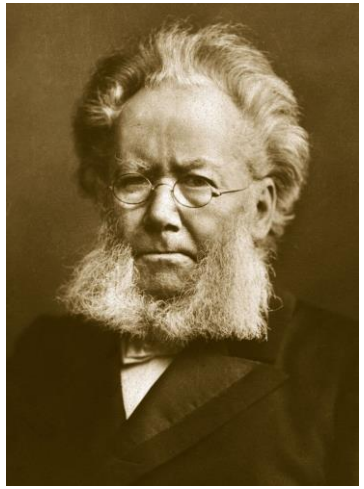
Digital Image Processing

Part 2: Digital Image Structure

By D.J. Lopez, CCpE, M.Sc.

A Picture is worth a Thousand Words

"A Picture is worth a thousand words"

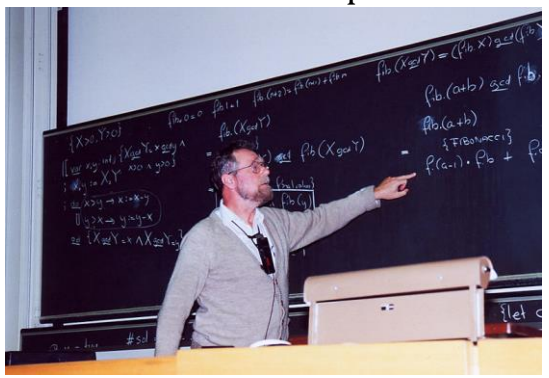


Henrik Ibsen

"百聞不如一見"

Confucius

"A picture may be worth a thousand words, a formula is worth a thousand pictures"



Edsger Dijkstra

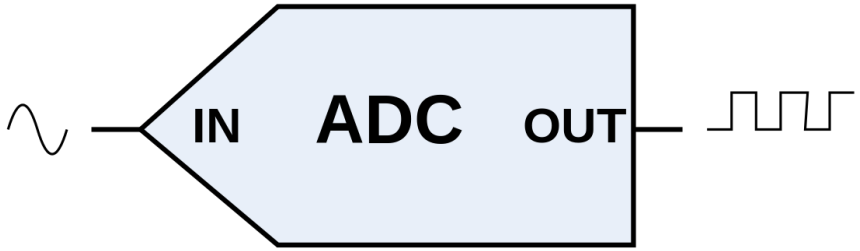
"If a picture paints a thousand words then why can't I paint you?"

Overview

- Review of Essentials
- Perception and Image Structure
- Colored Images

Digital Imaging

Analog to Digital Conversion

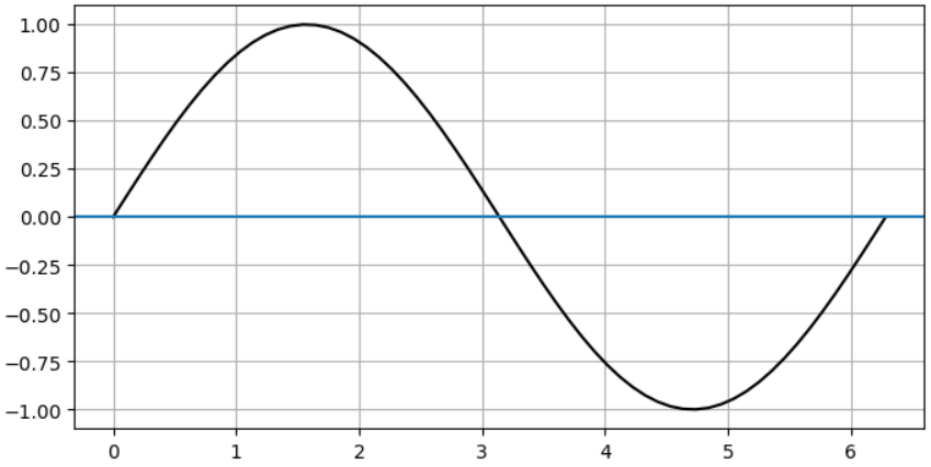


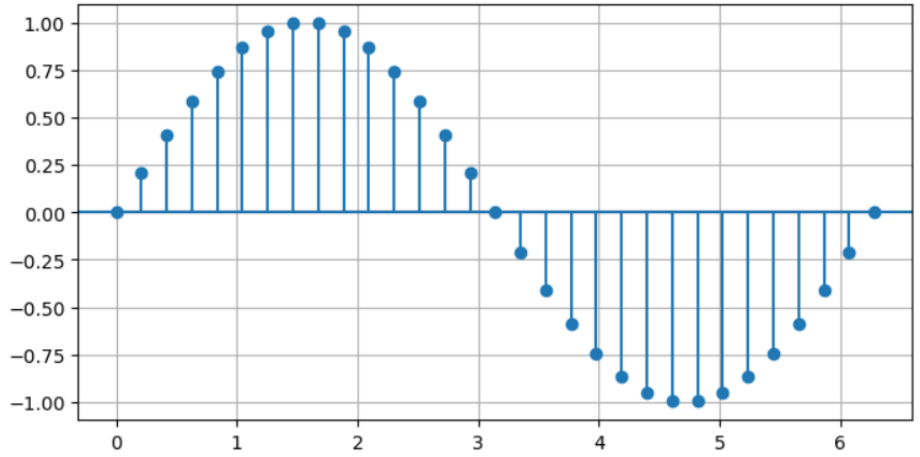
Step-by-step

Discrete Signal Processing

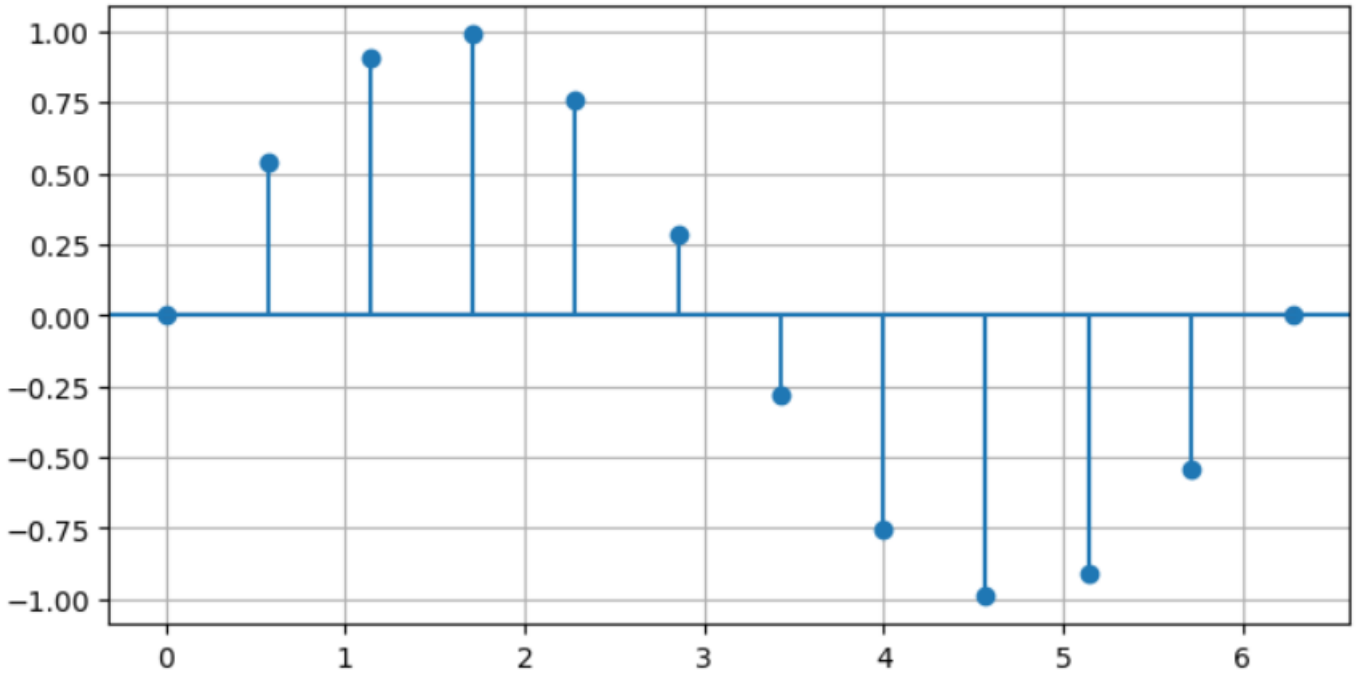
$$E = \int_{-\infty}^{\infty} x^2 dx$$

$$E = \sum_{i=0}^{N} x_i^2$$





One-dimensional signal

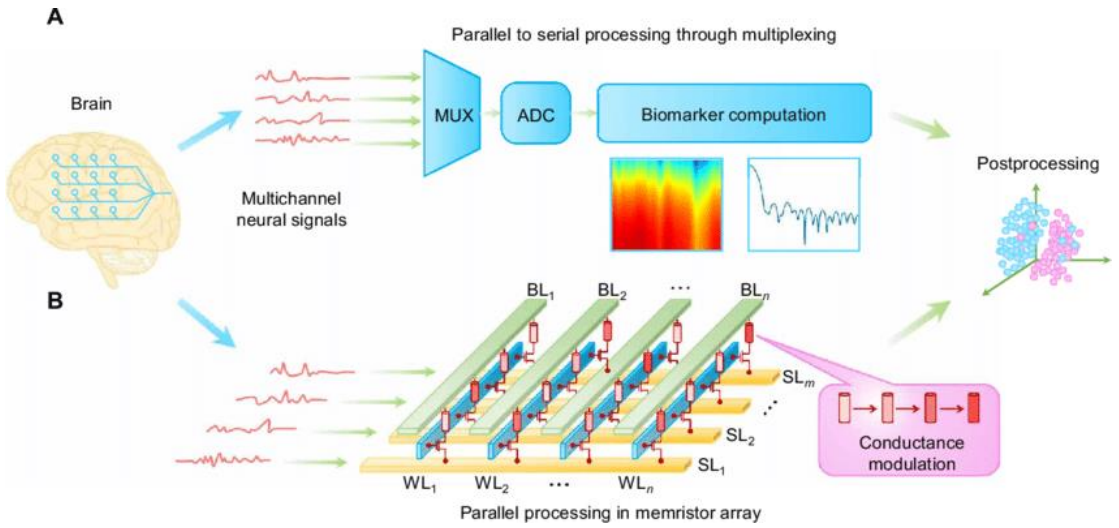


One-dimensional vector

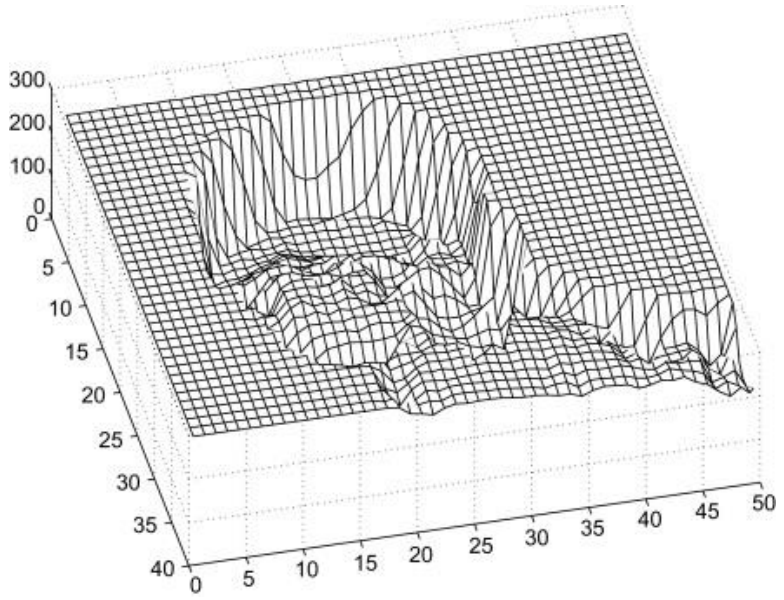
$$x = [0 \quad 0.54 \quad 0.91 \quad 0.99 \quad 0.76 \quad 0.28 \quad -0.28 \quad -0.76 \quad -0.99 \quad -0.91 \quad -0.54 \quad 0]$$

Multidimensional Signals and Tensors

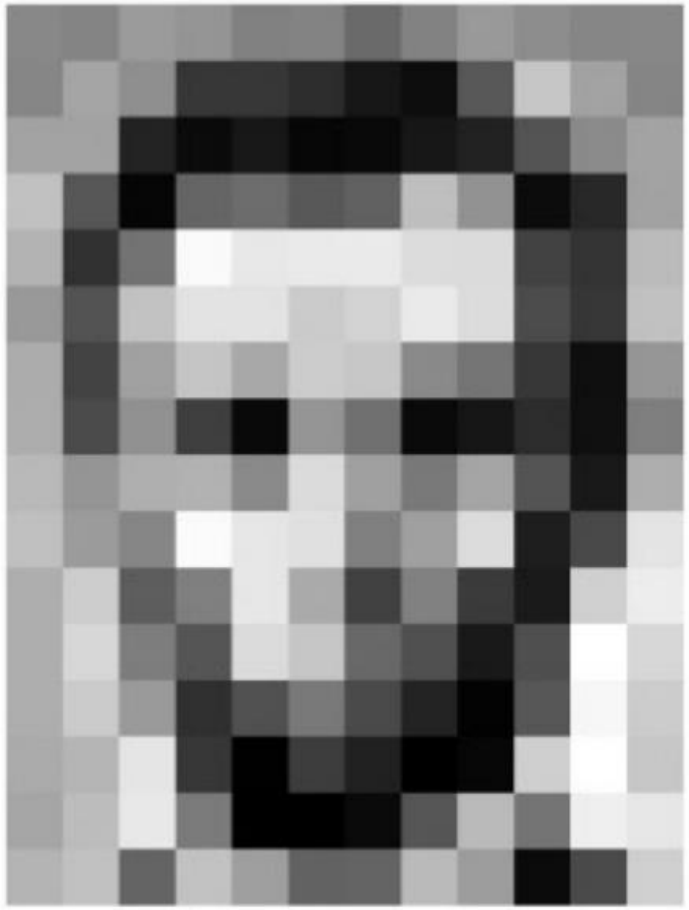
Multichannel Signal Processing



Multidimensional Signal Processing



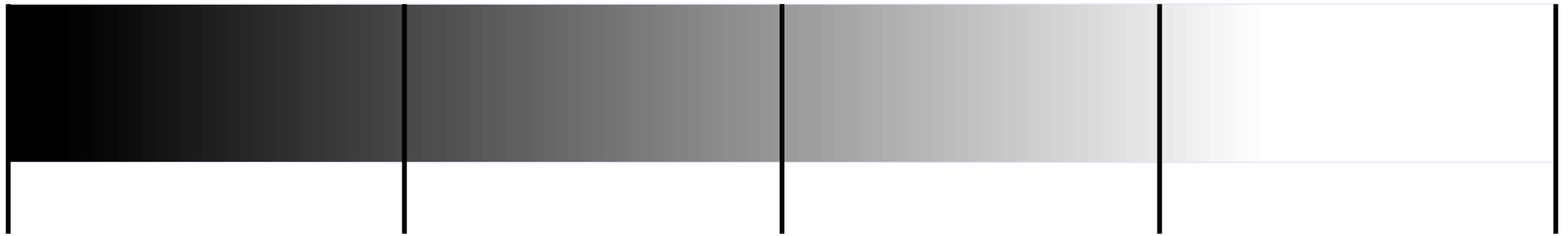
A Grayscale Picture



Yamashita, R., Nishio, M., Do, R.K.G. et al. Convolutional neural networks: an overview and application in radiology. Insights Imaging 9, 611–629 (2018). https://doi.org/10.1007/s13244-018-0639-9

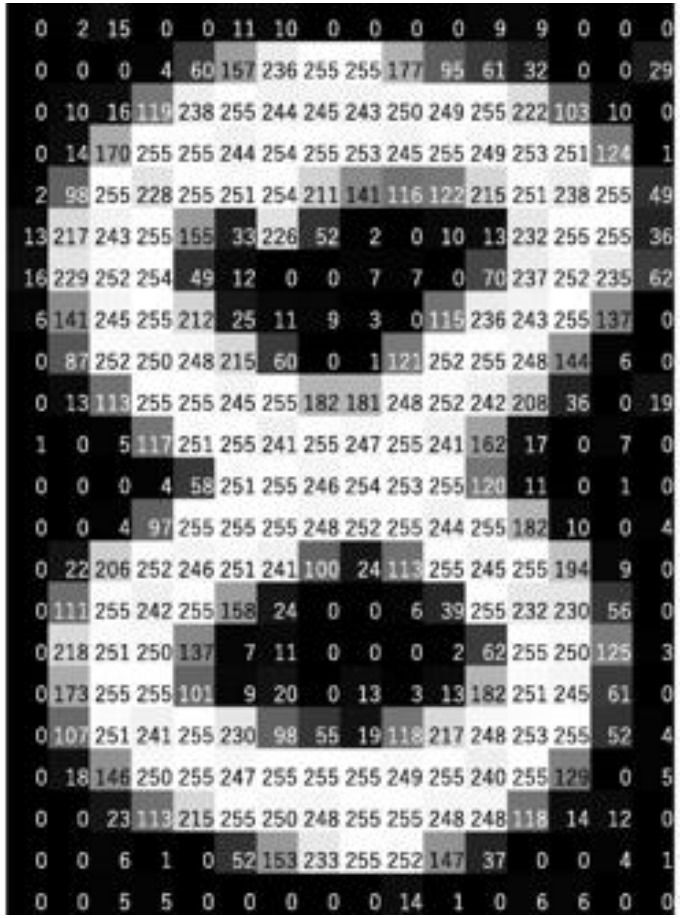
Melvin Wevers, Thomas Smits, The visual digital turn: Using neural networks to study historical images, *Digital Scholarship in the Humanities*, Volume 35, Issue 1, April 2020, Pages 194–207, https://doi.org/10.1093/llc/fqy085

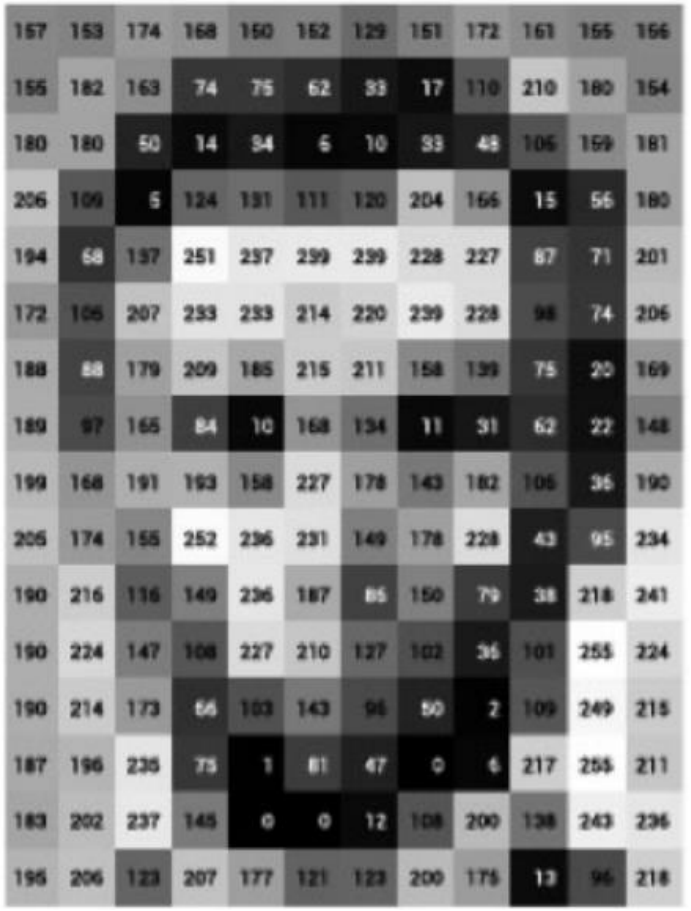
Grayscale?



float	0	0.25	0.5	0.75	1
uint	0	64	127	192	255

Two-dimensional signal





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Two-dimensional vector: A Matrix

$X_a =$

0	2	15	0	0	11	10	0	0	0	0	9	9	0	0	0
0	0	0	4	60	157	236	255	255	177	95	61	32	0	0	29
0	10	16	119	238	255	244	245	243	250	249	255	222	103	10	0
0	14	170	255	255	244	254	255	253	245	255	249	253	251	124	1
2	98	255	228	255	251	254	211	141	116	122	215	251	238	255	49
13	217	243	255	155	33	226	52	2	0	10	13	232	255	255	36
16	229	252	254	49	12	0	0	7	7	0	70	237	252	235	62
6	141	245	255	212	25	11	9	3	0	115	236	243	255	137	0
0	87	252	250	248	215	60	0	1	121	252	255	248	144	6	0
0	13	113	255	255	245	255	182	181	248	252	242	208	36	0	19
1	0	5	117	251	255	241	255	247	255	241	162	17	0	7	0
0	0	0	4	58	251	255	246	254	253	255	120	11	0	1	0
0	0	4	97	255	255	255	248	252	255	244	255	182	10	0	4
0	22	206	252	246	251	241	100	24	113	255	245	255	194	9	0
0	111	255	242	255	158	24	0	0	6	39	255	232	230	56	0
0	218	251	250	137	7	11	0	0	0	2	62	255	250	125	3
0	173	255	255	101	9	20	0	13	3	13	182	251	245	61	0
0	107	251	241	255	230	98	55	19	118	217	248	253	255	52	4
0	18	146	250	255	247	255	255	255	249	255	240	255	129	0	5
0	0	23	113	215	255	250	248	255	255	248	248	118	14	12	0
0	0	6	1	0	52	153	233	255	252	147	37	0	0	4	1
0	0	5	5	0	0	0	0	0	14	1	0	6	6	0	0

Shape: (rows, columns) = (22,16)

$X_b =$

157	153	174	168	150	152	129	151	172	161	155	156
155	182	163	74	75	62	33	17	110	210	180	154
180	180	50	14	34	6	10	33	48	106	159	181
206	109	5	124	131	111	120	204	166	15	56	180
194	68	137	251	237	239	239	228	227	87	71	201
172	105	207	233	233	214	220	239	228	98	74	206
188	88	179	209	185	215	211	158	139	75	20	169
189	97	165	84	10	168	134	11	31	62	22	148
199	168	191	193	158	227	178	143	182	106	36	190
205	174	155	252	236	231	149	178	228	43	95	234
190	216	116	149	236	187	86	150	79	38	218	241
190	224	147	108	227	210	127	102	36	101	255	224
190	214	173	66	103	143	96	50	2	109	249	215
187	196	235	75	1	81	47	0	6	217	255	211
183	202	237	145	0	0	12	108	200	138	243	236
195	206	123	207	177	121	123	200	175	13	96	218

Shape: (rows, columns) = (16,12)

Yamashita, R., Nishio, M., Do, R.K.G. et al. Convolutional neural networks: an overview and application in radiology. Insights Imaging 9, 611–629 (2018). https://doi.org/10.1007/s13244-018-0639-9

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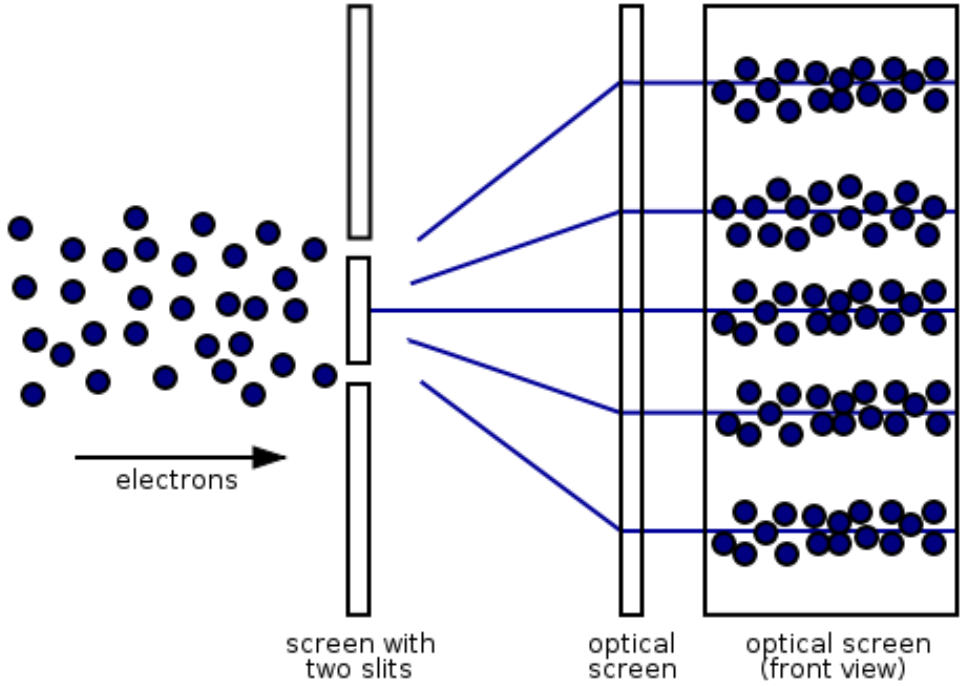
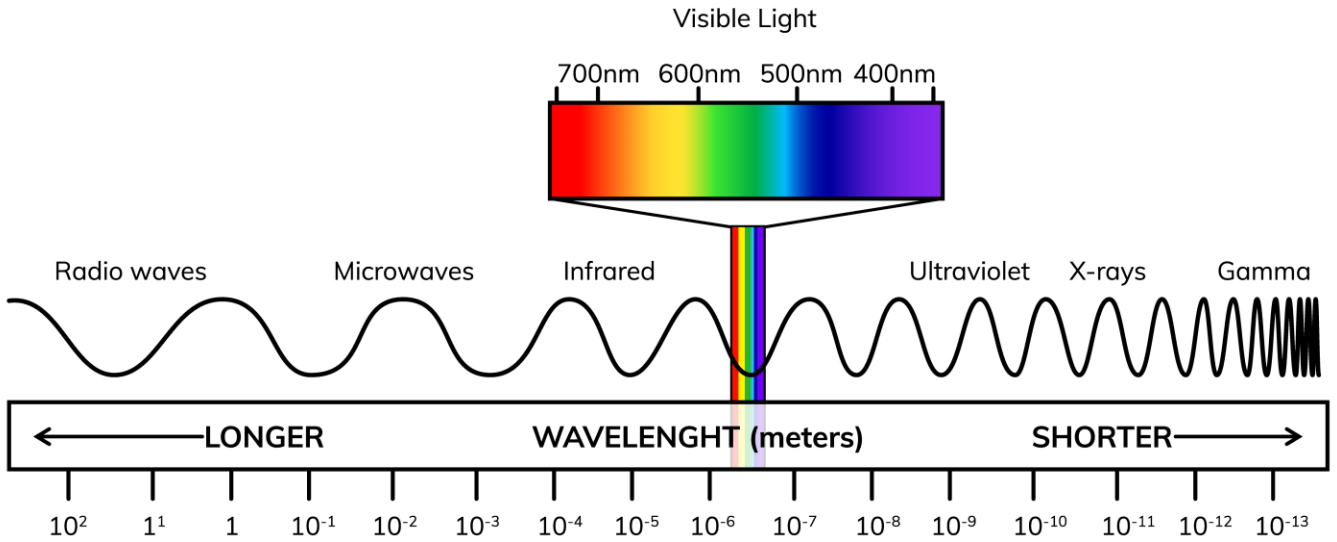
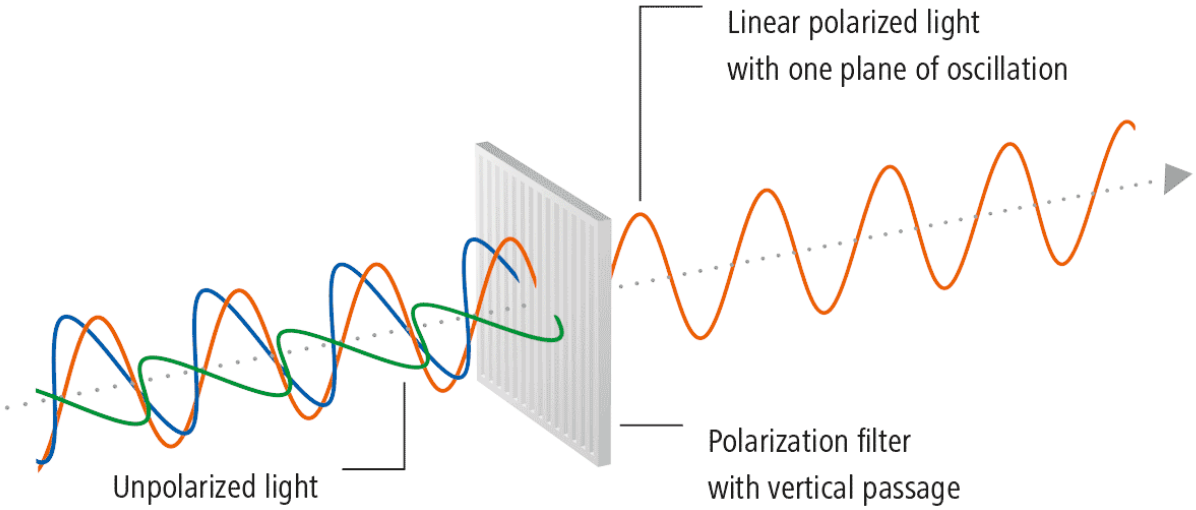
Colored Images and Perception

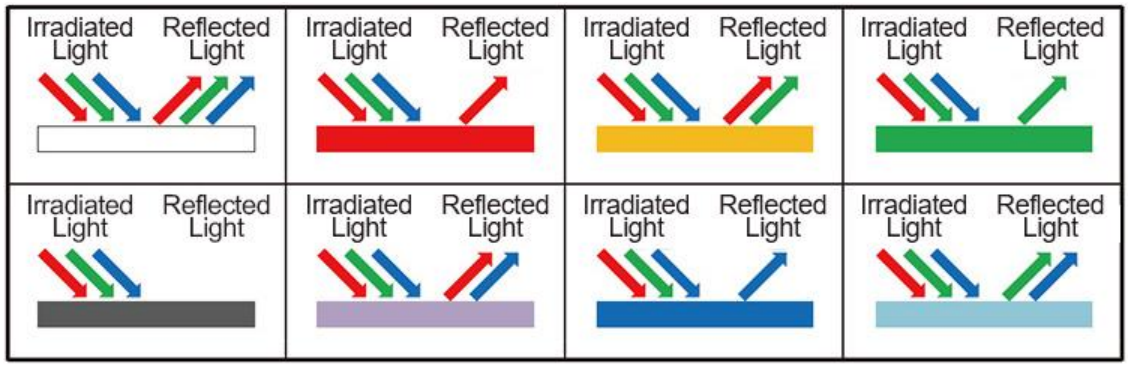
The Nature of Light



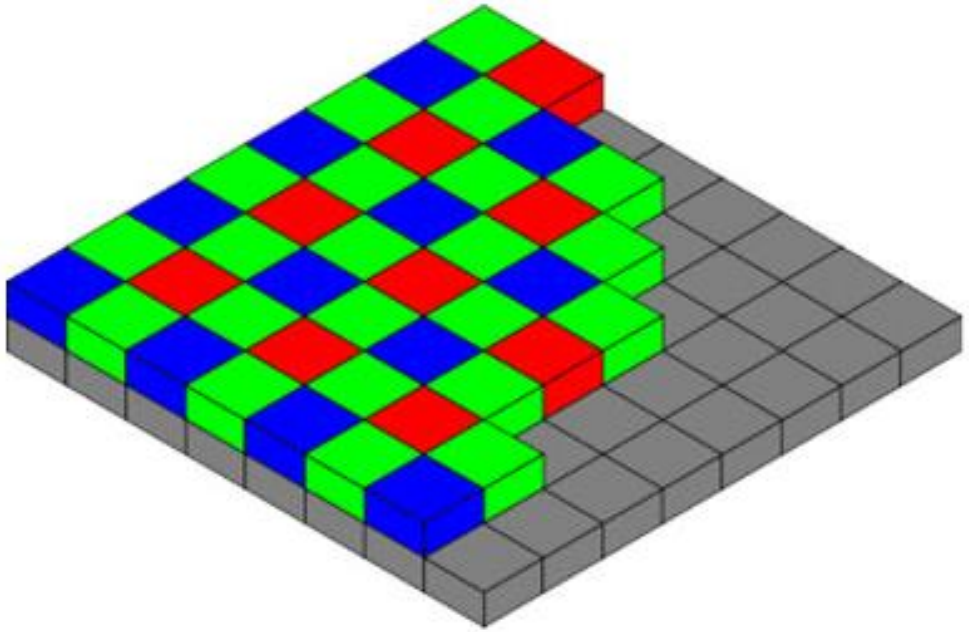


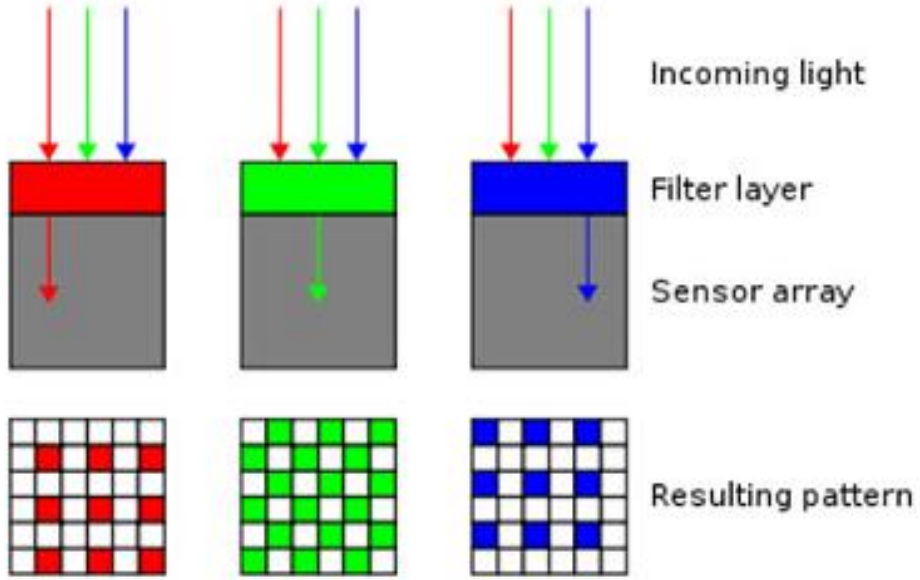
The Spectrum





From Perception to Transduction



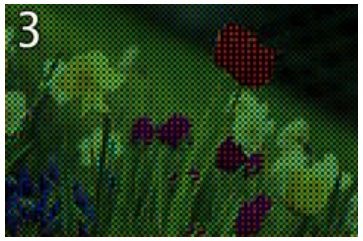


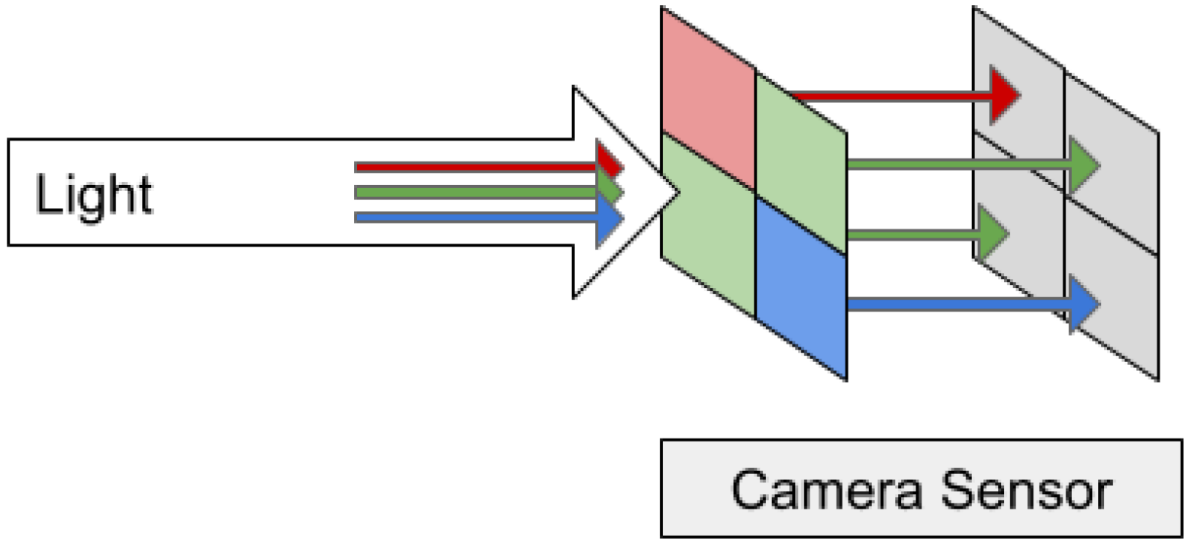
Capturing a moment
Bayer Lenses

The Actual Scene

Output of camera sensor

Color-coded output of the Bayer Filter





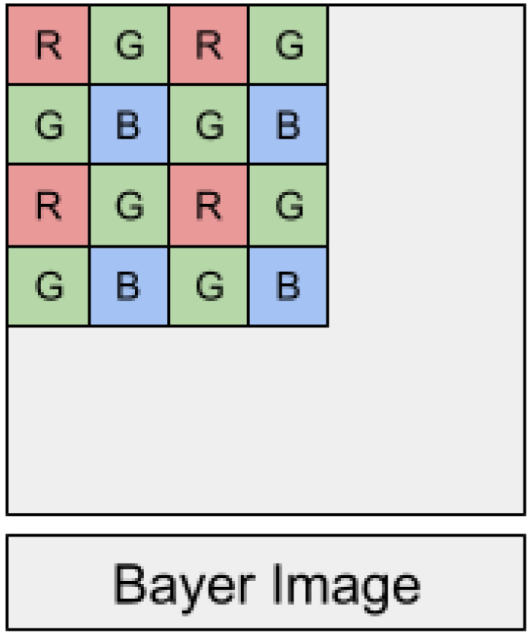
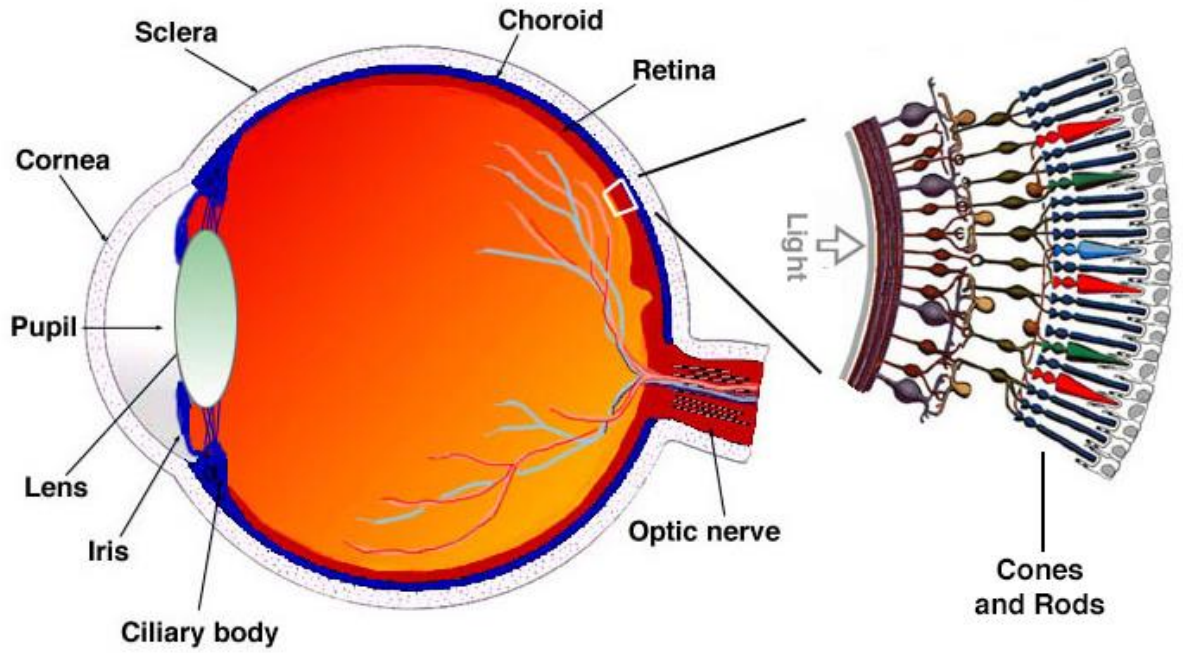


Image reconstruction (post-process)

Human Perception

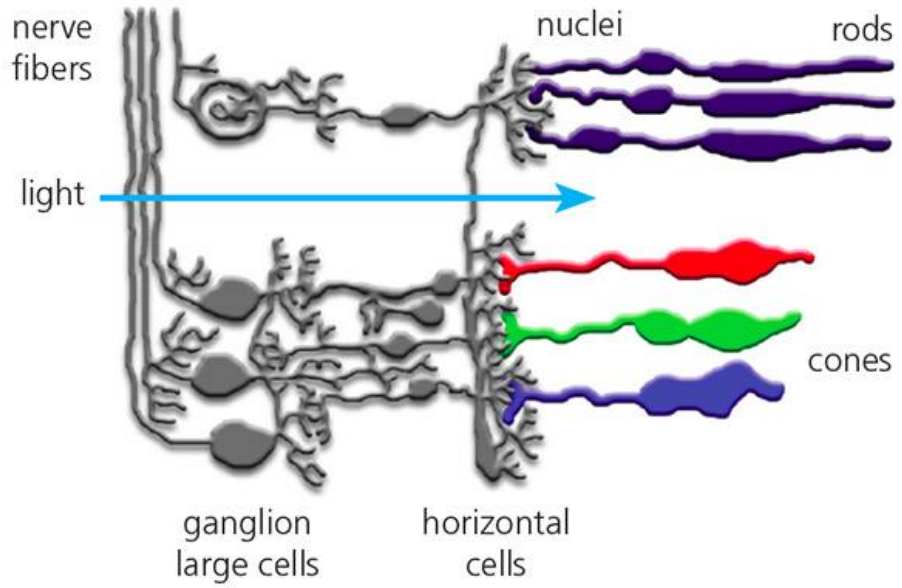
Vision or Light Perception is proposed to occur in three different theories:

1. Trichromatic Theory
2. Opponent Process Theory

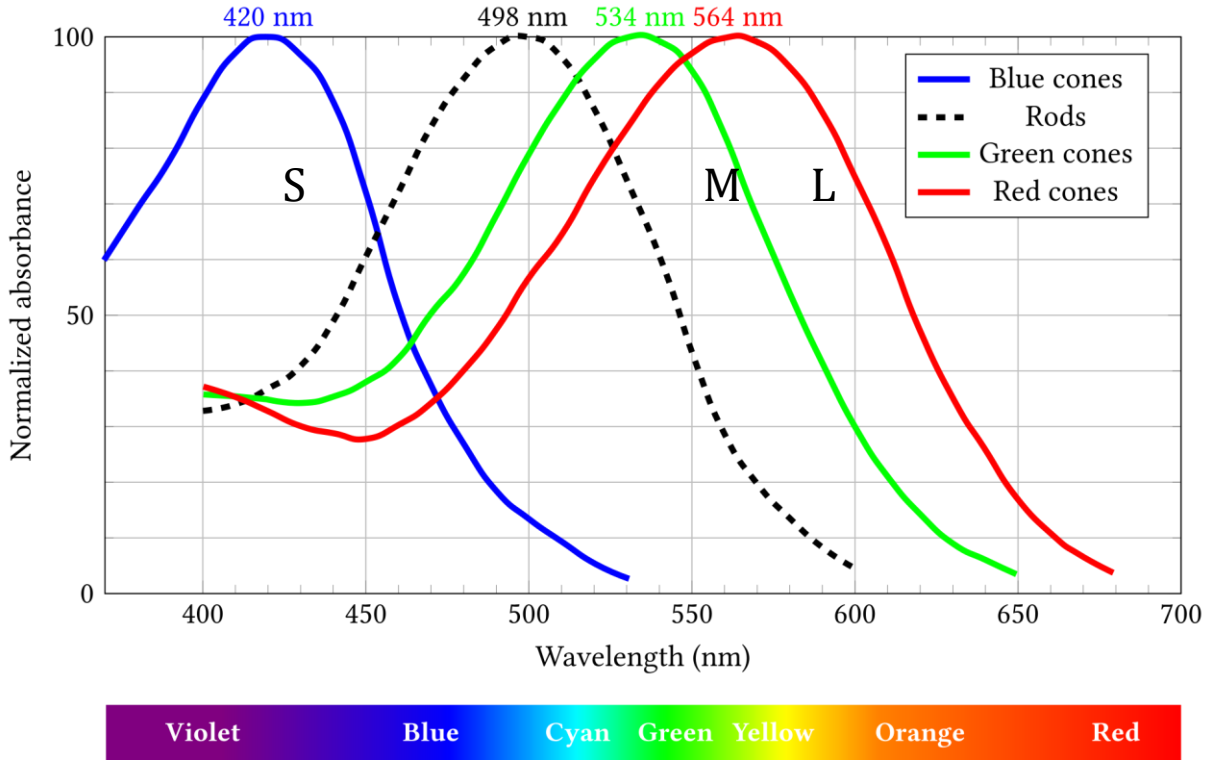


Human Perception

Trichromatic Theory



LMS Color System (Long, Medium, Short)



Photoreceptor Cells

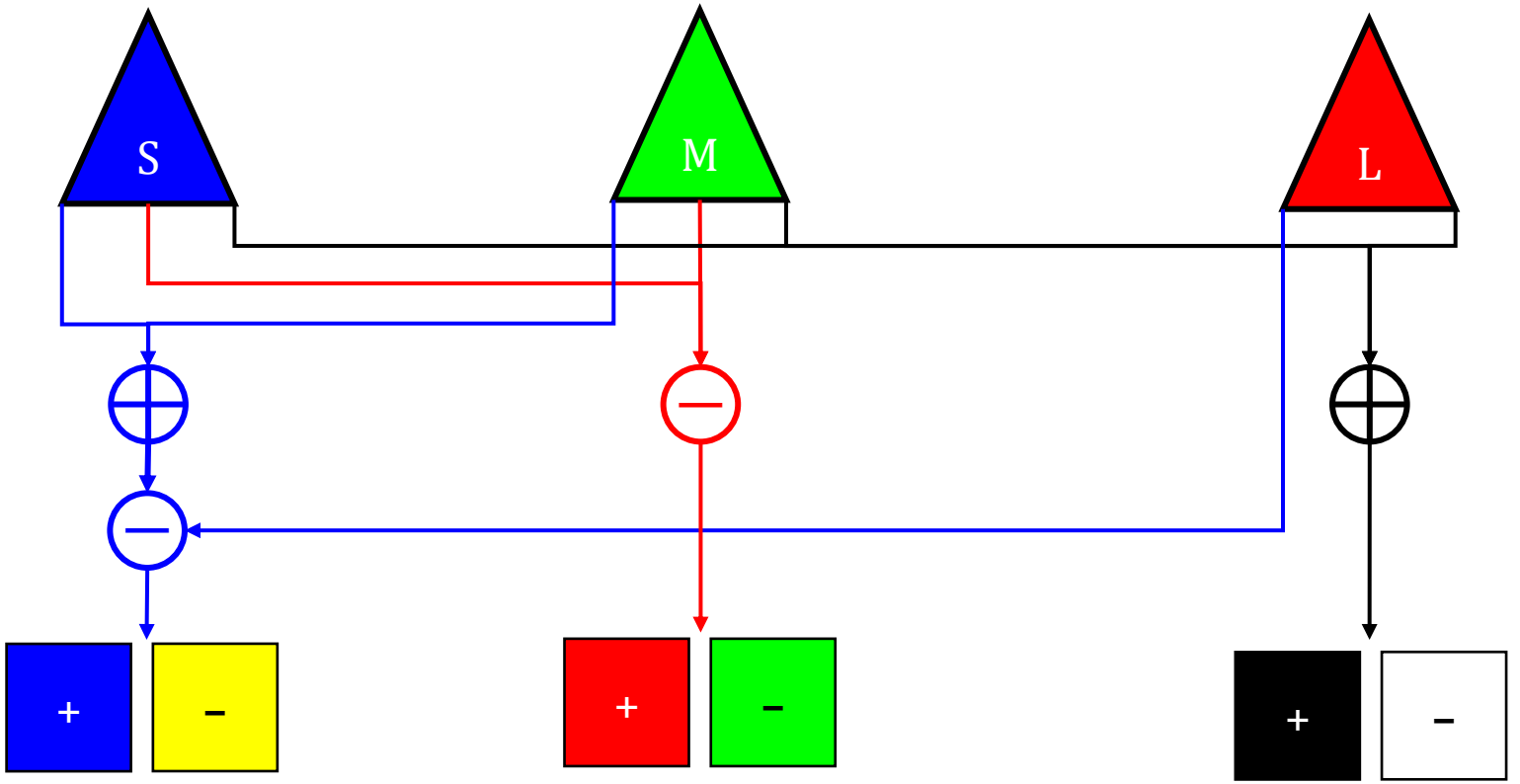
Cones are responsible for visible light reception

Rods are responsible for low light reception

Human Perception

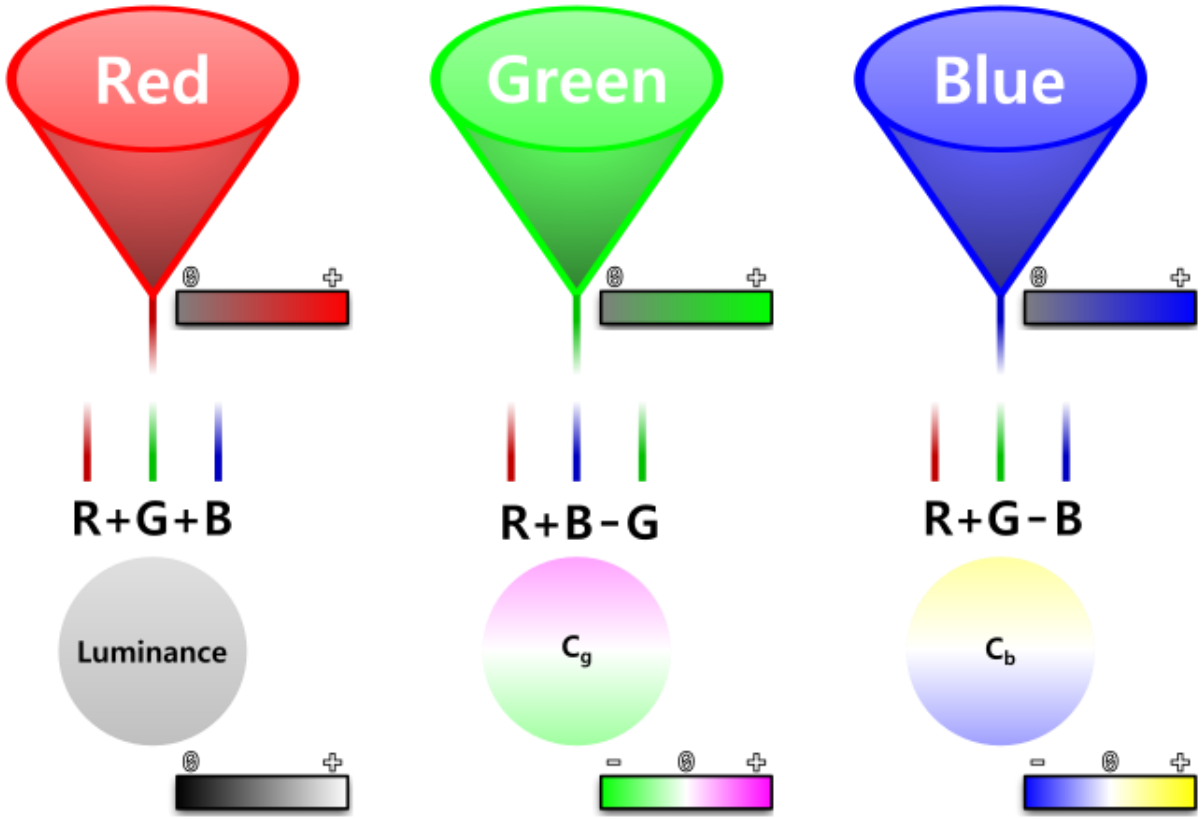
Opponent Process Theory

Chromatic



Achromatic

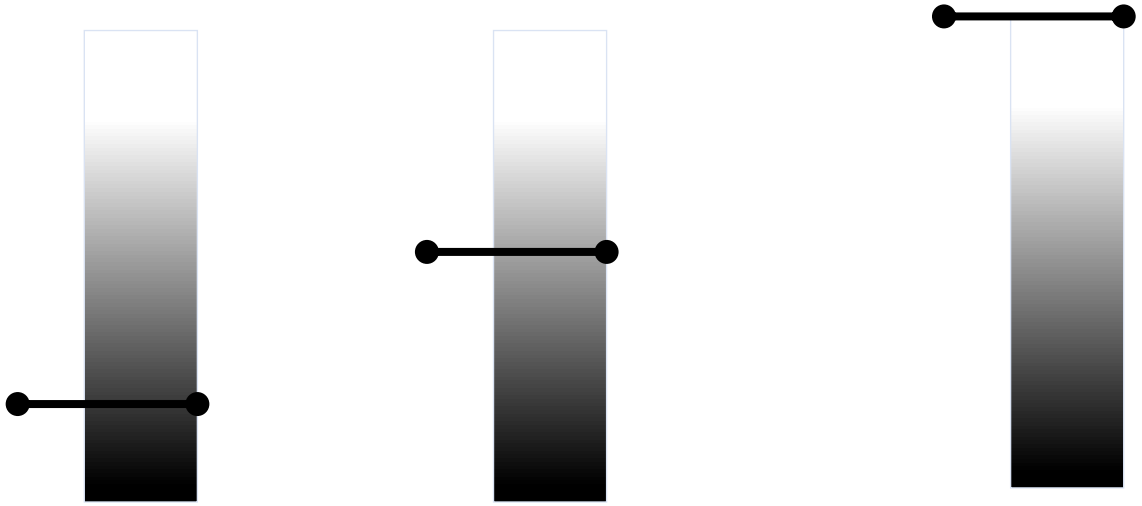
Human Perception



Color Systems

Into the Matrix

Channels

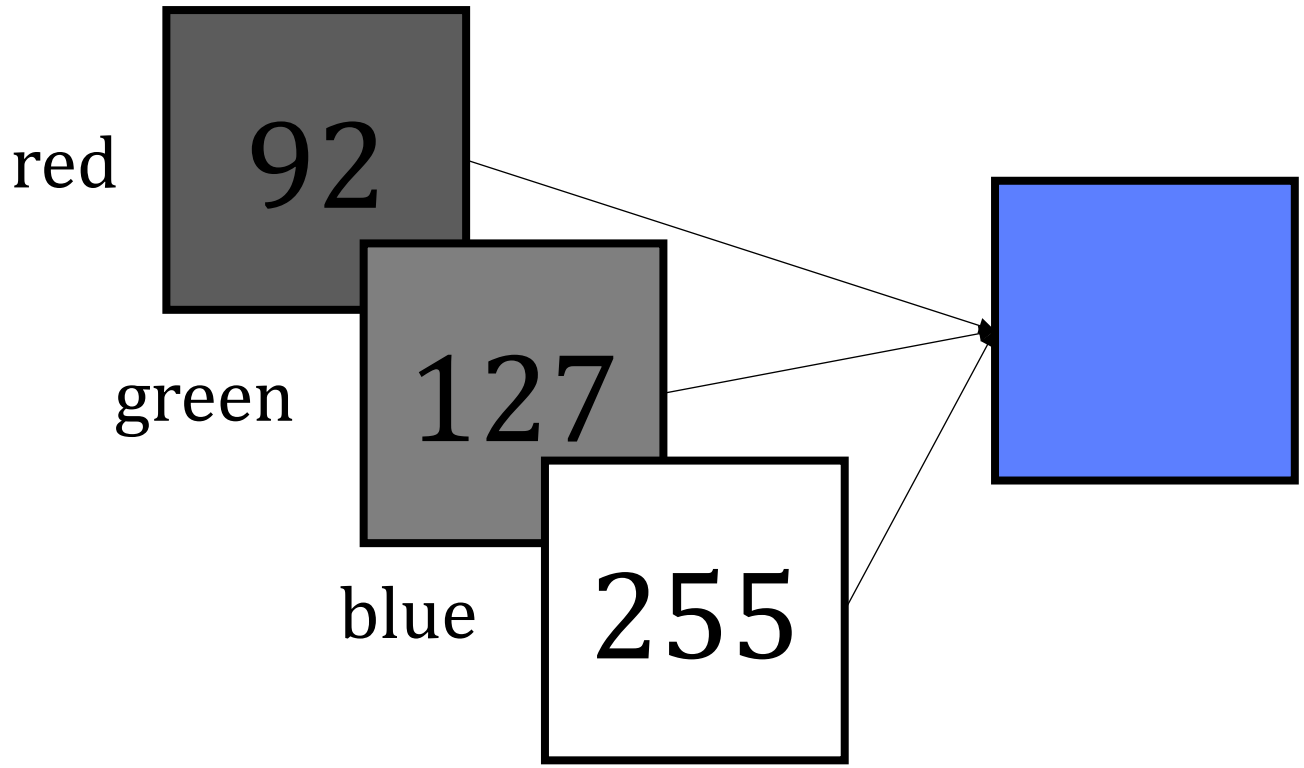


(92,127,255)

red green blue

Into the Matrix
Channels

Three-dimensional vector: A Tensor



Into the Matrix
Channels

Three-dimensional vector: A Tensor

red

(480,480)

green

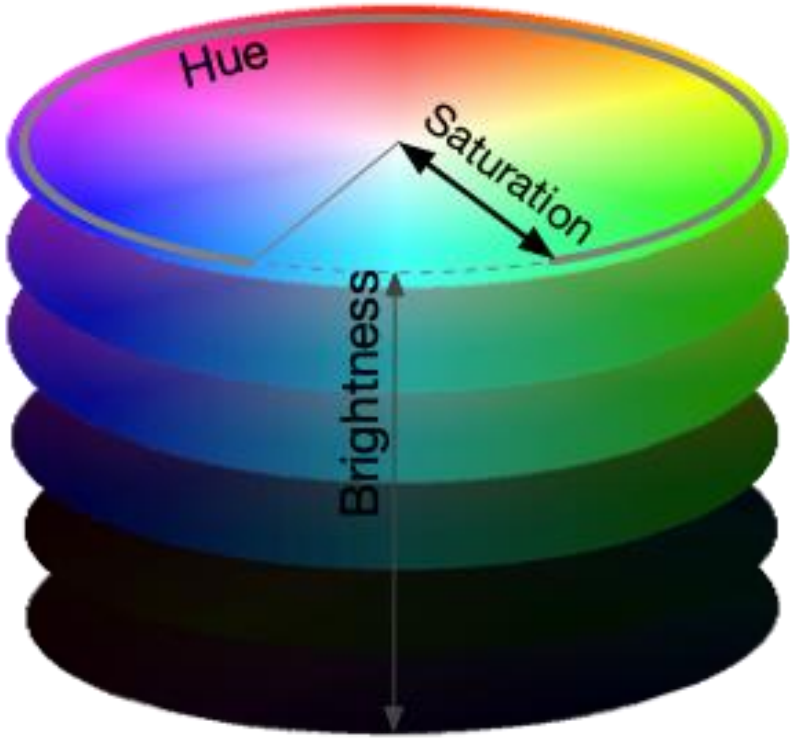
(480,480)

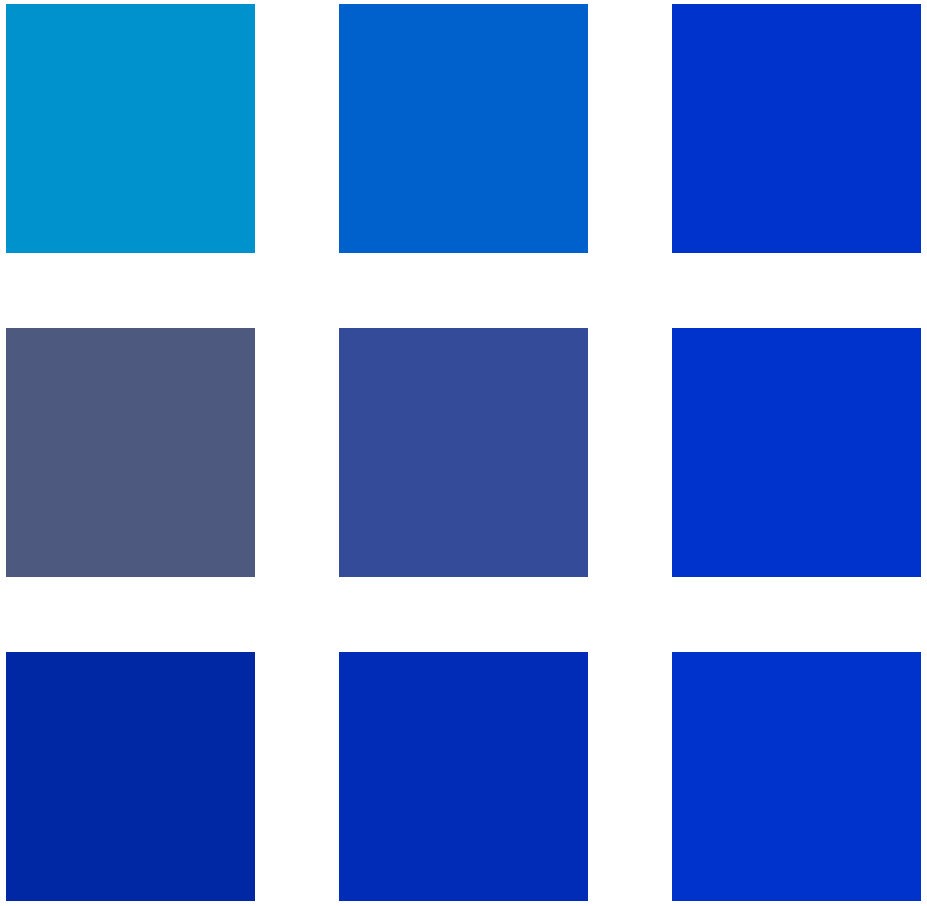
blue

(480,480)

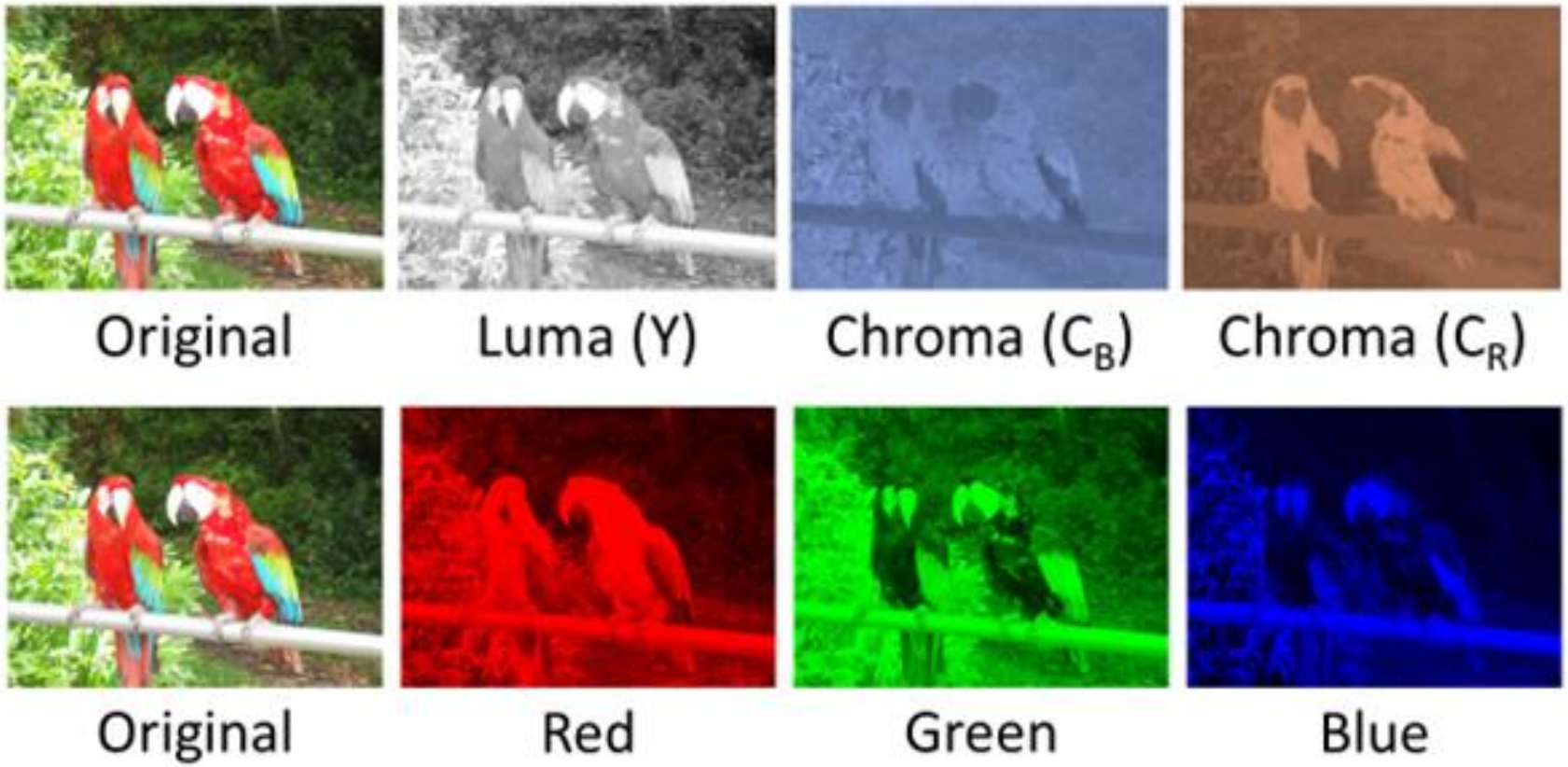
(480,480, 3)

HSL Color System

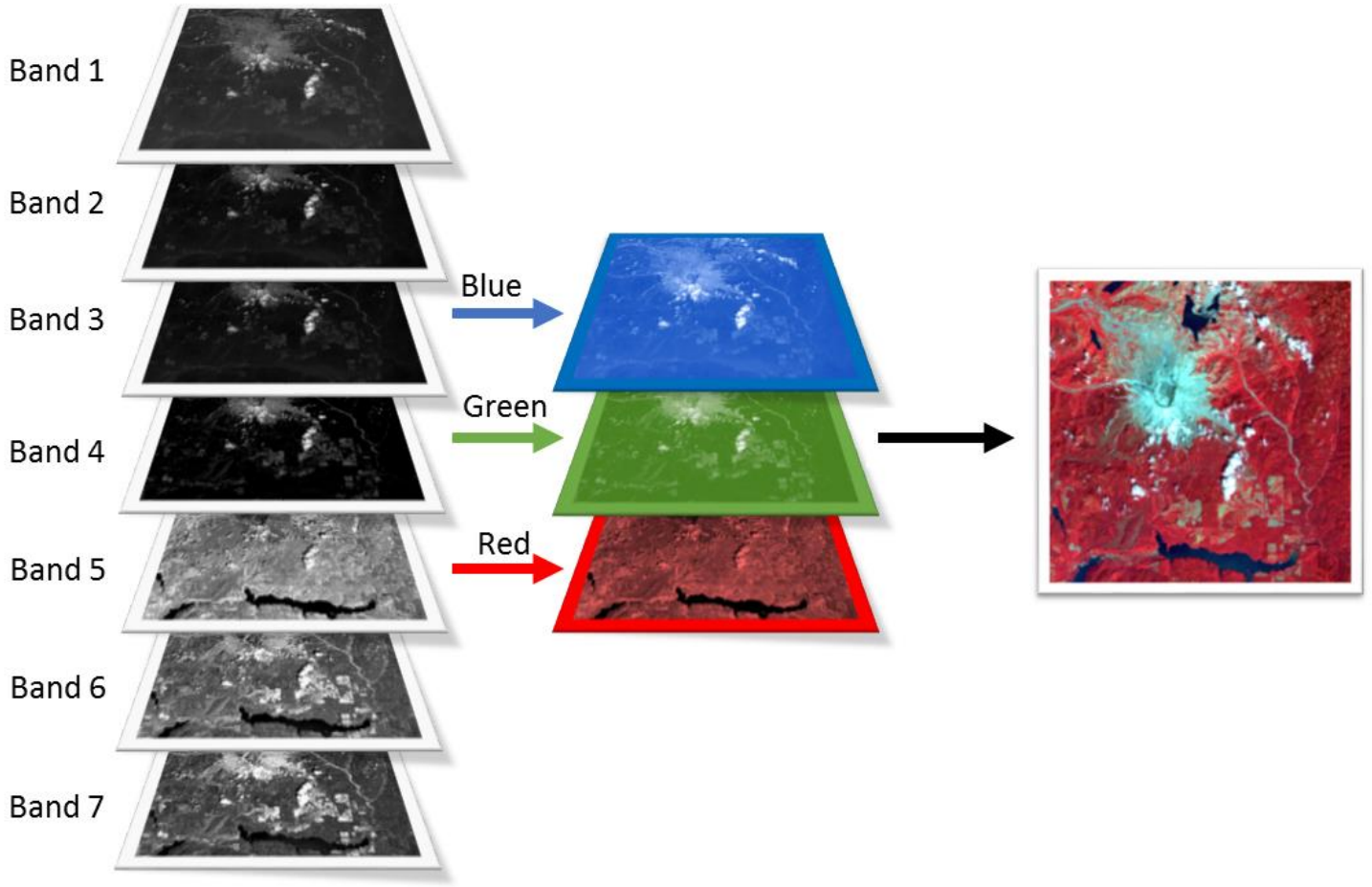




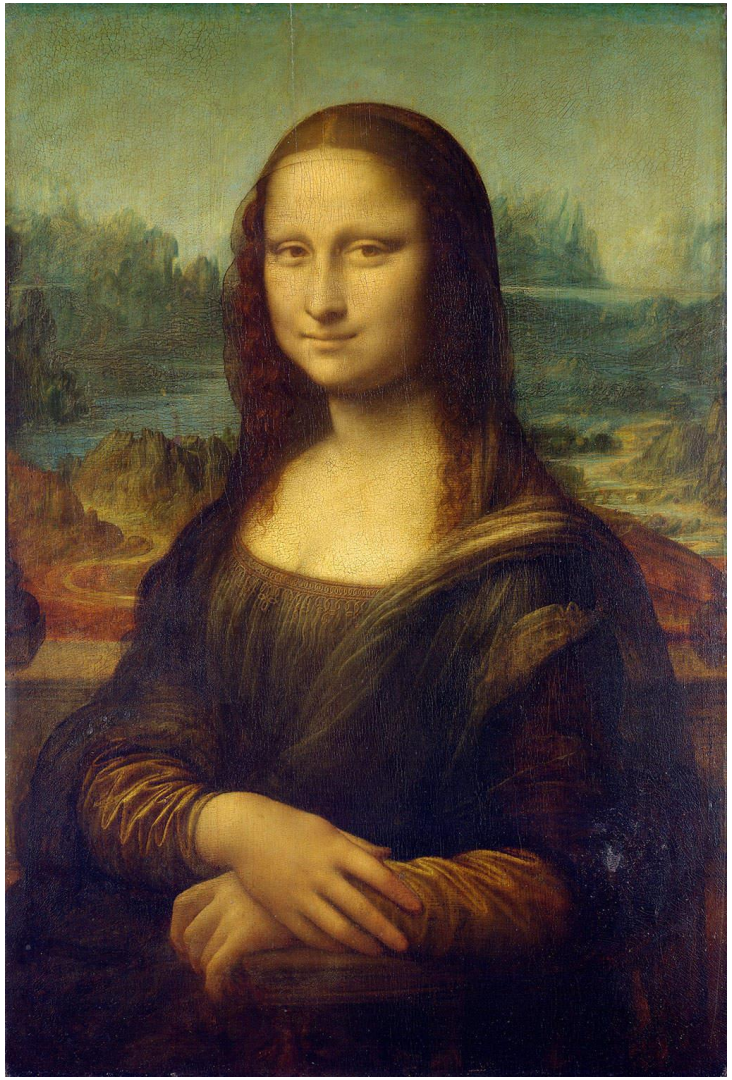
YCbCr Color System



High-dimensional Images?



Is a picture really worth a thousand words?



Let’s say this Mona Lisa is 7.2MB

If 1 word = 2 Bytes

Then by dimension analysis:

$$7.2 \times 10^6 \cancel{\text{Bytes}} = \frac{1 \text{ word}}{2 \cancel{\text{Bytes}}} = 3.6 \times 10^6 \text{words}$$

$$\therefore 1.0 \times 10^6 \text{words} \gg 1.0 \times 10^3 \text{words}$$

*A Good Digital
Picture is worth a
lot more than a
Thousand Words

Thank you