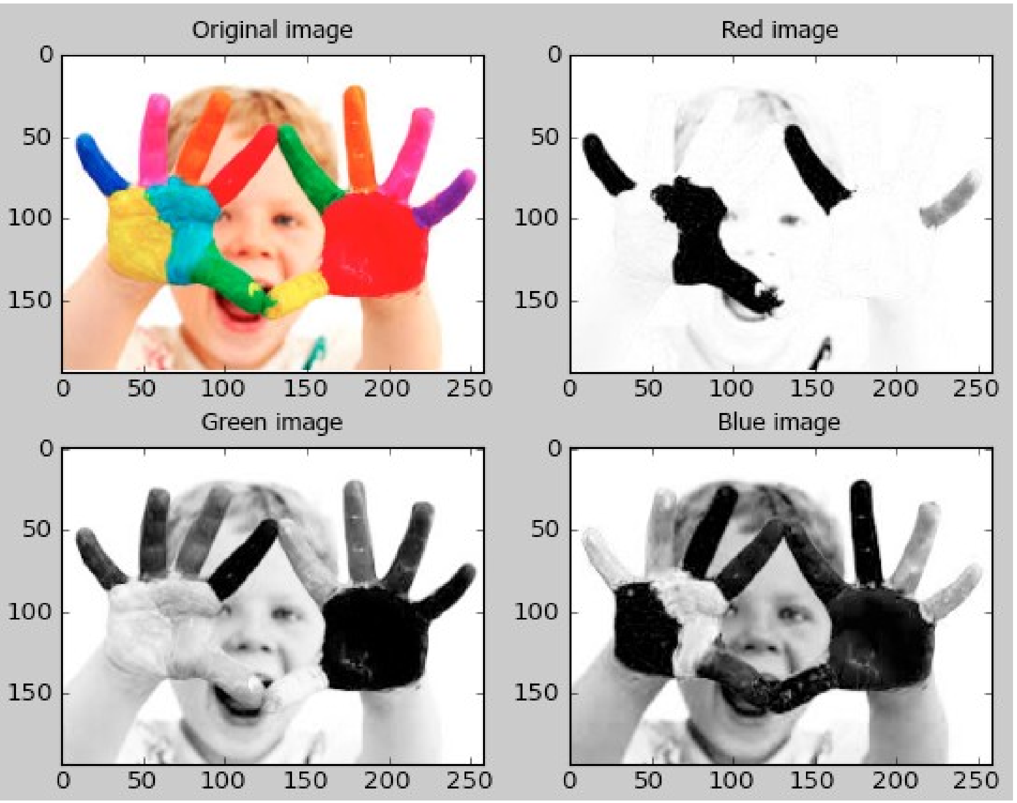
In the RGB (Red Green Blue) color space, each pixel is described by how much red, green and blue intensity it contains. The color of a pixel is defined by its position in the RGB cube (a 3D scatter plot) where origin (0,0,0) is black and the (1,1,1) is white.

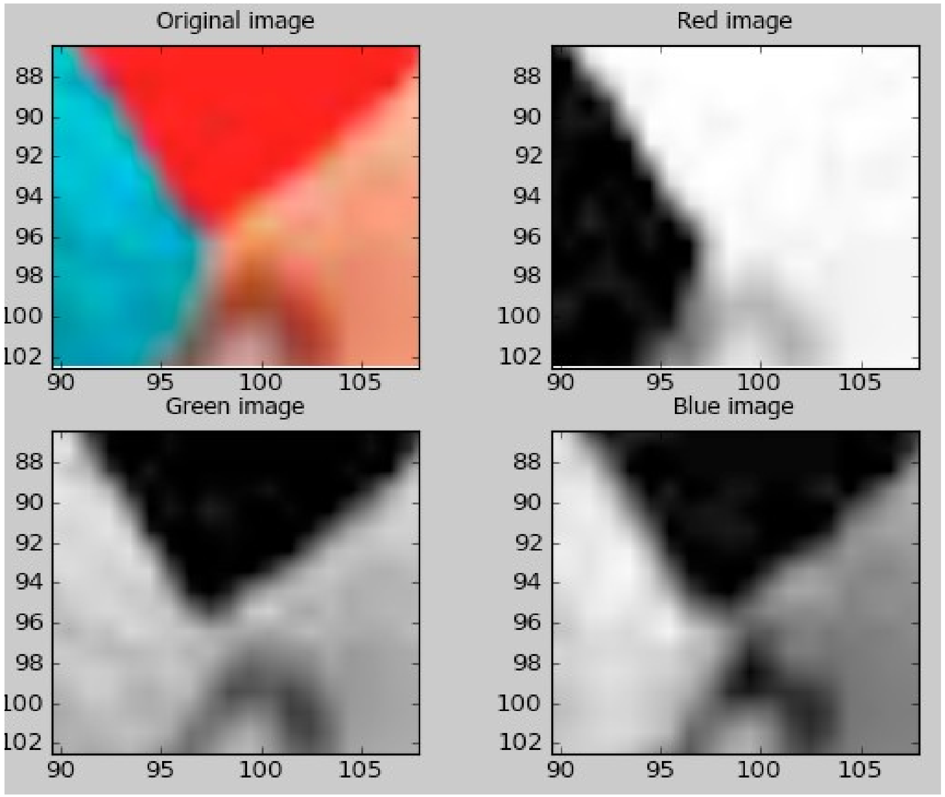


In the CMYK (Cyan Magenta Yellow Black) color space, each pixel describes how much pigment (color) of each of the primary colors that should be added at printing. It is, in some sense, the inverse of the RGB color space.



RGB color images



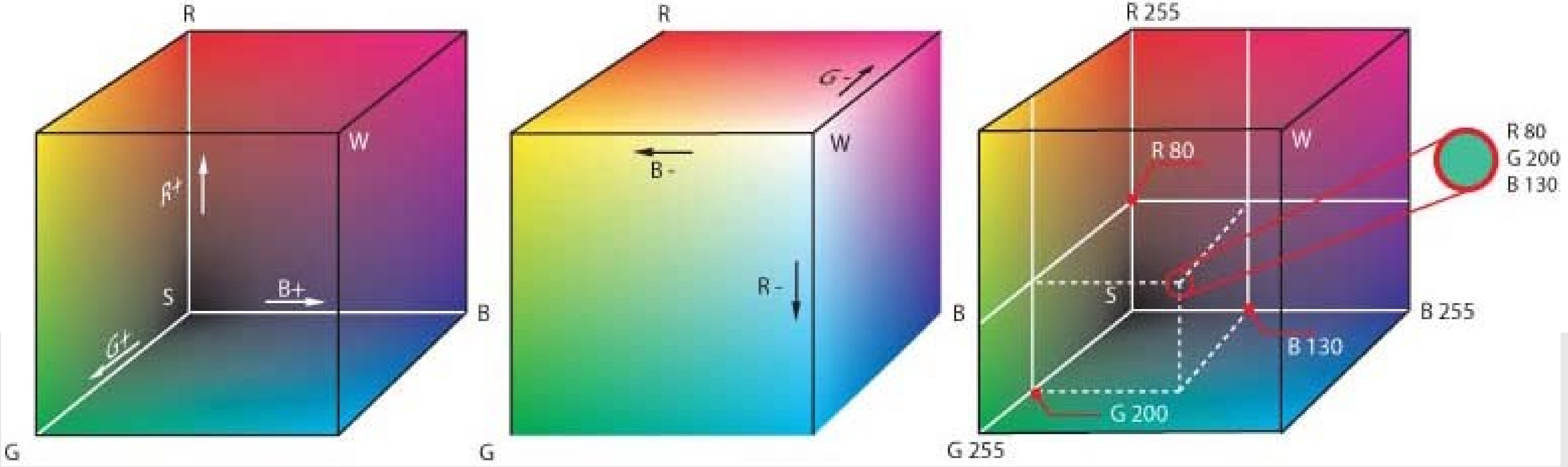


Mixing *light* means that the more colors you add, the lighter (and whiter) the resulting image.
R+G=Y
R+G+B= white

Color Spaces – RGB/CMY

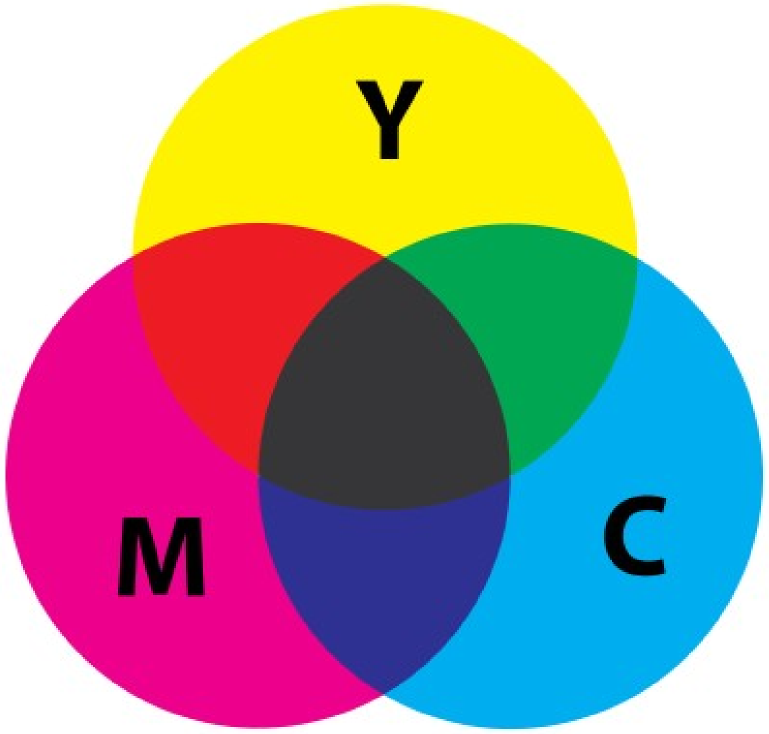
Red Green Blue / Cyan Magenta Yellow

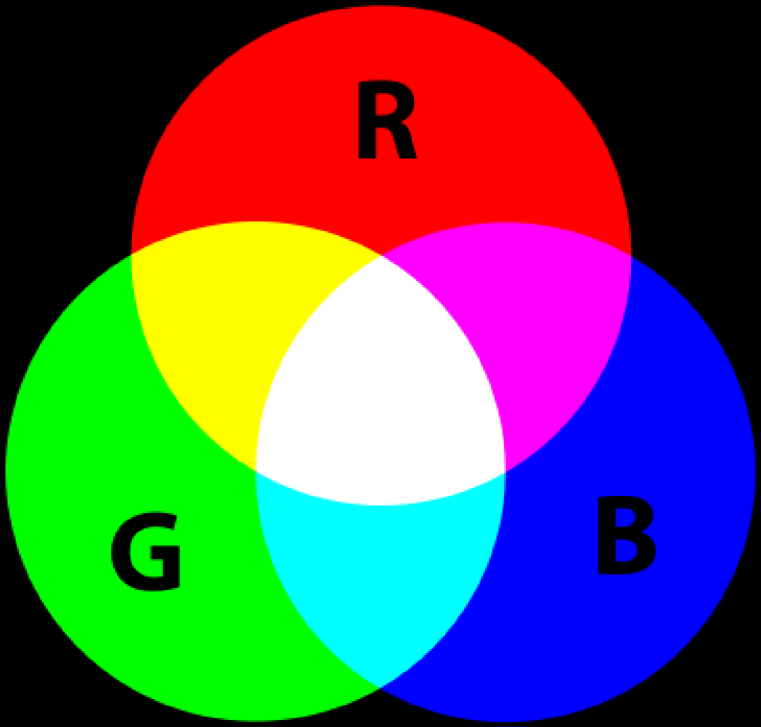
- Hardware oriented
- RGB is closer to the physiological side of our vision (the three cone types) rather than the psychological.
- [C M Y] = [1 1 1] - [R G B]



Subtractive Color Mixing

Primary colors of pigments





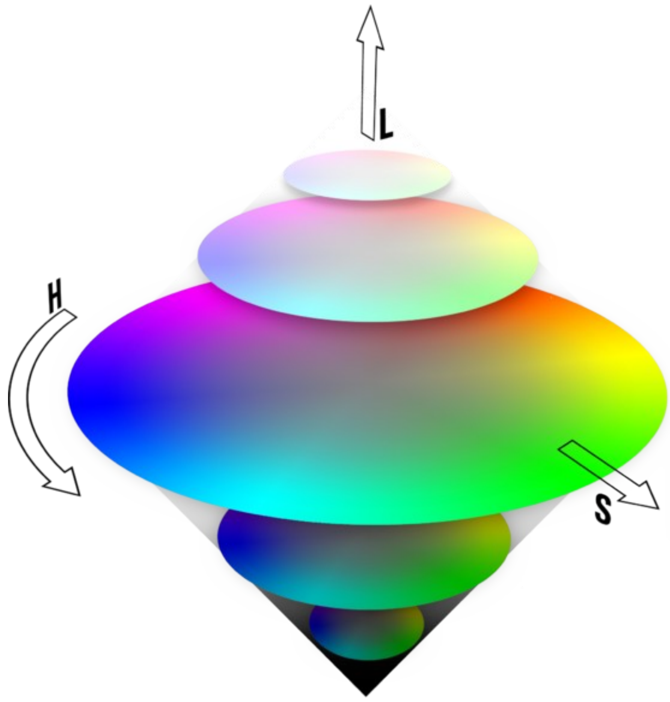
C + M + Y

Reflected light (object)

Color Spaces –HSL

Hue **S**aturation **L**ightness

- User oriented
- The HSL color space has intensity decoupled from color information.

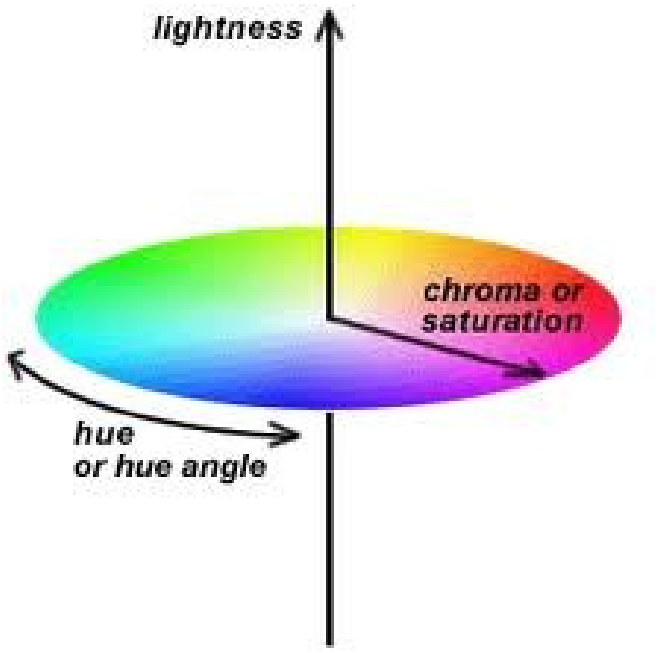


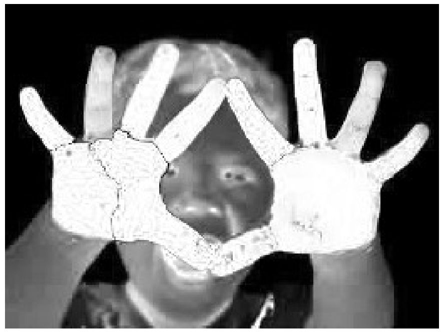
Hue, angle	(Färgton)
Saturation, radius	(Mättnad)
Value, **L**ightness, height	(Ljushet)

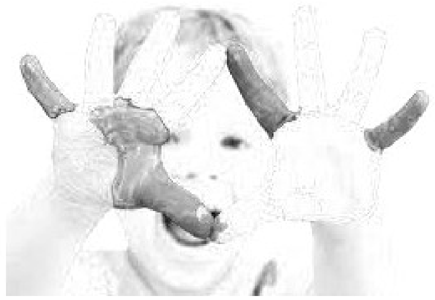
Color Spaces –HSL

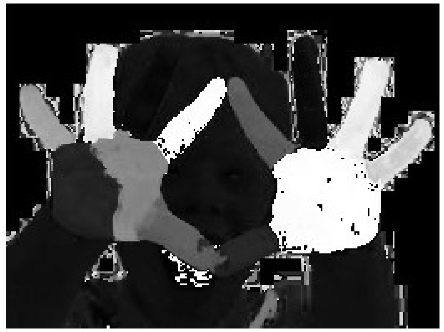
Hue **S**aturation **L**ightness

Makes it easier to compare objects with similar hue but varying lighting conditions.




saturation


lightness

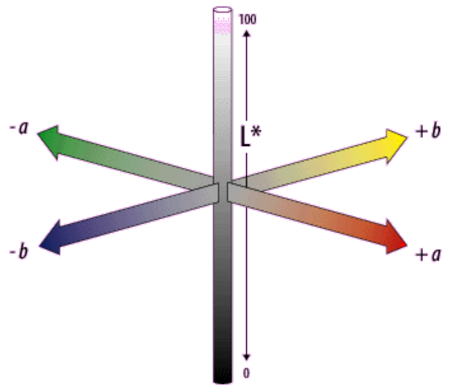

hue

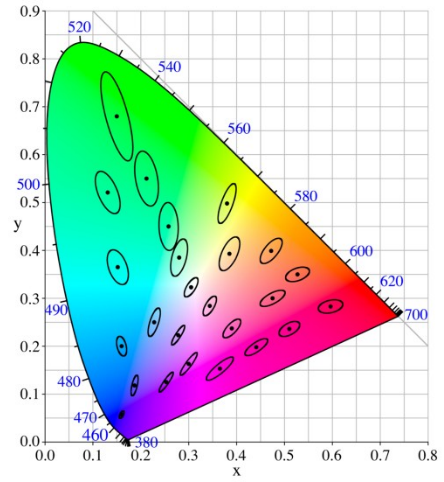
Note that the hue is a continuous angular scale of Hue where 0 and 360 degrees meet at red, so that red (360 degrees) has maximum hue while orange has minimum.

Color Spaces CIE L*a*b* or CIELAB

The most complete color space specified by the International Commission on Illumination, CIE in 1976

- Created to:
  - Represent all colors visible to human eye
  - Serve as a device independent model to be used as a reference
  - Be perceptually uniform - equal distance should have equal perceptual difference.





Color Spaces

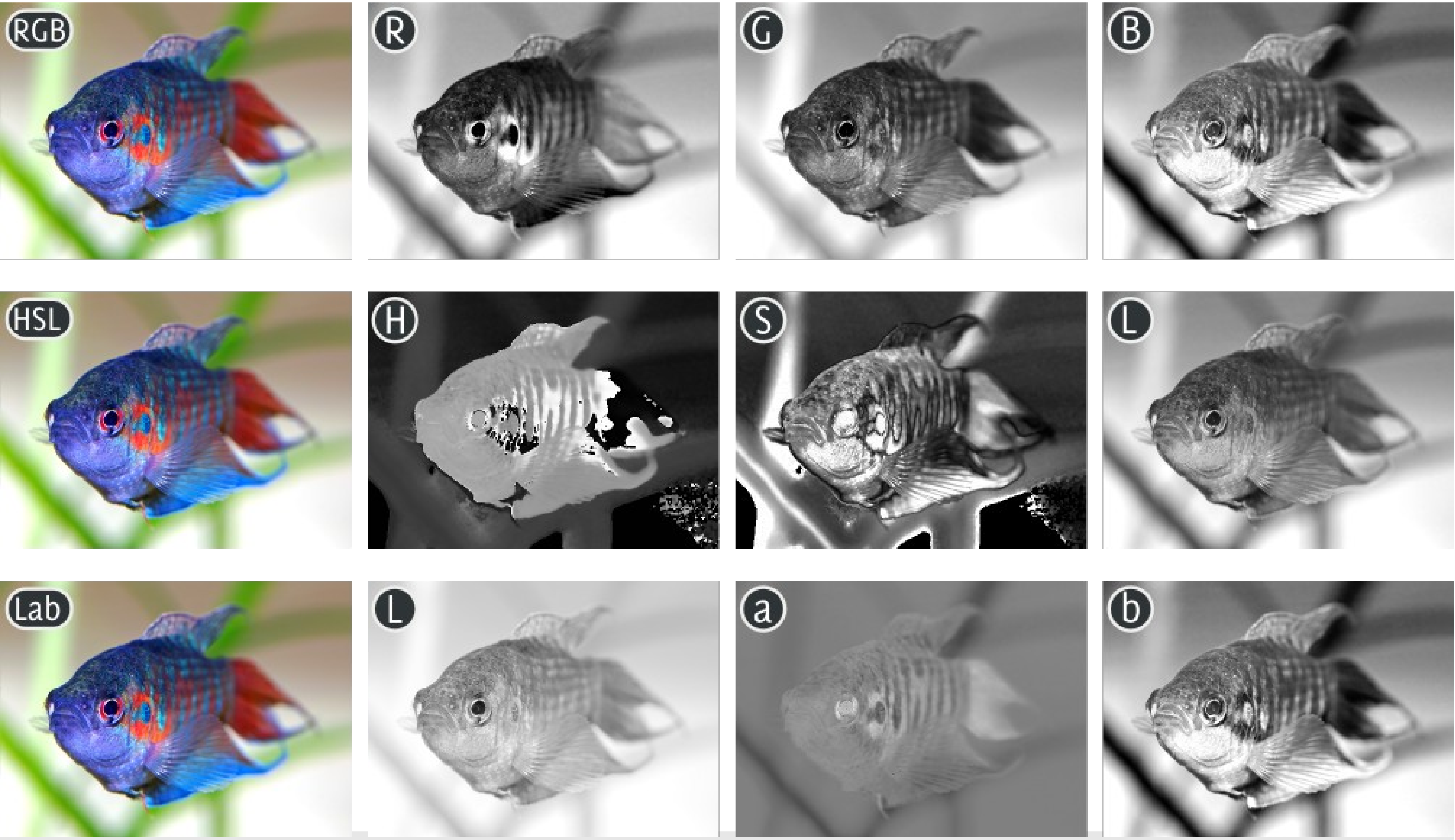
Even more color spaces

- **YCbCr** - similar to CIE L*a*b*
  - Used in the JPEG file format.
  - Uses the fact that the human eye is more sensitive to variation in lightness than in hue and saturation.

- **YUV** is similar to YCbCr, used for analogue TV

- **CMYK** is the CMY color space with a black component added, used for printing where a black pigment is used along with Cyan, Magenta and Yellow.

The list goes on ...



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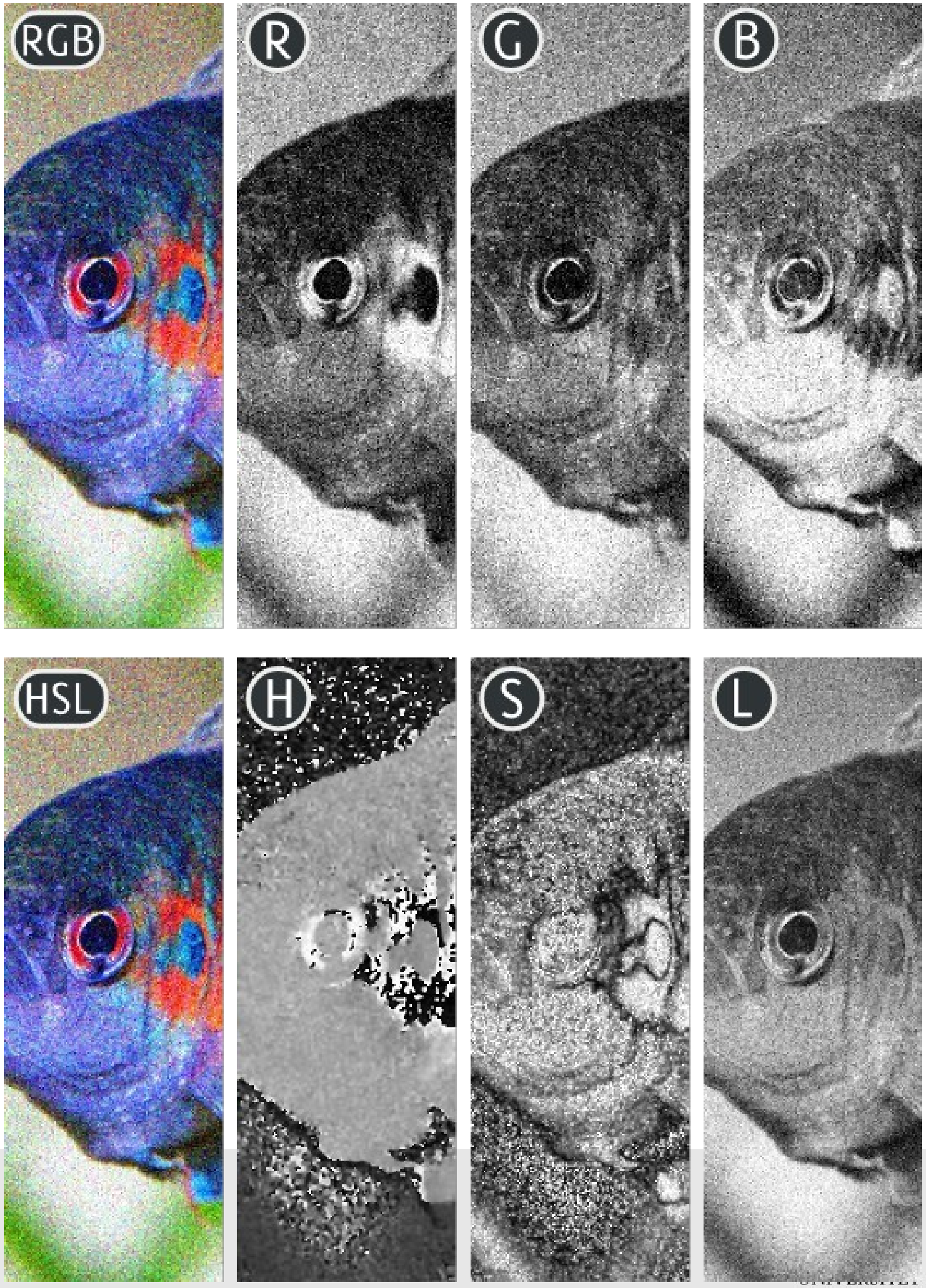
Noise in color images

- Gaussian noise in all color channels
- In a HSL representation the noise is most apparent in the H and S channel.

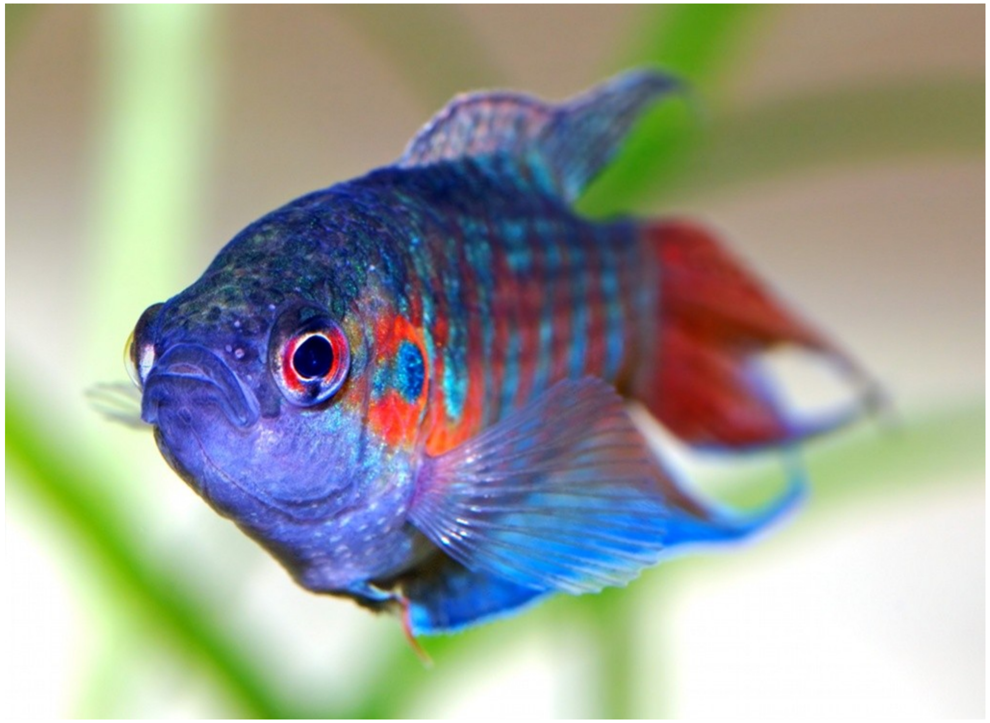


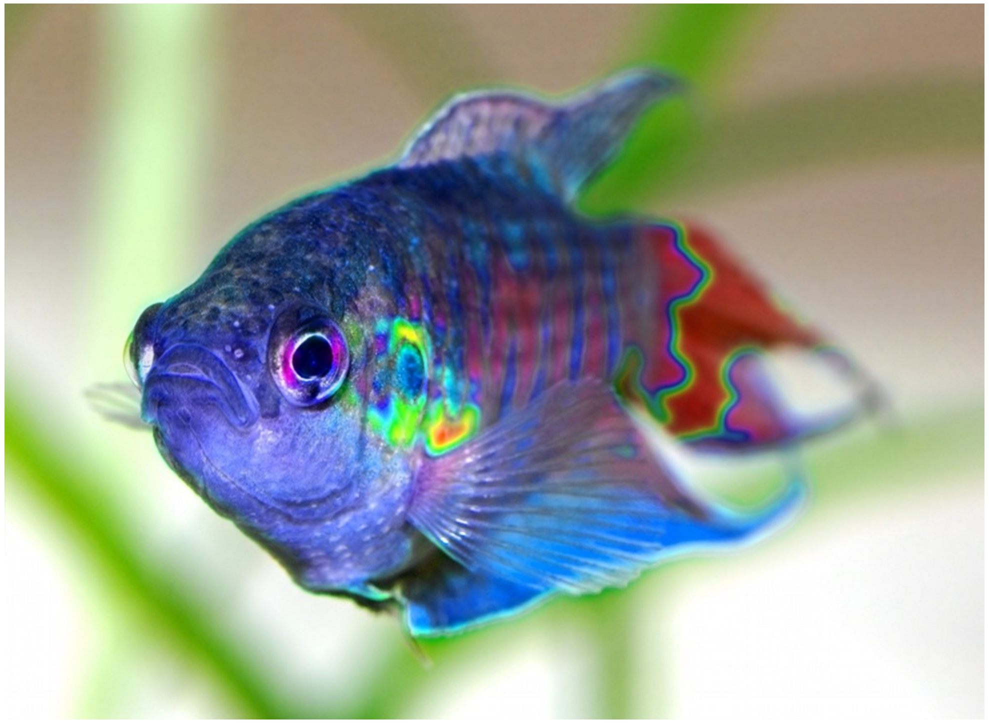
Gray level methods on color images

- In general all image processing methods used for grey level images can be used for color images.
- They can be carried out on each of the color channels or for example on the intensity only.
- There is no right or wrong, but the results differ.
- Be careful when using HSL.

The H-channel in HSL

- You might end up with color artifacts if the H-channel is filtered.
- Remember that the Hue channel is in degrees 0 to 360.

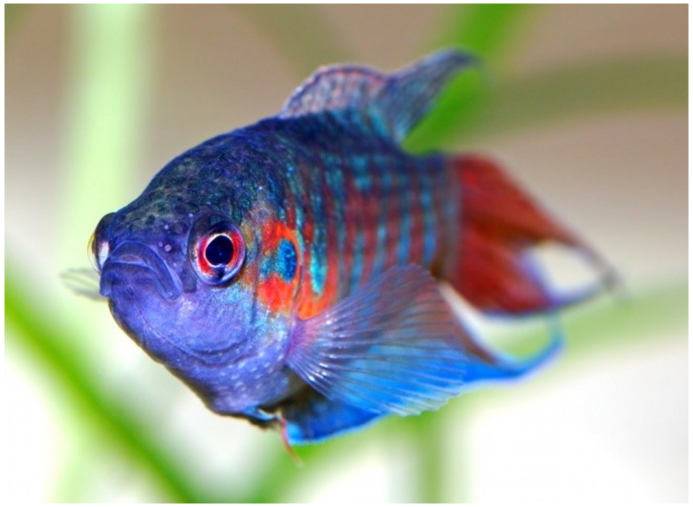


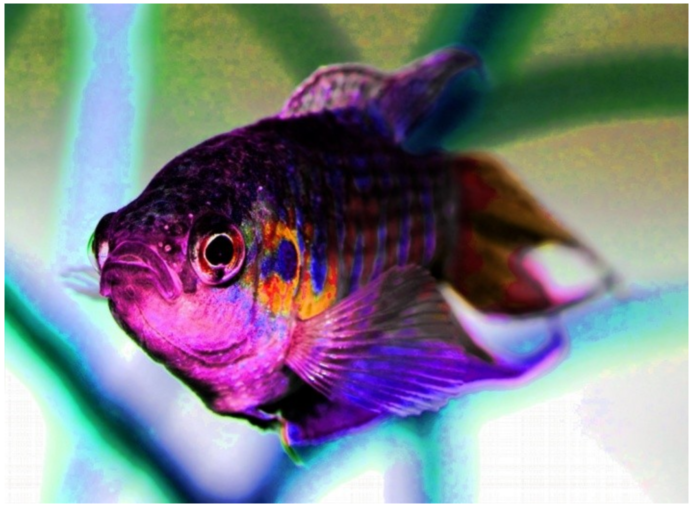


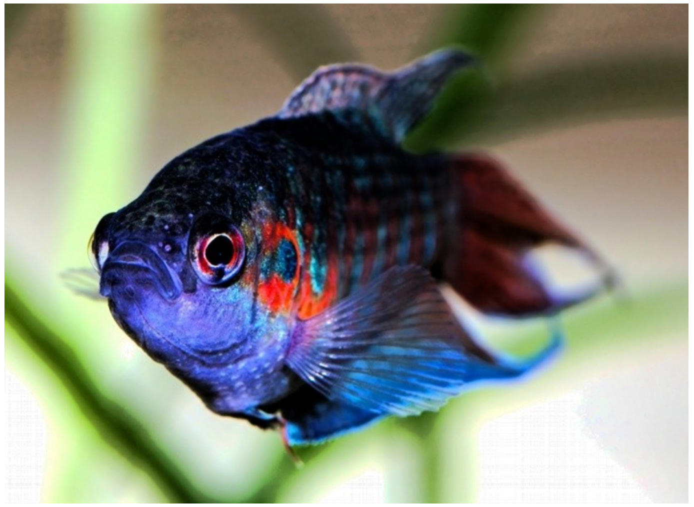
Gaussian filtered hue channel

More grey level methods on color images

- Histogram equalization on all channels in HSL can make things strange. Only used on the L channel the expected result is acquired.

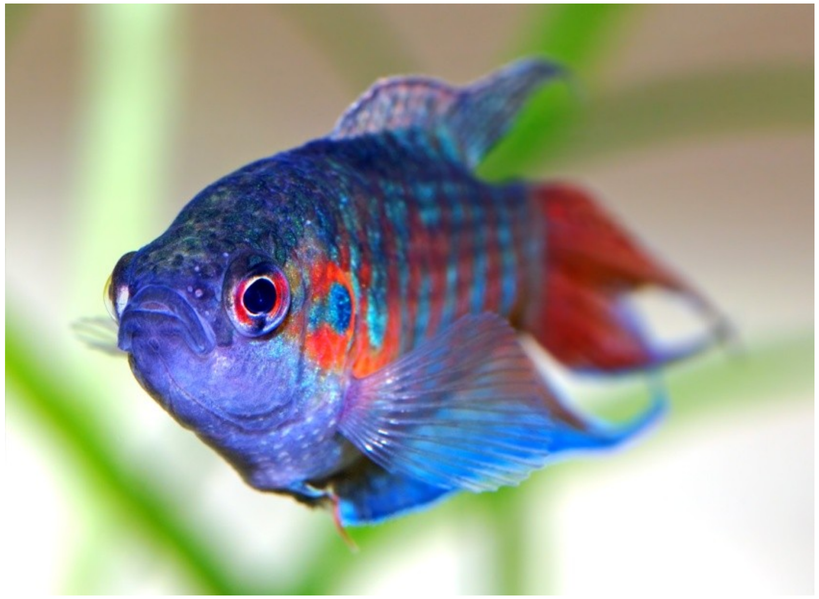

Original

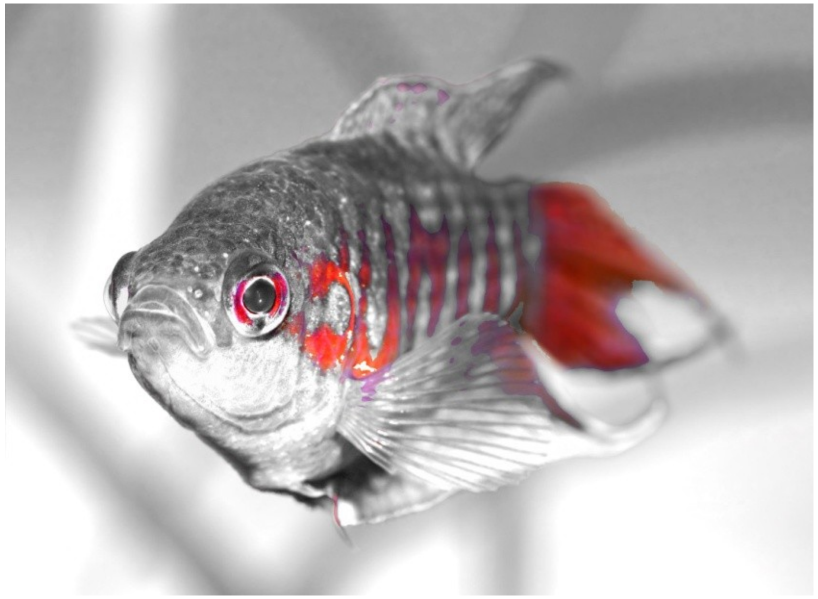

Histogram equalization in **all** channels


Histogram equalization in L channel

Segmentation Based on Hue

- Using a intensity decoupled color space segmentation based on color can be relative intuitive.
- Setting an interval for the hue around the hue value for red in HSL space the red part of the fish is segmented.





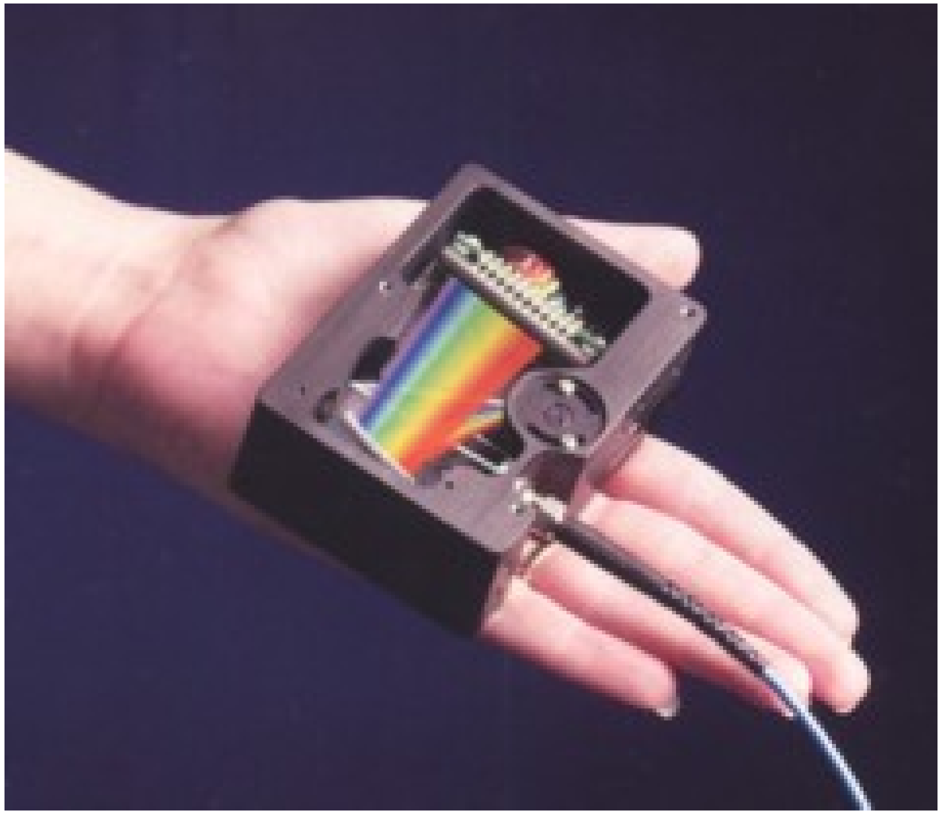
Segmented part of hue shown on the L channel.

Choosing Color Space

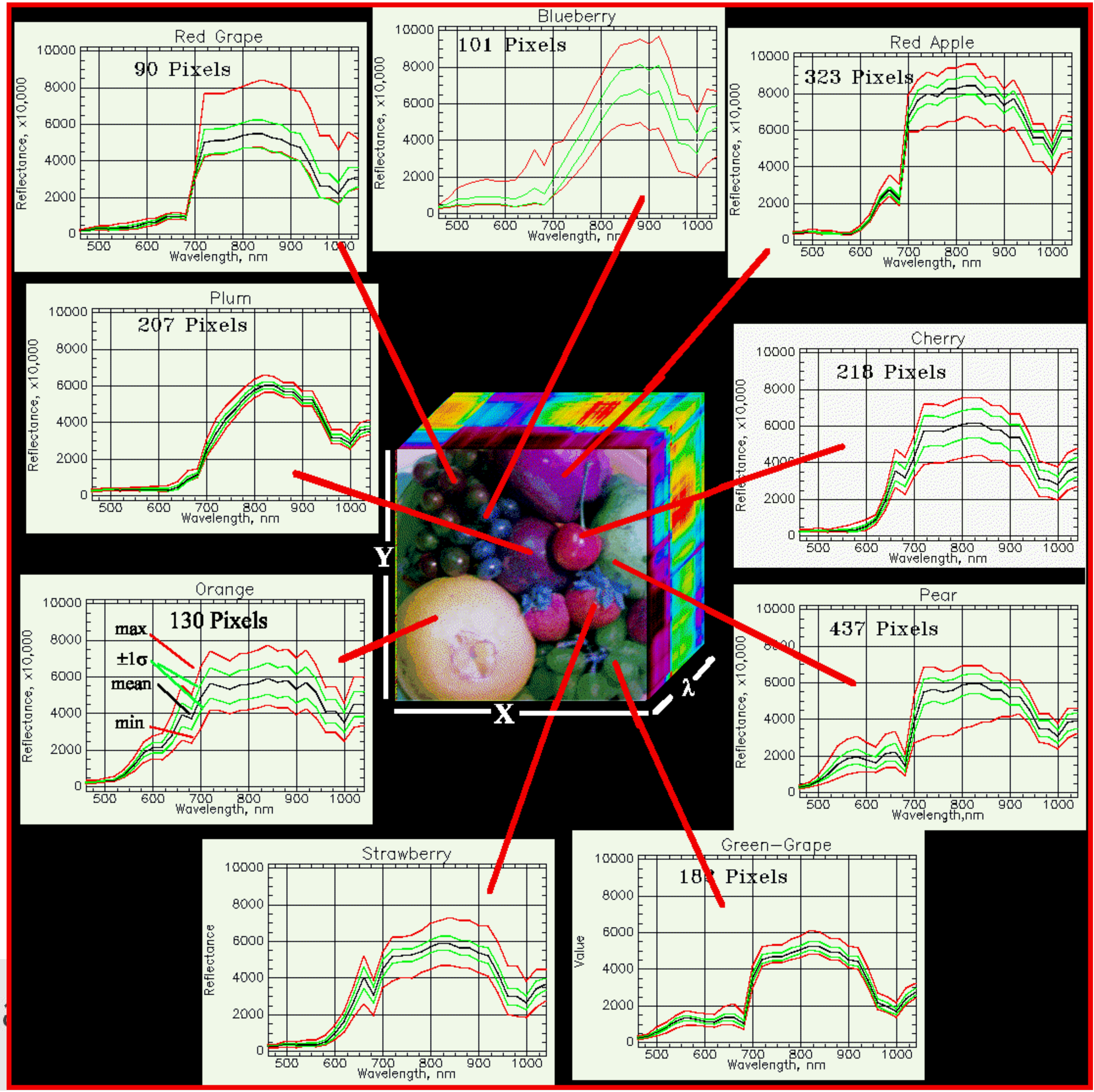
- A color space can be close to the hardware or close to the application. RGB is close to the output from a CCD, etc.
- Decoupled intensity can be very useful in image processing making it possible to use many grey-scale methods intuitively.
- Some spaces like HSL has a difficult transformation from, e.g., RGB. Singularities may exist.
- Regardless of which color space is used RGB is often the color space for the displaying device.

Spectrometer

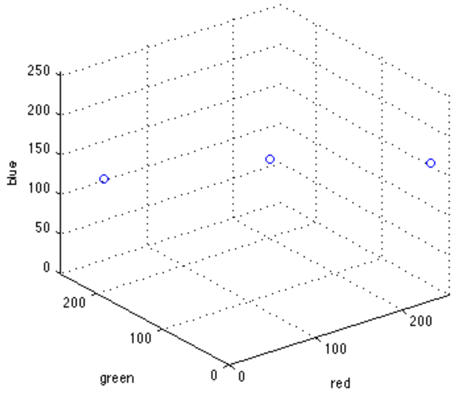
Ideally we measure the intensity for each wavelength of light over the entire range of interest. This can be done point by point by a spectrometer. Can easily provide thousands of measurement per pixel.

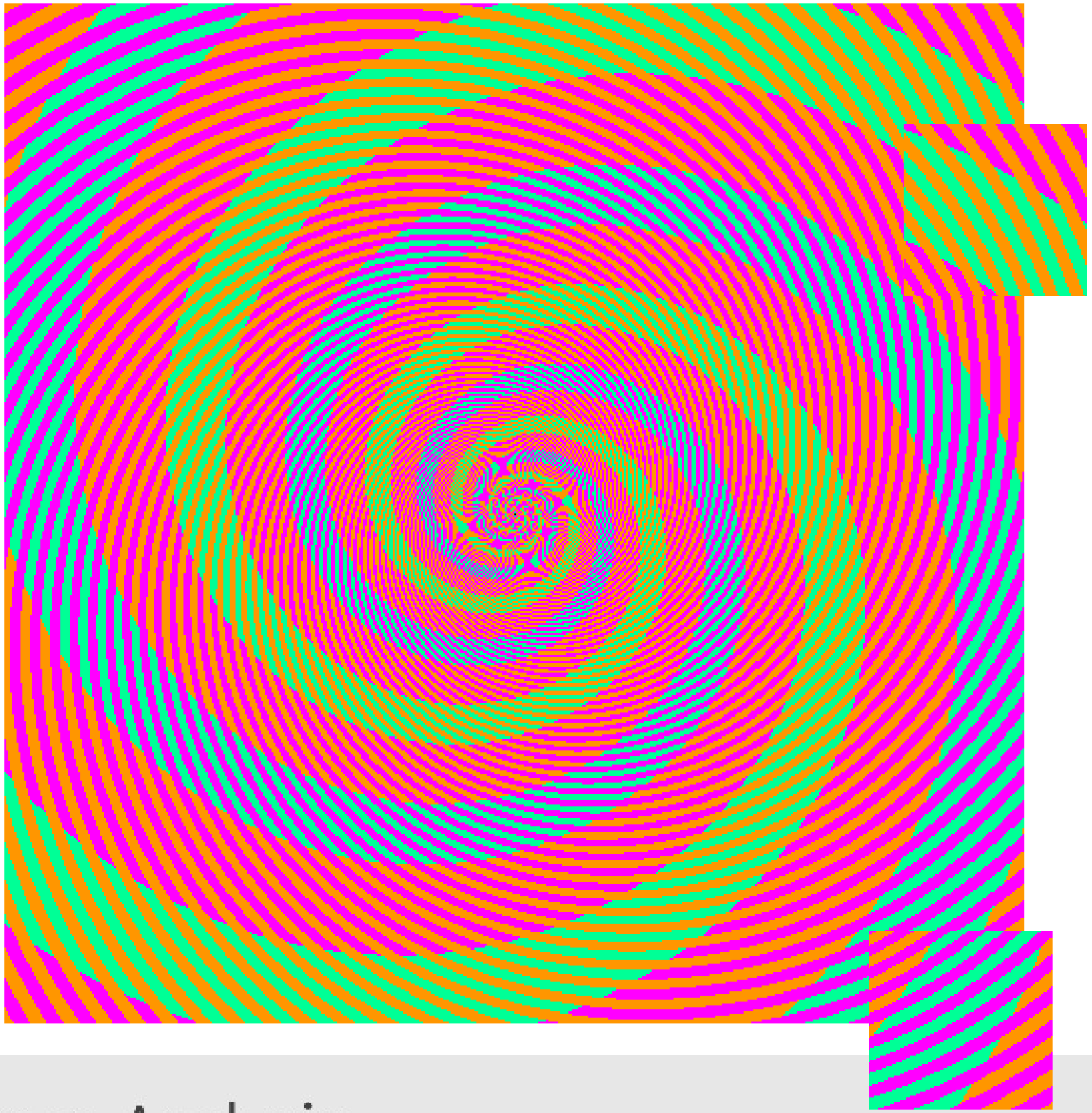


Each object in the image has its own spectrum



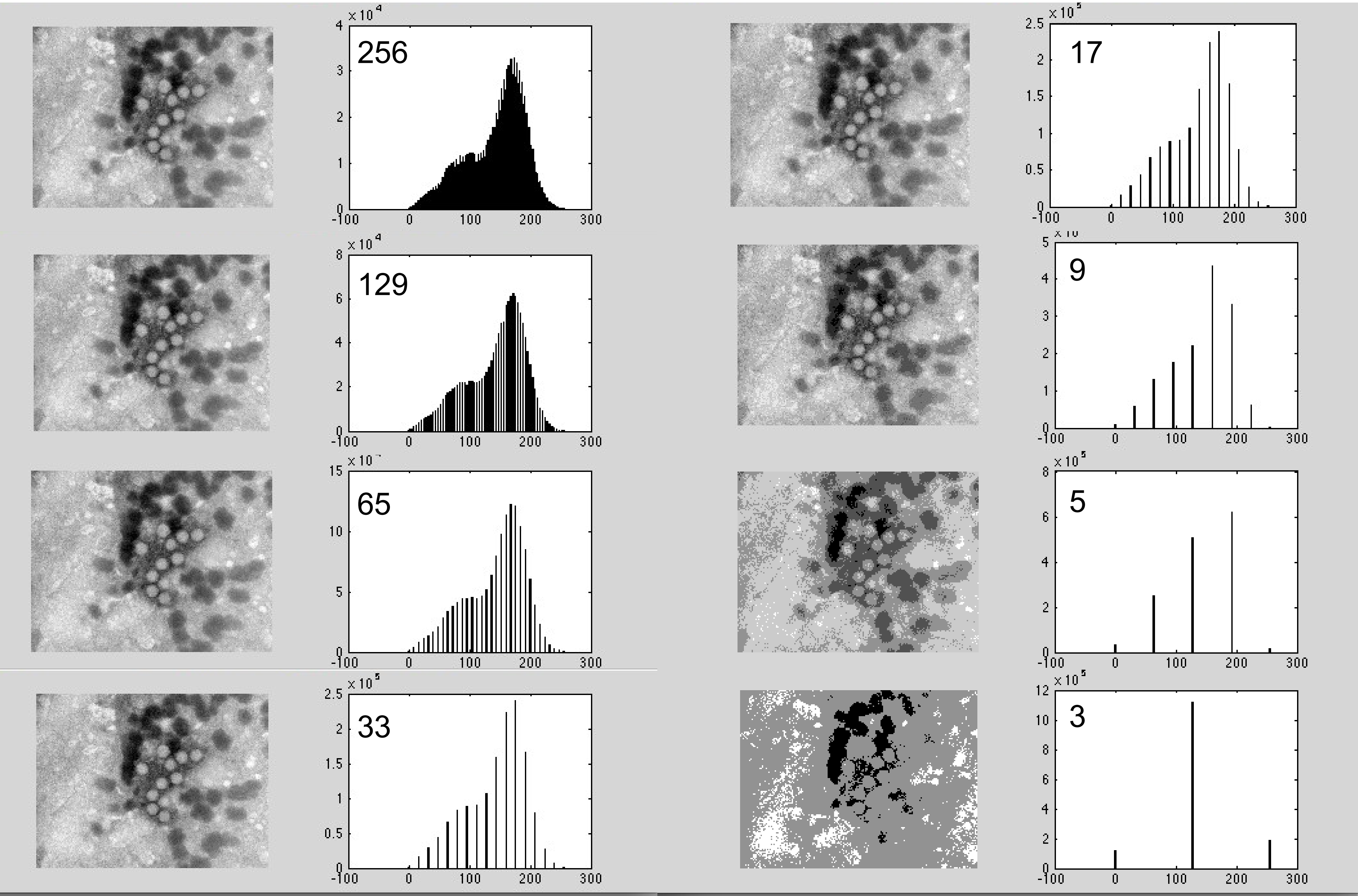
Why quantitative measurements of colors?





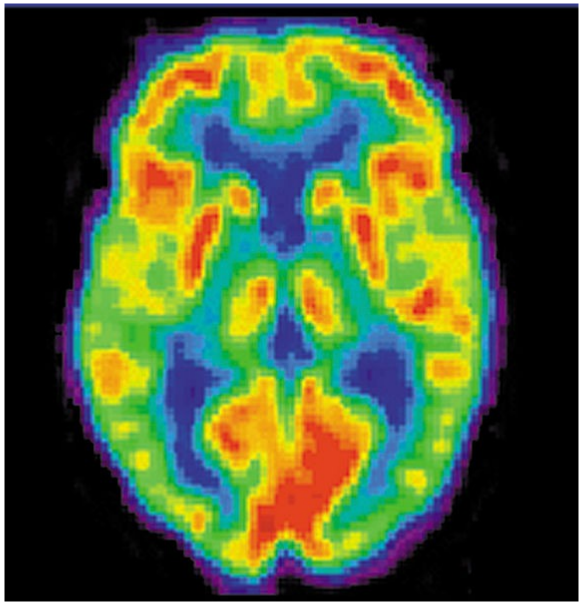
Intensity and visual information

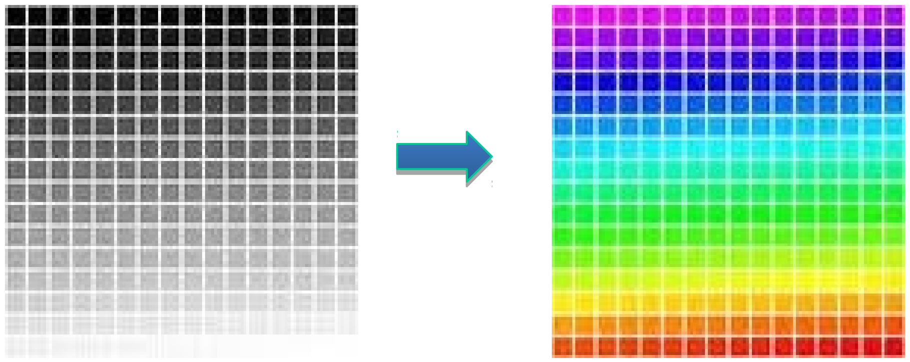
Microscopy images are often 12 or 16 bit images, meaning 4096 o
65536 different levels of gray, but the human eye can only
distinguish approximately 32 gray levels of locally.



Pseudo coloring

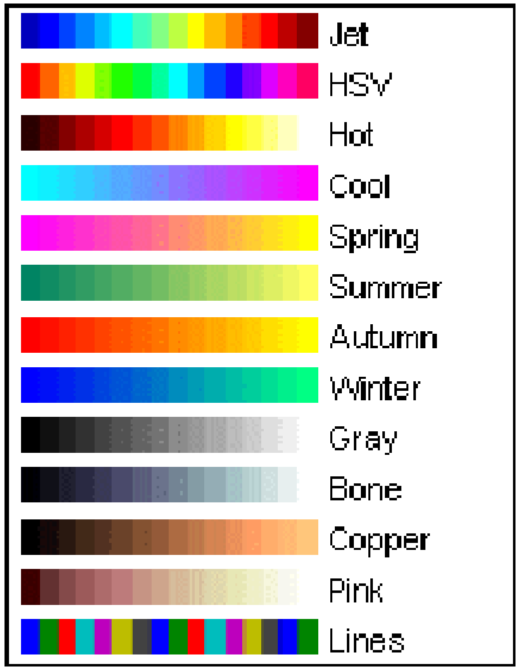
Example of pseudo-coloring in PET imaging

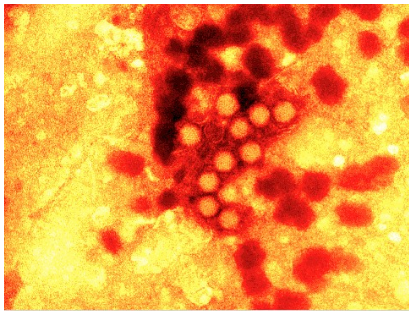




Each intensity value is mapped to a given color

Some popular color maps (from Matlab):





The viruses from the previous image, pseudo-colored using the color map 'Hot'

Pseudo-coloring makes small intensity differences more apparent as the human eye is better at seeing differences in color than in intensity

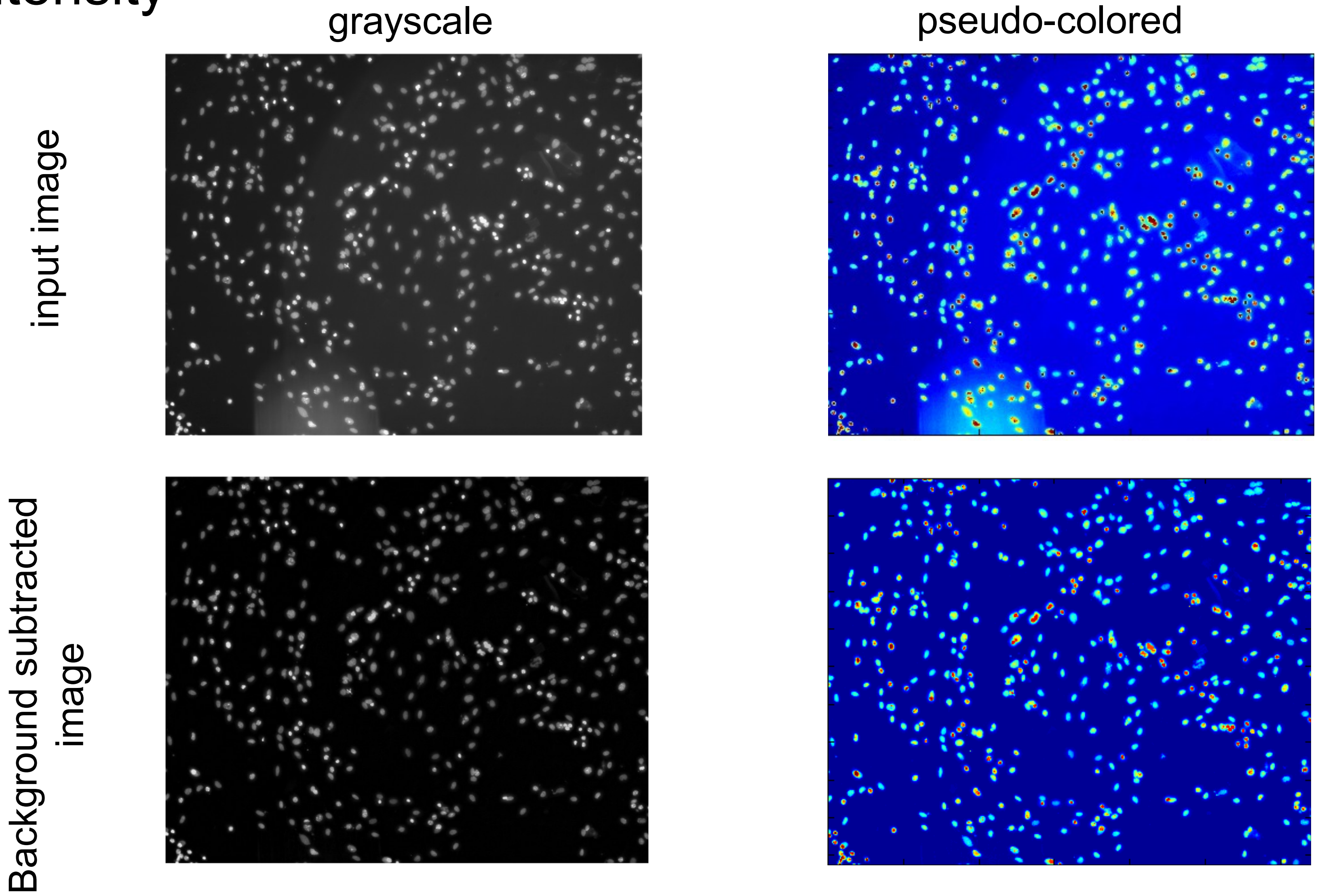


Image coding and compression

Redundancy
information and data

- *Data* is **not** the same thing as *information*.
- Data is the means with which information is expressed. The amount of data can be much larger than the amount of information.
- Redundant data doesn't provide additional information.
- Image coding or compression aims at reducing the amount of data while keeping the information by reducing the amount of redundancy.

Image Coding and Compression

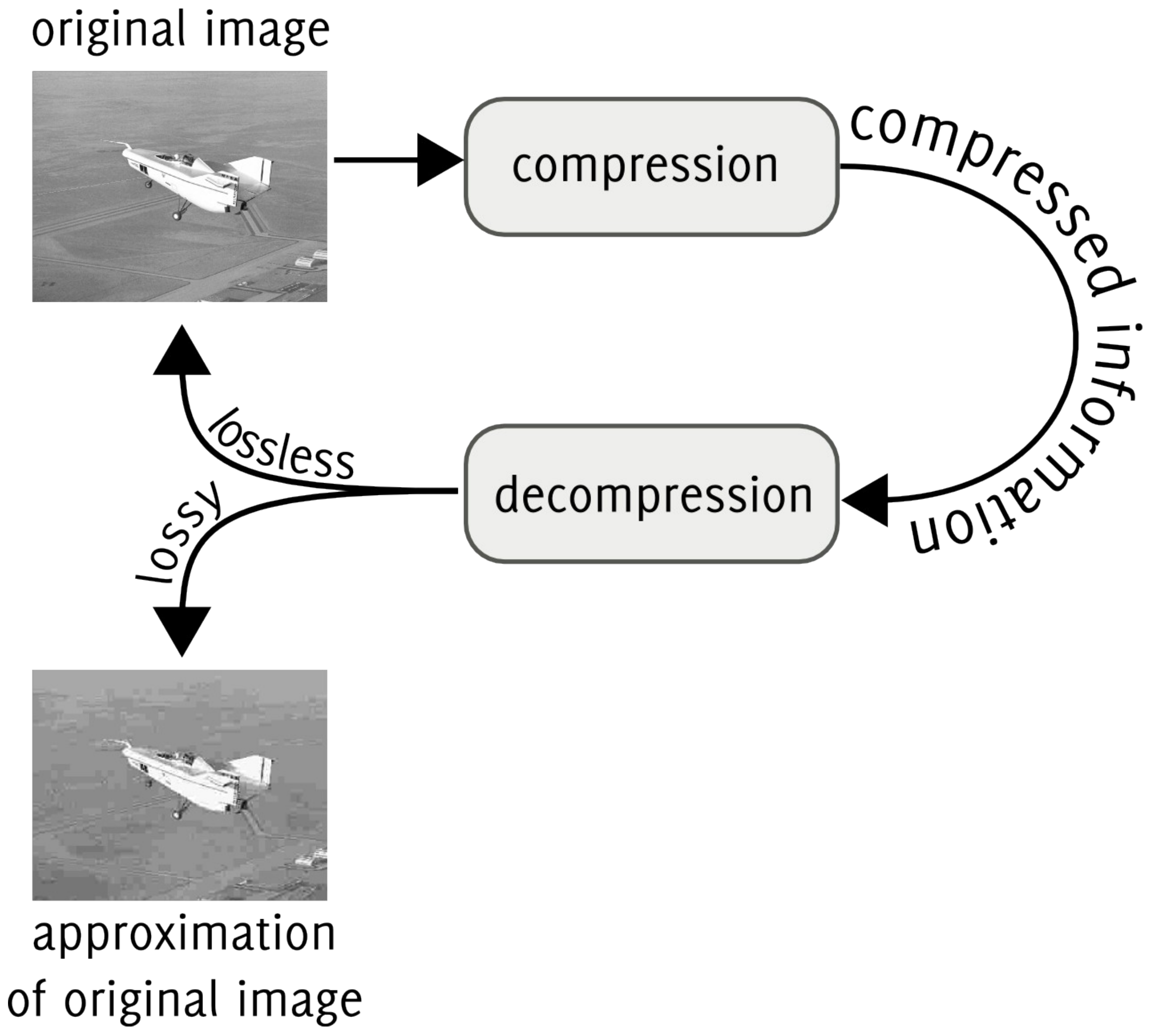


Image Compression

Image compression can be:

- **Reversible** (lossless), with no loss of information.
  - The image after compression and decompression is identical to the original image. Often necessary in image analysis applications.
  - The compression ratio is typically 2 to 10 times.
- **Non reversible** (lossy), with loss of some information.
  - Lossy compression is often used in image communication, compact cameras, video, www, etc.
  - The compression ratio is typically 10 to 30 times.

Image Coding and Compression

- Image coding
  - How the image data can be represented.
- Image compression
  - Reducing the amount of data required to represent an image.
  - Enabling efficient image storing and transmission.

Objective Measures of Image Quality

- Error

$$e(x,y) = \hat{f}(x,y) - f(x,y)$$

- Total Error

$$e_{tot} = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left(\hat{f}(x,y) - f(x,y)\right)$$

- Root-Mean-Square

$$e_{RMS} = \frac{1}{MN} \sqrt{\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left(\hat{f}(x,y) - f(x,y)\right)^2}$$

Subjective Measures of Image Quality

- Problem
  - The objective image quality measures previously shown does not always fit with our perception of image quality.
- Solution
  - Let a number of test persons rate the image quality of the images on a scale. This will result in a subjective measure of image quality, or rather fidelity, but it will be based on how we perceive the quality of the images.

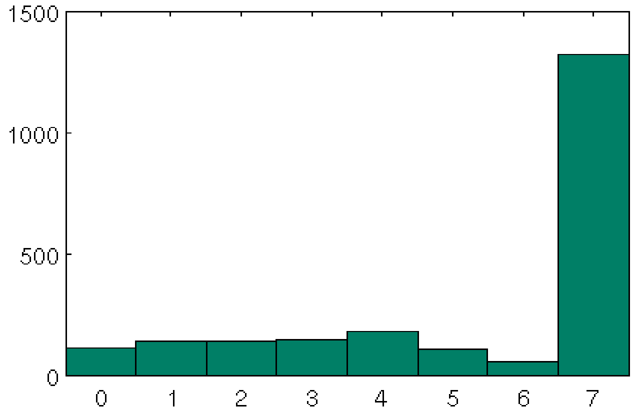
Measure the amount of data

- The amount of data in an $M \times N$ image with L gray levels is equal to MNL_{avg}, where

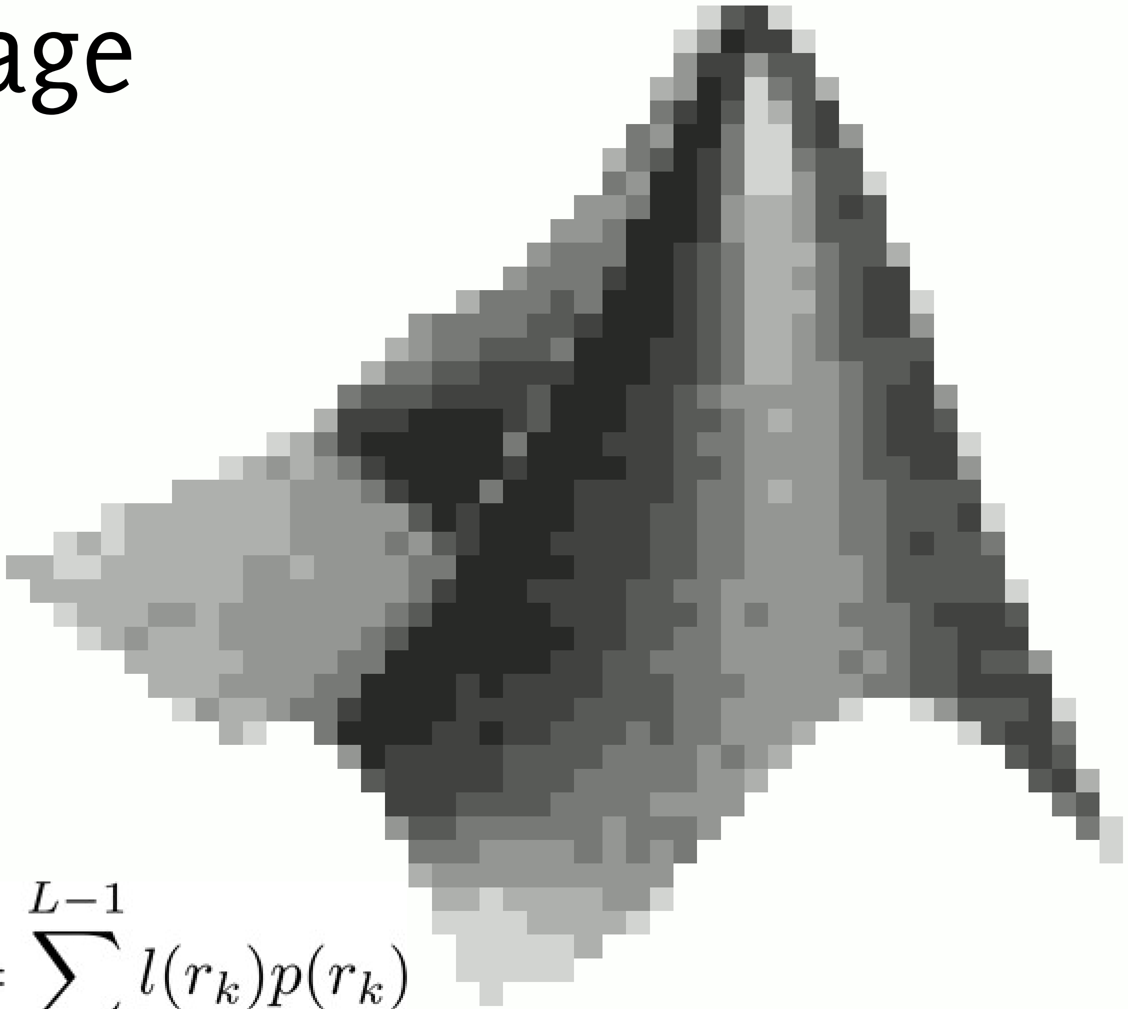
$$L_{avg} = \sum_{k=0}^{L-1} l(r_k)p(r_k),$$

$l(r_k)$ is the number of bits used to represent gray level and $p(r_k)$ is the probability of gray level r_k in the image.

Example 3-bit image



r_k	count	$p(r_k)$	source
0	113	0.051	000
1	139	0.063	001
2	142	0.064	010
3	145	0.066	011
4	181	0.082	100
5	105	0.047	101
6	52	0.023	110
7	1323	0.601	111

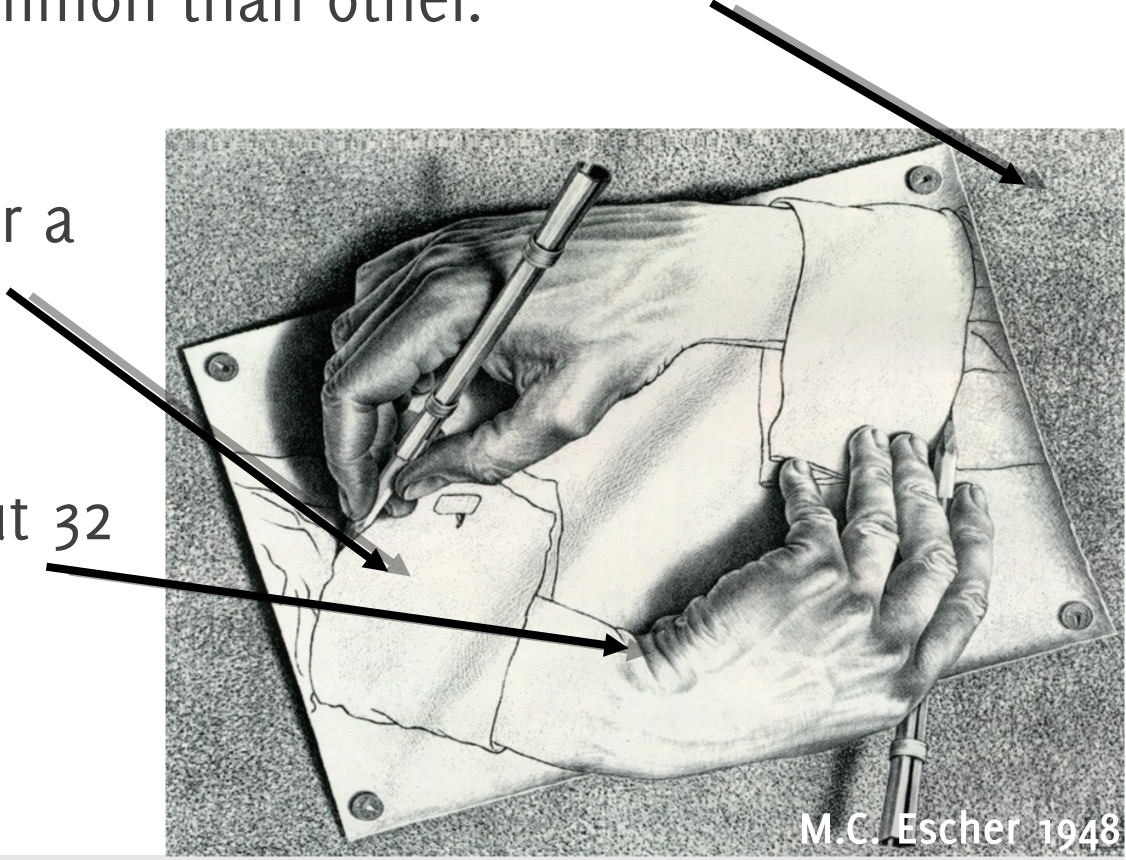


$$L_{avg} = \sum_{k=0}^{L-1} l(r_k)p(r_k)$$

$$L_{avg} = 3$$

Different Types of Redundancy

- Coding Redundancy
  - Some gray levels are more common than other.
- Interpixel redundancy
  - The same gray level may cover a large area.
- Psycho-Visual Redundancy
  - The eye can only resolve about 32 gray levels locally.



Coding redundancy

- **Basic idea:** Different gray levels occur with different probability (non uniform histogram). Use shorter code words for the more common gray levels and longer code words for less common gray levels. This is called *Variable Code Length*.

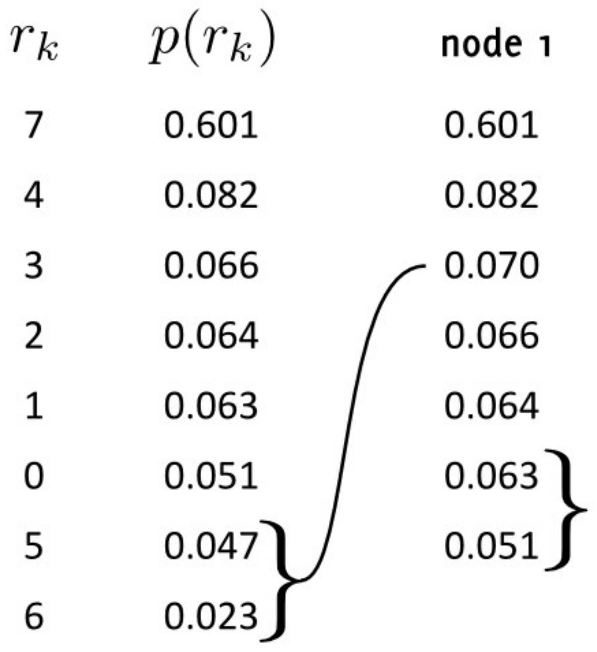
Huffman Coding

- **First**
  1. Sort the gray levels by decreasing probability
  2. Sum the two smallest probabilities.
  3. Sort the new value into the list.
  4. Repeat 1 to 3 until only two probabilities remains.
- Second
  1. Give the code 0 to the highest probability, and the code 1 to the lowest probability in the summed pair.
  2. Go backwards through the tree one node and repeat from 1 until all gray levels have a unique code.

Example of Huffman coding

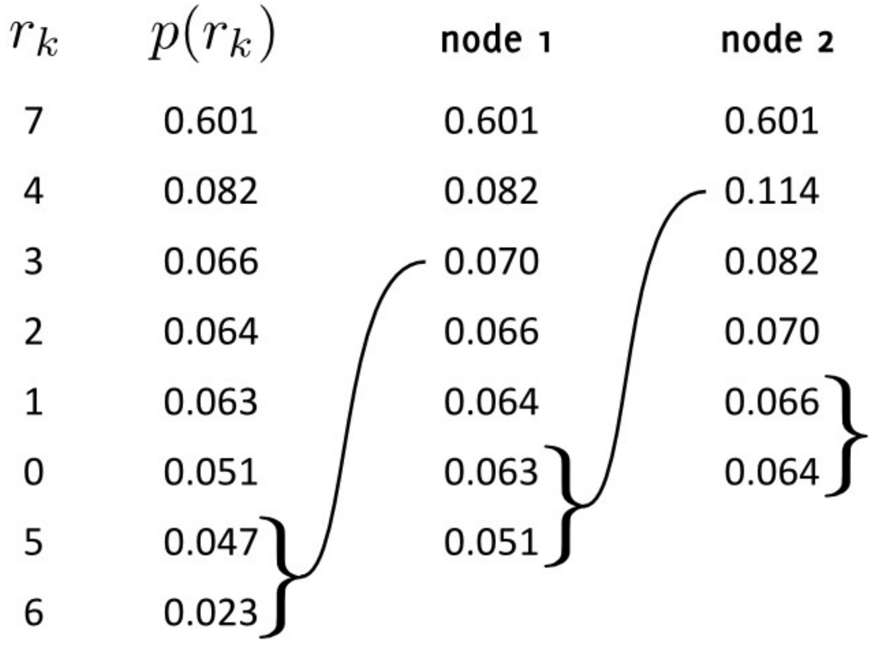
r_k	$p(r_k)$
7	0.601
4	0.082
3	0.066
2	0.064
1	0.063
0	0.051
5	0.047 $\rbrace$
6	0.023 $\rbrace$

Example of Huffman coding



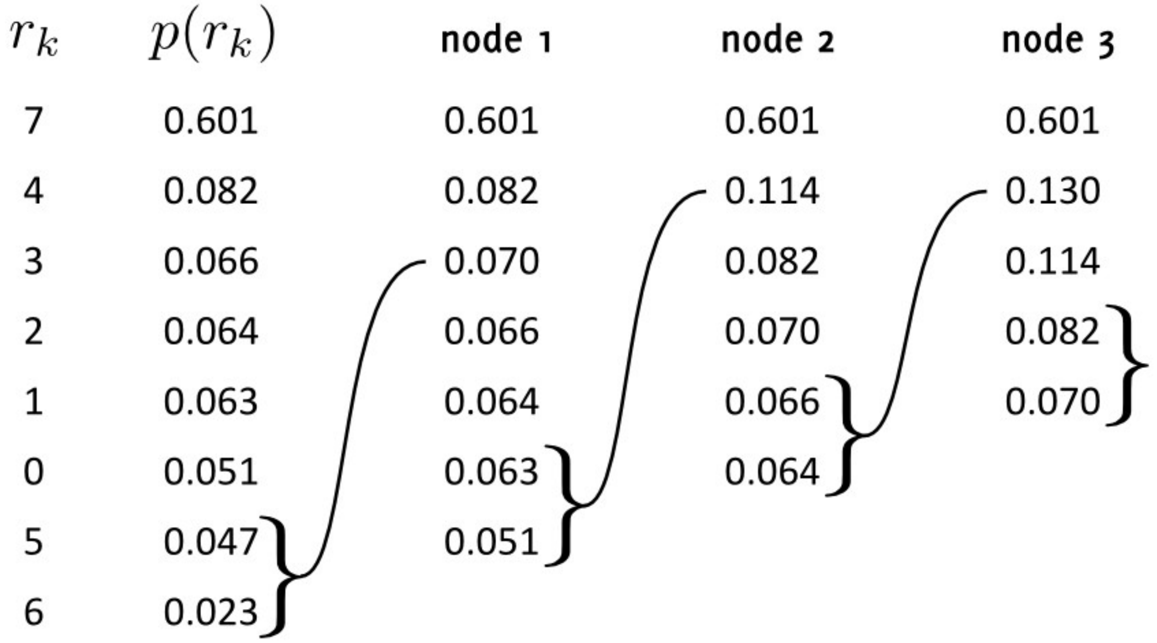
r_k	$p(r_k)$	node 1
7	0.601	0.601
4	0.082	0.082
3	0.066	0.070
2	0.064	0.066
1	0.063	0.064
0	0.051	0.063
5	0.047	0.051
6	0.023	

Example of Huffman coding



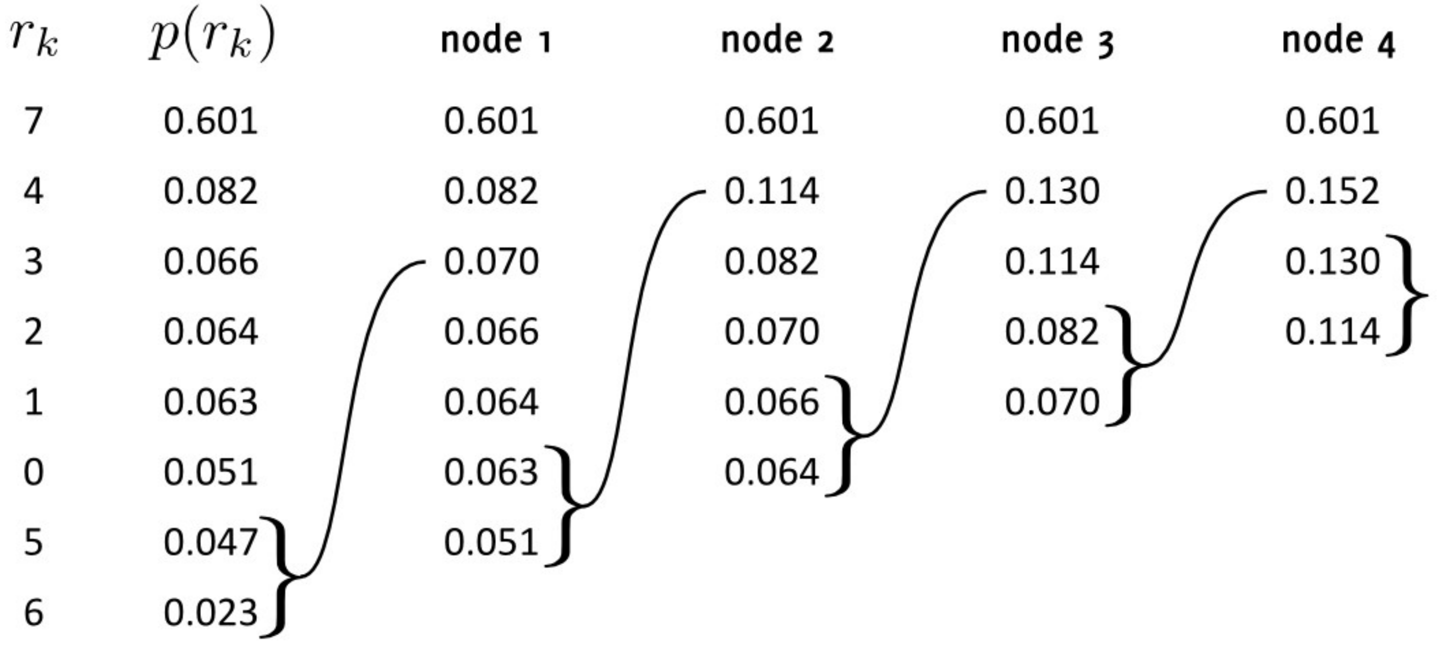
r_k	$p(r_k)$	node 1	node 2
7	0.601	0.601	0.601
4	0.082	0.082	0.114
3	0.066	0.070	0.082
2	0.064	0.066	0.070
1	0.063	0.064	0.066
0	0.051	0.063	0.064
5	0.047	0.051	
6	0.023		

Example of Huffman coding



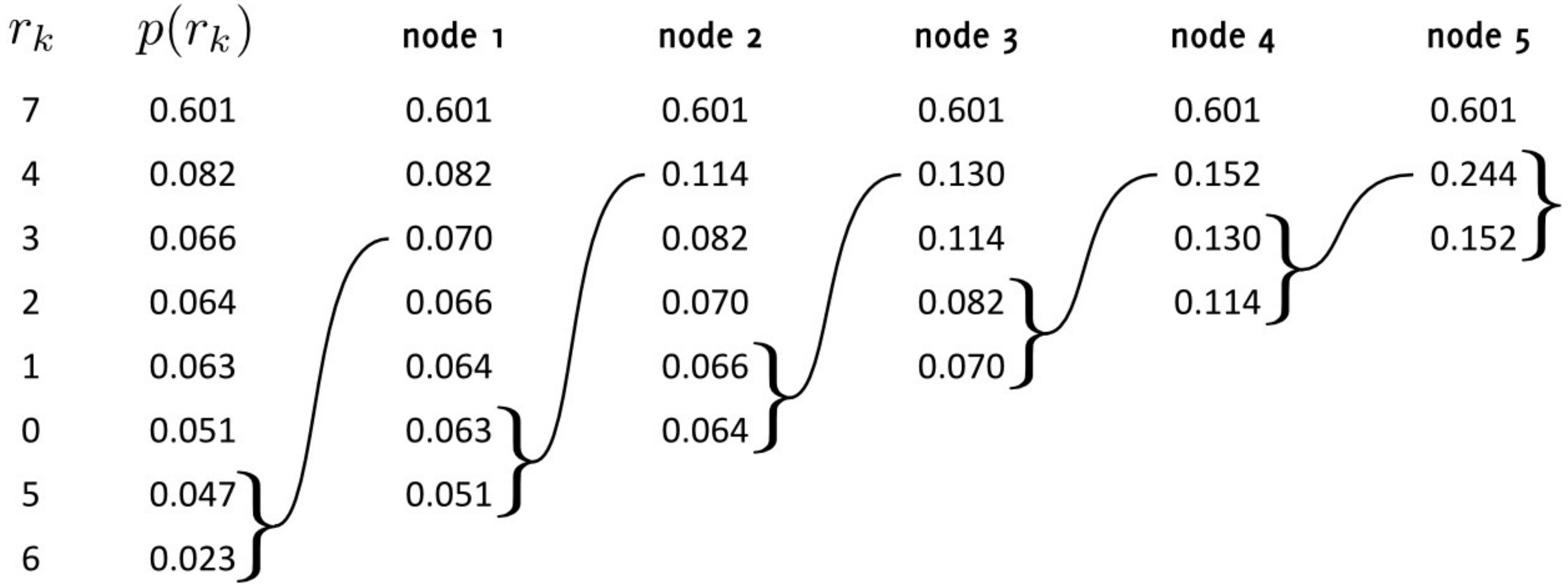
r_k	$p(r_k)$	node 1	node 2	node 3
7	0.601	0.601	0.601	0.601
4	0.082	0.082	0.114	0.130
3	0.066	0.070	0.082	0.114
2	0.064	0.066	0.070	0.082
1	0.063	0.064	0.066	0.070
0	0.051	0.063	0.064	
5	0.047	0.051		
6	0.023			

Example of Huffman coding



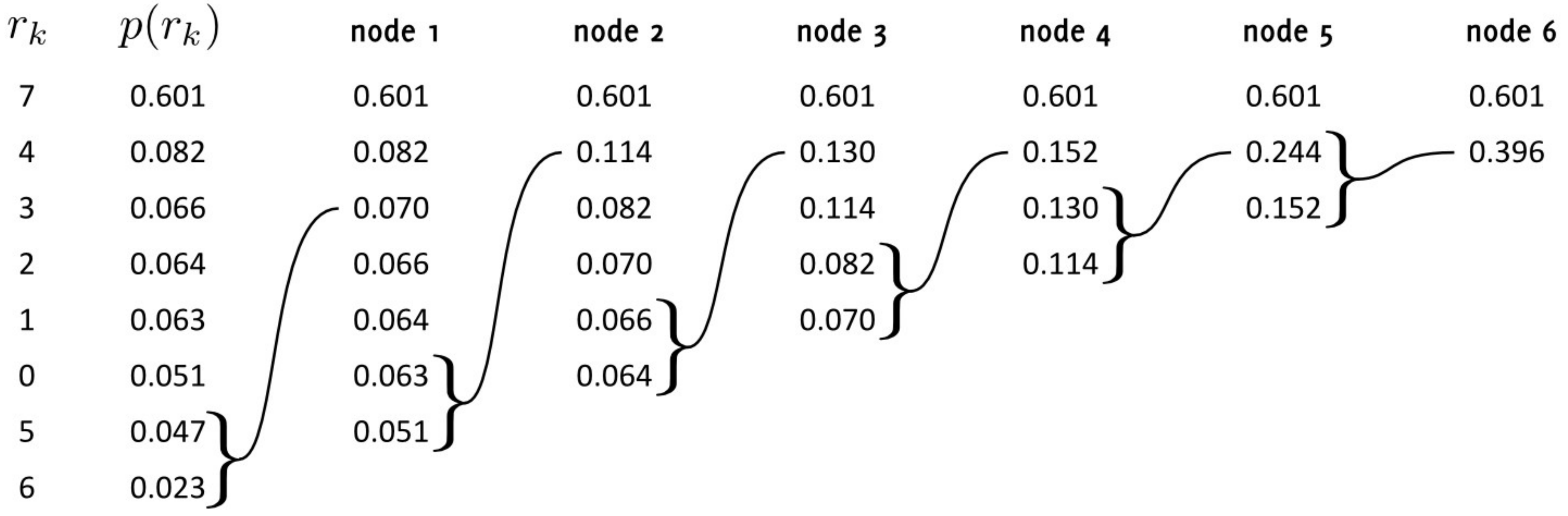
r_k	$p(r_k)$	node 1	node 2	node 3	node 4
7	0.601	0.601	0.601	0.601	0.601
4	0.082	0.082	0.114	0.130	0.152
3	0.066	0.070	0.082	0.114	0.130
2	0.064	0.066	0.070	0.082	0.114
1	0.063	0.064	0.066	0.070	
0	0.051	0.063	0.064		
5	0.047	0.051			
6	0.023				

Example of Huffman coding



r_k	$p(r_k)$	node 1	node 2	node 3	node 4	node 5
7	0.601	0.601	0.601	0.601	0.601	0.601
4	0.082	0.082	0.114	0.130	0.152	0.244
3	0.066	0.070	0.082	0.114	0.130	0.152
2	0.064	0.066	0.070	0.082	0.114	
1	0.063	0.064	0.066	0.070		
0	0.051	0.063	0.064			
5	0.047	0.051				
6	0.023					

Example of Huffman coding



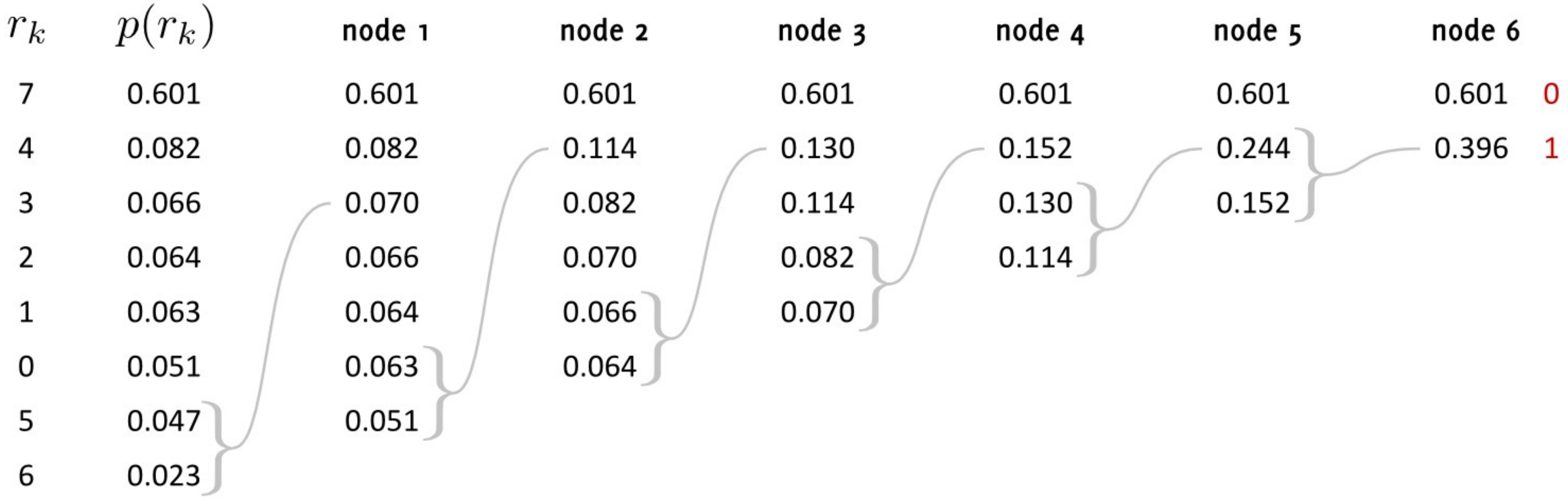
r_k	$p(r_k)$	node 1	node 2	node 3	node 4	node 5	node 6
7	0.601	0.601	0.601	0.601	0.601	0.601	0.601
4	0.082	0.082	0.114	0.130	0.152	0.244	0.396
3	0.066	0.070	0.082	0.114	0.130	0.152	
2	0.064	0.066	0.070	0.082	0.114		
1	0.063	0.064	0.066	0.070			
0	0.051	0.063	0.064				
5	0.047	0.051					
6	0.023						

Huffman Coding

- First
  1. Sort the gray levels by decreasing probability
  2. Add the two smallest probabilities.
  3. Sort the new value into the list.
  4. Repeat 1 to 3 until only two probabilities remains.
- Second
  1. Give the code 0 to the highest probability, and the code 1 to the lowest probability in the summed pair.
  2. Go backwards through the tree one node and repeat from 1 until all gray levels have a unique code.

Example of Huffman coding

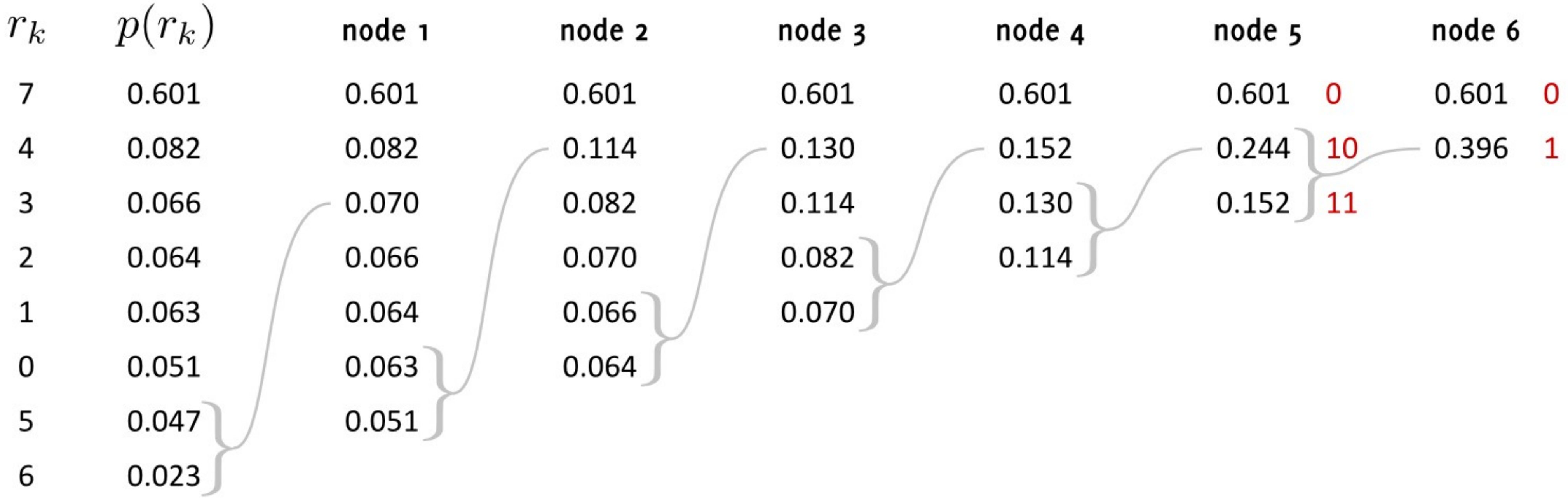
Assigning codes



r_k	$p(r_k)$	node 1	node 2	node 3	node 4	node 5	node 6	
7	0.601	0.601	0.601	0.601	0.601	0.601	0.601	0
4	0.082	0.082	0.114	0.130	0.152	0.244	0.396	1
3	0.066	0.070	0.082	0.114	0.130	0.152		
2	0.064	0.066	0.070	0.082	0.114			
1	0.063	0.064	0.066	0.070				
0	0.051	0.063	0.064					
5	0.047	0.051						
6	0.023							

Example of Huffman coding

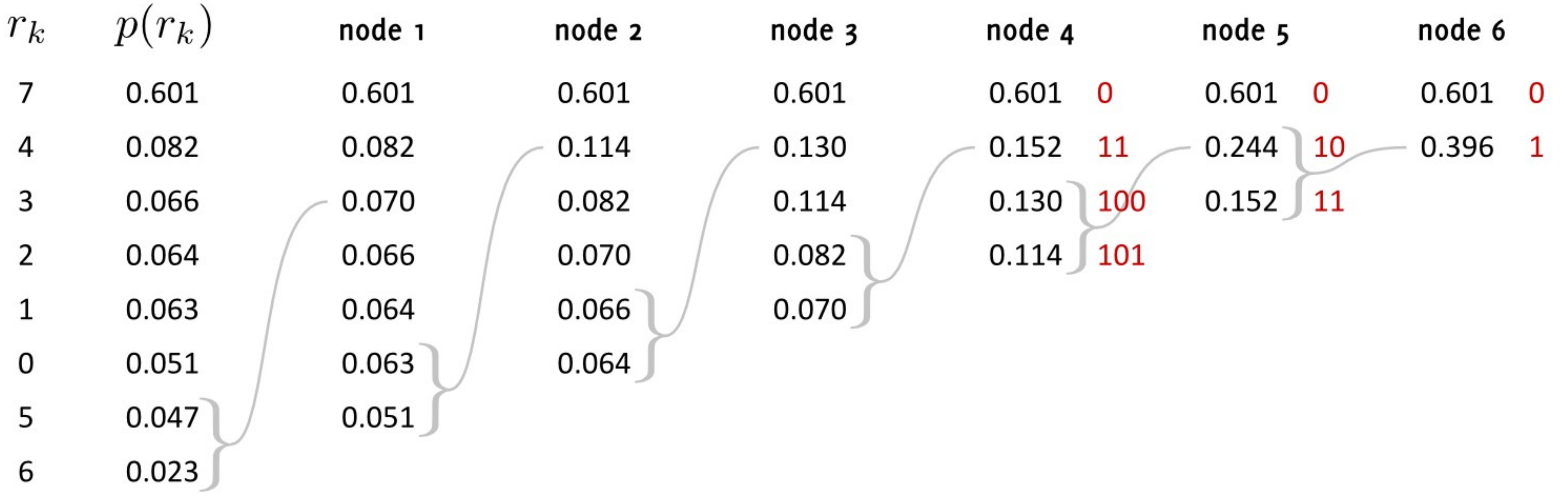
Assigning codes



r_k	$p(r_k)$	node 1	node 2	node 3	node 4	node 5		node 6	
7	0.601	0.601	0.601	0.601	0.601	0.601	0	0.601	0
4	0.082	0.082	0.114	0.130	0.152	0.244	10	0.396	1
3	0.066	0.070	0.082	0.114	0.130	0.152	11		
2	0.064	0.066	0.070	0.082	0.114				
1	0.063	0.064	0.066	0.070					
0	0.051	0.063	0.064						
5	0.047	0.051							
6	0.023								

Example of Huffman coding

Assigning codes



r_k	$p(r_k)$	node 1	node 2	node 3	node 4		node 5		node 6	
7	0.601	0.601	0.601	0.601	0.601	0	0.601	0	0.601	0
4	0.082	0.082	0.114	0.130	0.152	11	0.244	10	0.396	1
3	0.066	0.070	0.082	0.114	0.130	100	0.152	11		
2	0.064	0.066	0.070	0.082	0.114	101				
1	0.063	0.064	0.066	0.070						
0	0.051	0.063	0.064							
5	0.047	0.051								
6	0.023									

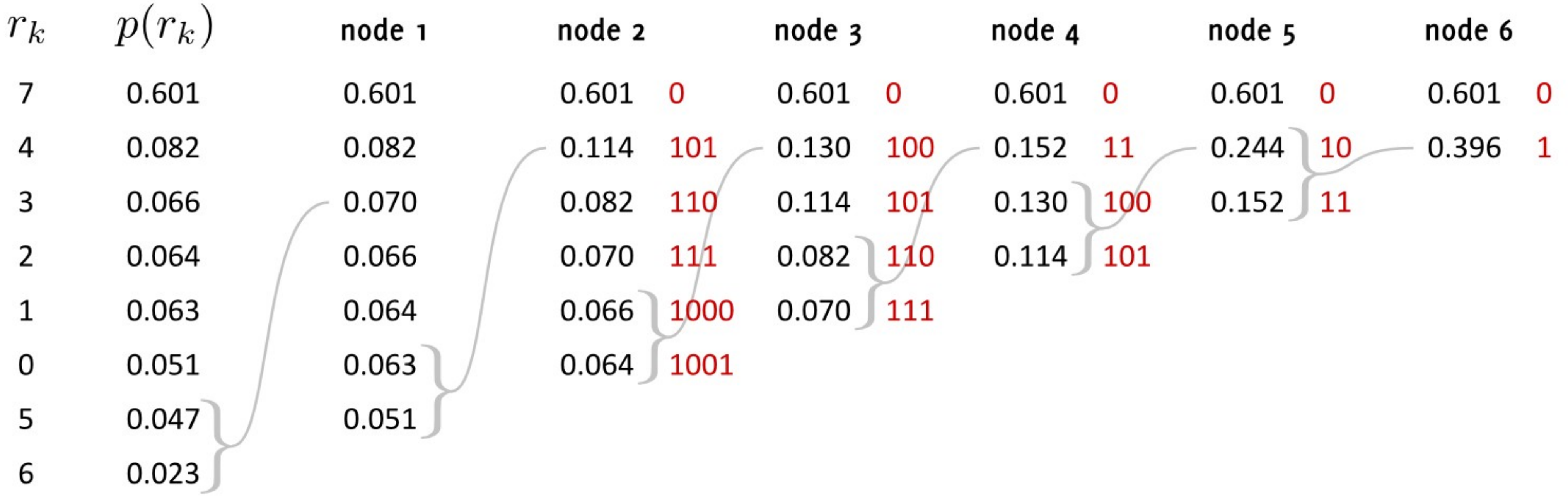
Example of Huffman coding

Assigning codes

r_k	$p(r_k)$	node 1	node 2	node 3		node 4		node 5		node 6	
7	0.601	0.601	0.601	0.601	0	0.601	0	0.601	0	0.601	0
4	0.082	0.082	0.114	0.130	100	0.152	11	0.244	10	0.396	1
3	0.066	0.070	0.082	0.114	101	0.130	100	0.152	11		
2	0.064	0.066	0.070	0.082	110	0.114	101				
1	0.063	0.064	0.066	0.070	111						
0	0.051	0.063	0.064								
5	0.047	0.051									
6	0.023										

Example of Huffman coding

Assigning codes



r_k	$p(r_k)$	node 1	node 2		node 3		node 4		node 5		node 6	
7	0.601	0.601	0.601	0	0.601	0	0.601	0	0.601	0	0.601	0
4	0.082	0.082	0.114	101	0.130	100	0.152	11	0.244	10	0.396	1
3	0.066	0.070	0.082	110	0.114	101	0.130	100	0.152	11		
2	0.064	0.066	0.070	111	0.082	110	0.114	101				
1	0.063	0.064	0.066	1000	0.070	111						
0	0.051	0.063	0.064	1001								
5	0.047	0.051										
6	0.023											

Example of Huffman coding

Assigning codes

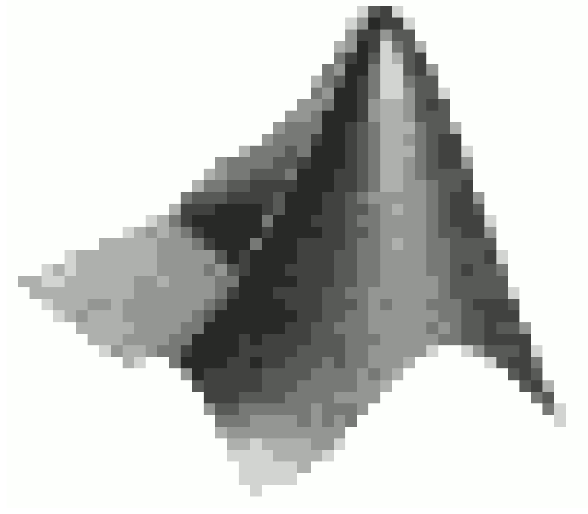
r_k	$p(r_k)$	node 1		node 2		node 3		node 4		node 5		node 6	
7	0.601	0.601	0	0.601	0	0.601	0	0.601	0	0.601	0	0.601	0
4	0.082	0.082	110	0.114	101	0.130	100	0.152	11	0.244	10	0.396	1
3	0.066	0.070	111	0.082	110	0.114	101	0.130	100	0.152	11		
2	0.064	0.066	1000	0.070	111	0.082	110	0.114	101				
1	0.063	0.064	1001	0.066	1000	0.070	111						
0	0.051	0.063	1010	0.064	1001								
5	0.047	0.051	1011										
6	0.023												

Example of Huffman coding

Assigning codes

r_k	$p(r_k)$	code	node 1		node 2		node 3		node 4		node 5		node 6	
7	0.601	0	0.601	0	0.601	0	0.601	0	0.601	0	0.601	0	0.601	0
4	0.082	110	0.082	110	0.114	101	0.130	100	0.152	11	0.244	10	0.396	1
3	0.066	1000	0.070	111	0.082	110	0.114	101	0.130	100	0.152	11		
2	0.064	1001	0.066	1000	0.070	111	0.082	110	0.114	101				
1	0.063	1010	0.064	1001	0.066	1000	0.070	111						
0	0.051	1011	0.063	1010	0.064	1001								
5	0.047	1110	0.051	1011										
6	0.023	1111												

Example of Huffman coding



r_k	$p(r_k)$	code
7	0.601	0
4	0.082	110
3	0.066	1000
2	0.064	1001
1	0.063	1010
0	0.051	1011
5	0.047	1110
6	0.023	1111

$$L_{avg} = \sum_{k=0}^{L-1} l(r_k)p(r_k) = 2.10$$

(Before Huffman coding $L_{avg} = 3$)

$$C_R = \frac{n_1}{n_2} = \frac{3}{2.10} = 1.43$$

$$R_D = 1 - \frac{1}{C_R} = \frac{n_1 - n_2}{n_1} = \frac{3-2.10}{3} = 0.3$$

Huffman Coding

- The Huffman code is completely reversible, i.e., lossless.
- The table for the translation has to be stored together with the coded image.
- The resulting code is unambiguous.
  - That is, for the previous example, the encoded string 011011101011 can only be parsed into the code words 0, 110, 1110, 1011 and decoded as 7, 4, 5, 0.
- The Huffman code does not take correlation between adjacent pixels into consideration.

Interpixel Redundancy

Also called spatial or geometric redundancy

- Adjacent pixels are often correlated, i.e., the value of neighboring pixels of an observed pixel can often be predicted from the value of the observed pixel.

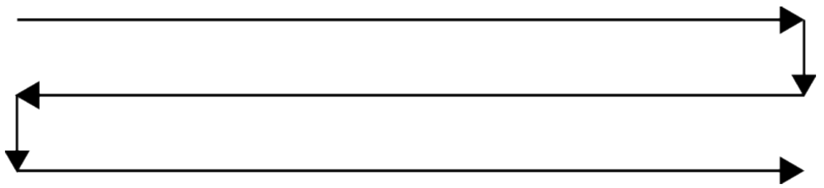
Run-length coding

- Every code word is made up of a pair (g,l) where g is the gray level, and l is the number of pixels with that gray level (length or "run").
- E.g.,

56	56	56	82	82	82	83	80
56	56	56	56	56	80	80	80

creates the run-length code (56,3)(82,3)(83,1)(80,4)(56,5)

- The code is calculated row by row.



Difference Coding

- Keep the first pixel in a row. The rest of the pixels are stored as the difference to the previous pixel
- Example:

original	56	56	56	82	82	82	83	80	80	80	80
code $f(x_i)$	56	0	0	26	0	0	1	-3	0	0	0

- The code is calculated row by row.
- Both run-length and difference coding are reversible and can be combined with, e.g., Huffman coding.

Example of Combined Difference and Huffman Coding

Original image

9	8	7	7	7	5	5	5
7	7	7	7	4	4	5	5
6	6	6	9	9	9	6	6
6	6	7	7	7	9	9	9
3	7	7	8	8	8	3	3
3	3	3	3	3	3	3	3
10	10	11	7	7	7	6	6
4	4	5	5	5	2	2	6

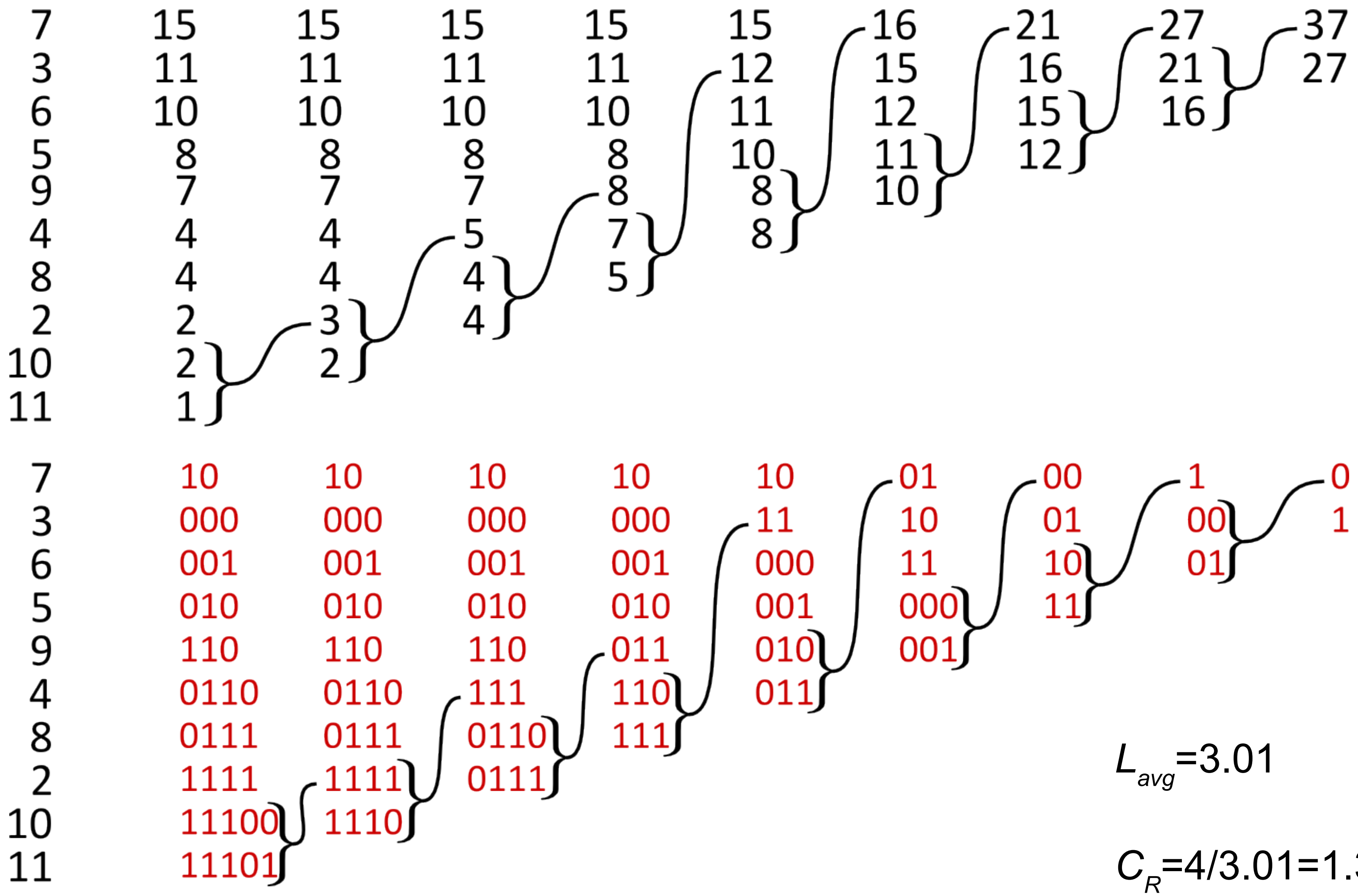
Difference image

9	-1	-1	0	0	-2	0	0
0	0	0	3	0	-1	0	0
-1	0	0	3	0	0	-3	0
0	-1	0	0	-2	0	0	3
-3	4	0	1	0	0	-5	0
0	0	0	0	0	0	0	0
7	0	1	-4	0	0	-1	0
0	-1	0	0	3	0	-4	0

Number of bits used to represent the gray scale values: 4

L_{avg}=4

Huffman Coding



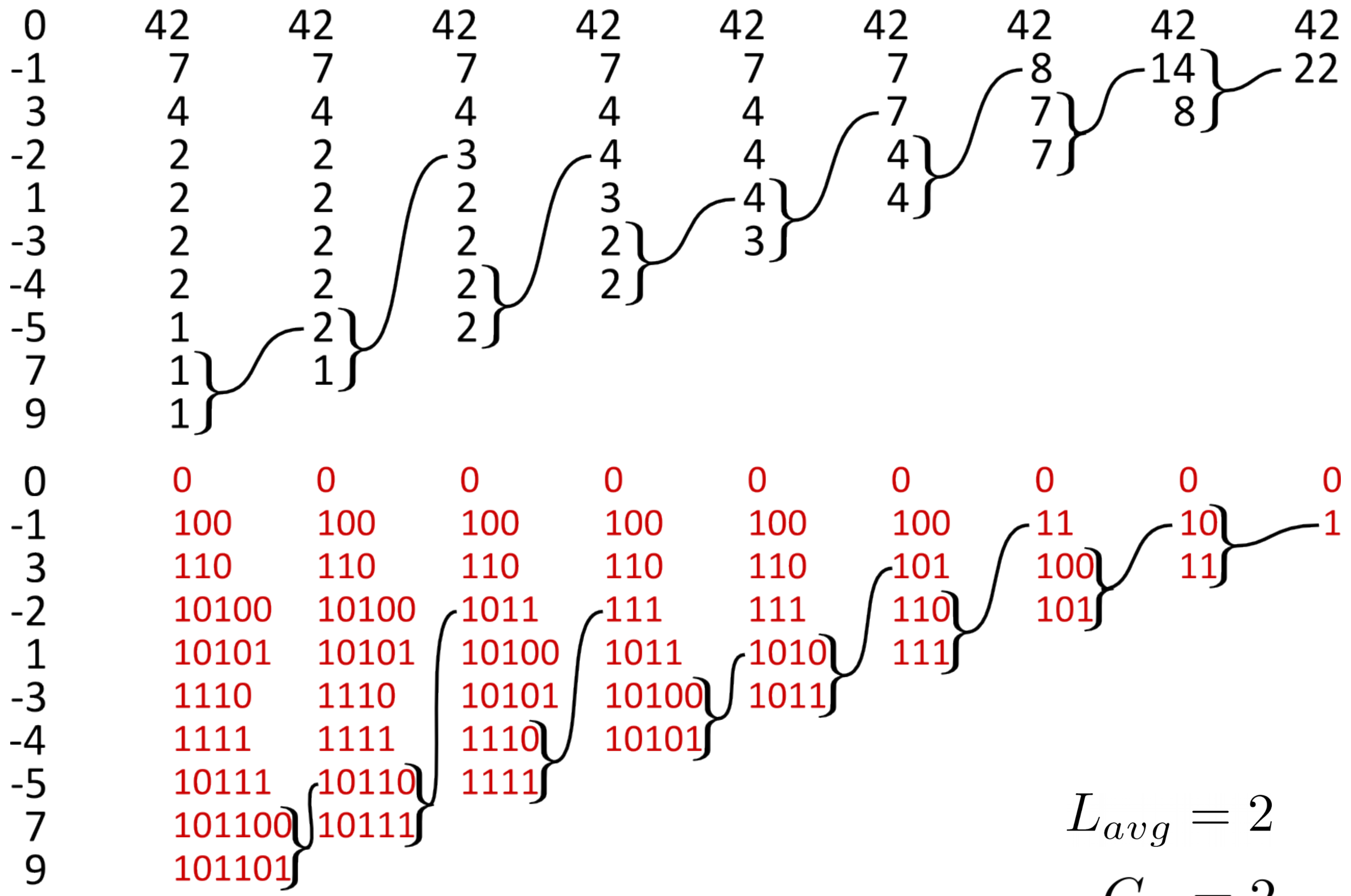
7	15	15	15	15	15	16	21	27	37
3	11	11	11	11	12	15	16	21	27
6	10	10	10	10	11	12	15	16	
5	8	8	8	8	10	11	12		
9	7	7	7	8	8	10			
4	4	4	5	7	8				
8	4	4	4	5					
2	2	3	4						
10	2	2							
11	1								

7	10	10	10	10	10	01	00	1	0
3	000	000	000	000	11	10	01	00	1
6	001	001	001	001	000	11	10	01	
5	010	010	010	010	001	000	11		
9	110	110	110	011	010	001			
4	0110	0110	111	110	011				
8	0111	0111	0110	111					
2	1111	1111	0111						
10	11100	1110							
11	11101								

L_{avg}=3.01

C_R=4/3.01=1.33

Difference Coding and Huffman Coding



0	42	42	42	42	42	42	42	42	42
-1	7	7	7	7	7	7	8	14	22
3	4	4	4	4	4	7	7	8	
-2	2	2	3	4	4	4	7		
1	2	2	2	3	4	4			
-3	2	2	2	2	3				
-4	2	2	2	2					
-5	1	2	2						
7	1	1							
9	1								

0	0	0	0	0	0	0	0	0	0
-1	100	100	100	100	100	100	11	10	1
3	110	110	110	110	110	101	100	11	
-2	10100	10100	1011	111	111	110	101		
1	10101	10101	10100	1011	1010	111			
-3	1110	1110	10101	10100	1011				
-4	1111	1111	1110	10101					
-5	10111	10110	1111						
7	101100	10111							
9	101101								

$$L_{avg} = 2$$

$$C_R = 2$$

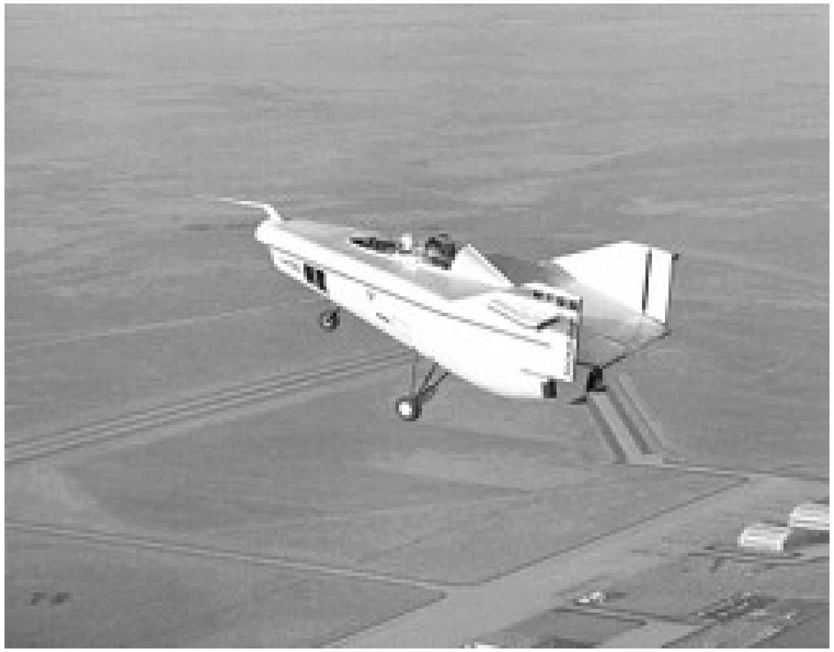
Coding and Interpixel redundancy methods

- Coding redundancy: Huffman coding
- Coding and interpixel redundancy: LZW, Lempel-Ziv-Welch
- Interpixel redundancy: run-length coding, difference coding

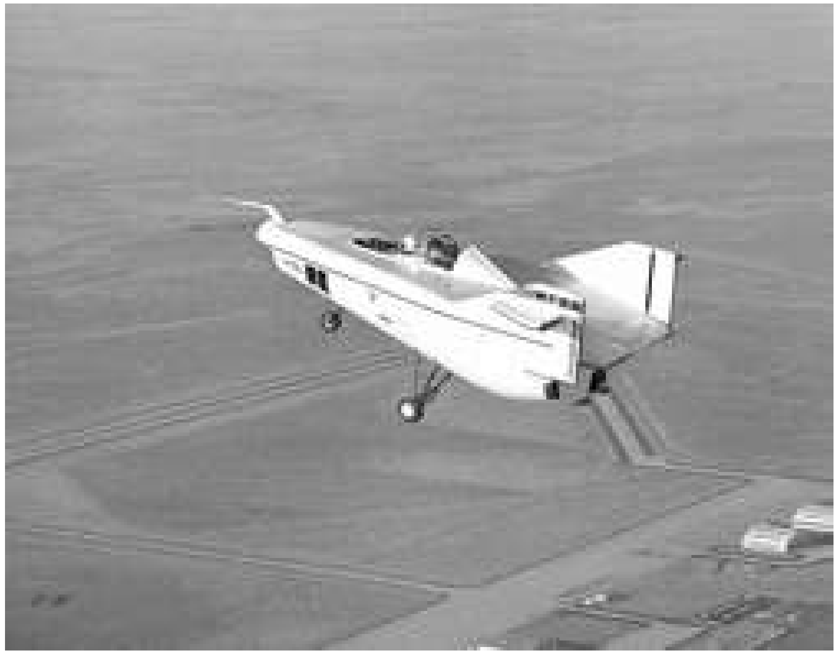
Psycho-Visual Redundancy

- If the image will only be used for visual observation much of the information is usually psycho-visual redundant. It can be removed without changing the visual quality of the image. This kind of compression is usually lossy.

50 kB (uncompressed TIFF)

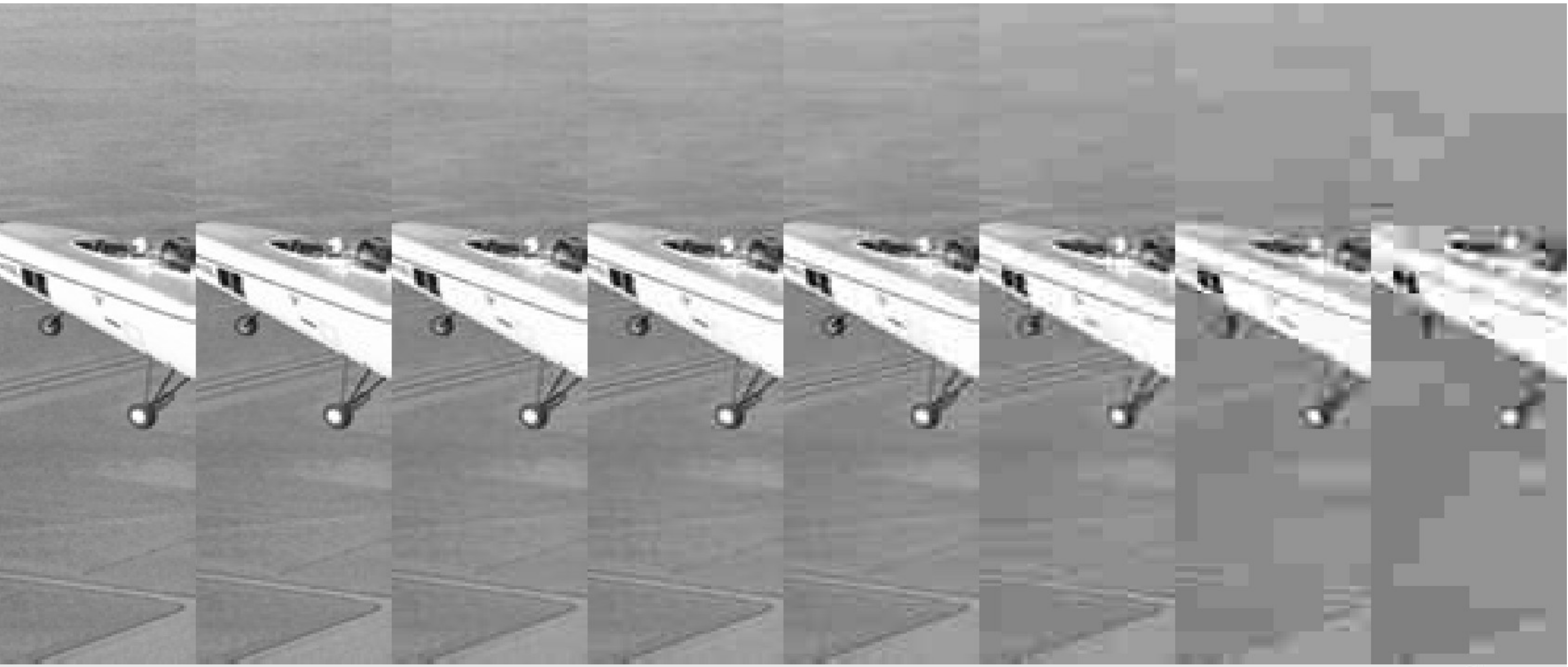


5 kB (JPEG)



JPEG: example of transform coding

File size in bytes	9486	3839	2086	1711	1287	822	533	380
JPEG quality	100 %	90 %	80 %	60 %	40 %	20 %	10 %	5 %



File Formats with **Lossy** Compression

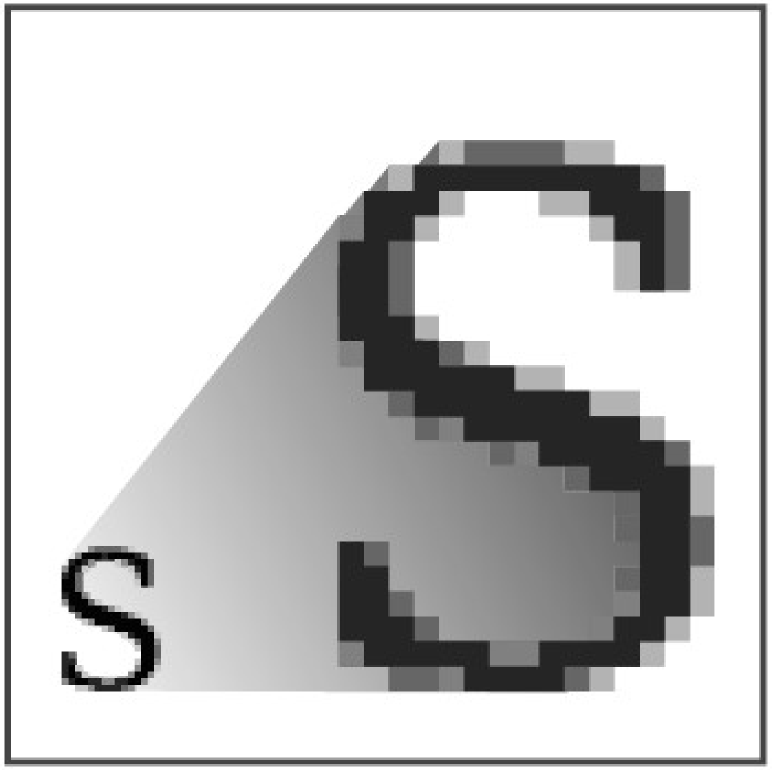
- **JPEG,** **J**oint **P**hotographic **E**xperts **G**roup, based on a cosine transform on 8x8 pixel blocks and Run-Length coding. Give rise to ringing and block artifacts. (`.jpg .jpe .jpeg`)
- **JPEG2000,** created by the **J**oint **P**hotographic **E**xperts **G**roup in **2000.** Based on *wavelet* transform. Give rise only to ringing artifacts and allows flexible decompression (progressive transmission, region of interest, ...) and reading. (`.jp2 .jpx`)

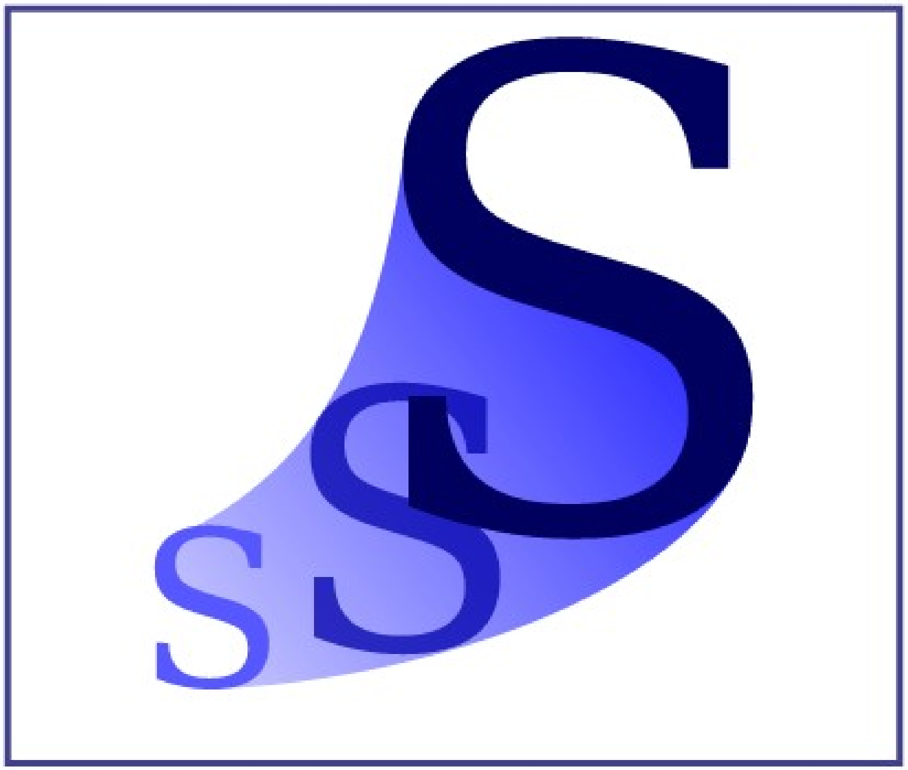
File Formats with **Lossless** Compression

- **TIFF**, **T**agged **I**mage **F**ile **F**ormat, flexible format often supporting up to 16 bits/pixel in 4 channels. Can use several different compression methods, e.g., Huffman, LZW.
- **GIF, G**raphics **I**nterchange **F**ormat. Supports 8 bits/pixel in one channel, that is only 256 colors. Uses LZW compression. Supports animations.
- **PNG, P**ortable **N**etwork **G**raphics, supports up to 16 bits/pixel in 4 channels (RGB + transparency). Uses Deflate compression (~LZW and Huffman). Good when interpixel redundancy is present.

Vector based file formats

- Uses predefined shapes





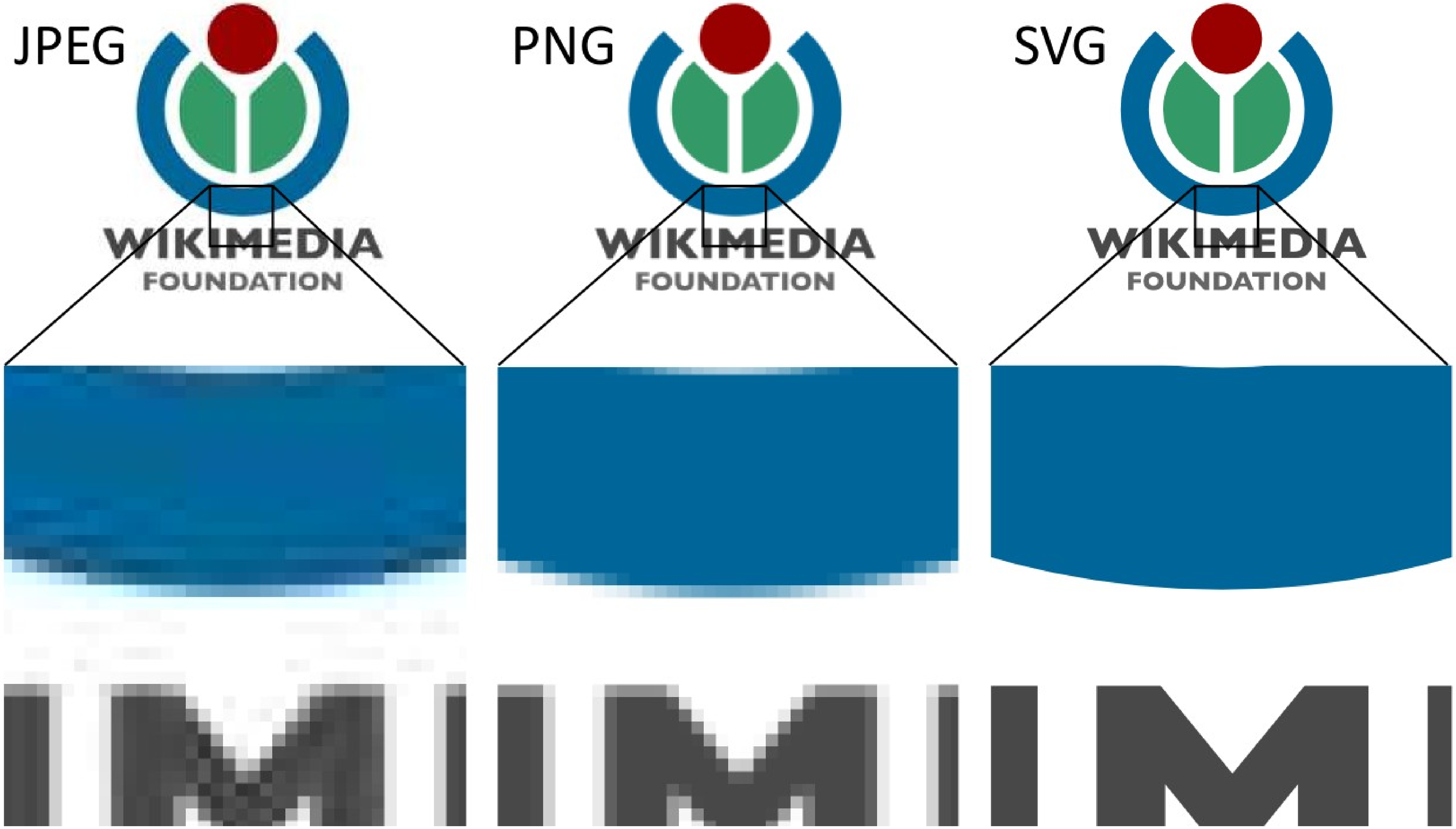
Vector based file formats

- **PS**, **P**ost**S**cript, is a page description language developed in 1982 for sending text documents to printers.
- **EPS, E**ncapsulated **P**ost**S**cript, like PS but can embed raster images internally using the TIFF format.
- **PDF**, **P**ortable **D**ocument **F**ormat, widely used for documents and are supported by a wide range of platforms. Supports embedding of fonts and raster/bitmap images. Beware of the choice of coding. Both lossy and lossless compressions are supported.
- **SVG, S**calable **V**ector **G**raphics, based on XML supports both static and dynamic content. All major web browsers supports it (Internet Explorer from version 9).

Choosing image file format

- Image analysis
  - Lossless formats are vital. TIFF supports a wide range of different bit depths and lossless compression methods.
- Images for use on the web
  - JPEG for photos (JPEG2000), PNG for illustrations. GIF for small animations. Vector format: SVG, nowadays supported by web browsers.
- Line art, illustrations, logotypes, etc.
  - Lossless formats such as PNG etc. (or a vector format)

Lossy, lossless, and vector graphics



Summary

Color
- Color spaces
- Multispectral images
- Pseudocoloring
- Color image processing

Coding/Compression
- Information and Data
- Redundancy
- Coding
- Compression
- File formats