COMPUTER VISION
Lecture 2

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2018-09-04

CONTENTS

Chapter 1

Brief Summary

LECTURES

JACOBS UNIVERSITY

- Attendance not mandatory
- **Direct** correlation between attendance and passing the exam
- **Direct** correlation between attendance and grade of the exam

COMMUNICATION

- **ACT!** Don't wait until it is too late!
- If something not clear, google, ask your friends, contact the TA, contact me.
- Every professor is busy, but **will find time for you**!

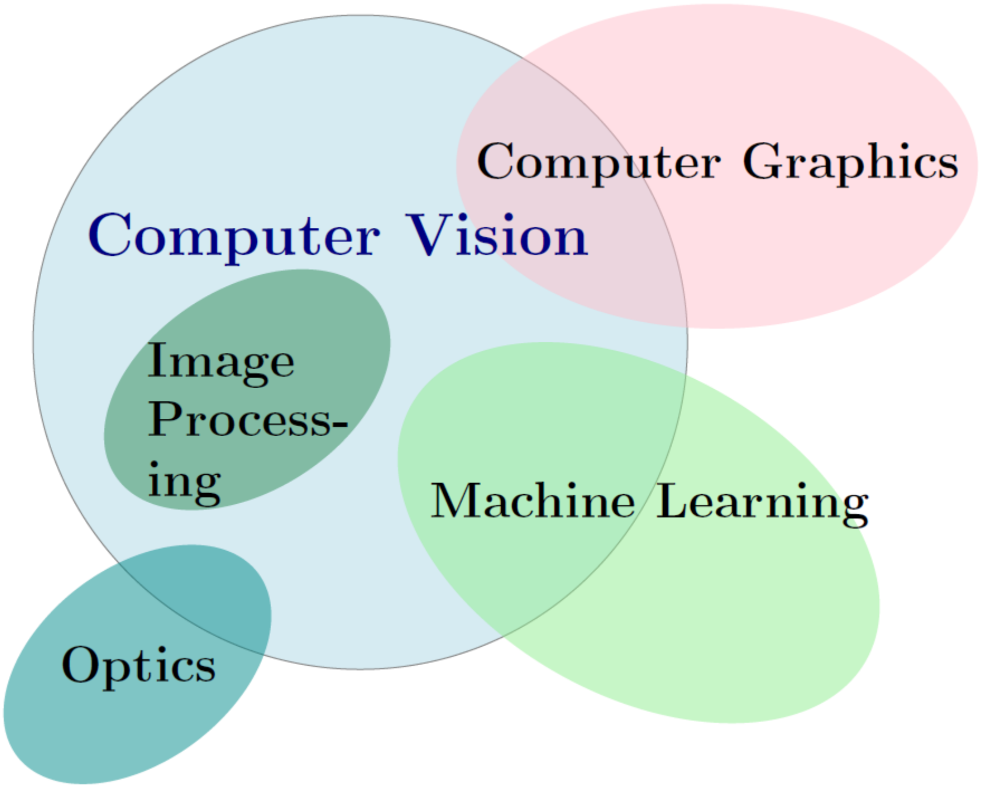
- Participate in classes, ask questions, review slides, check if anything needs to be better clarified

Academic calendar 2019/20 plus September

EXAMS

2019				2020								
September	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
1 Su	1 Tu	1 Fr	1 Su	1 We	1 Sa	1 Su	1 We	1 Fr	1 Mo Pentecost	1 We	1 Sa	1 Tu classes begin
2 Mo classes begin	2 We	2 Sa	2 Mo	2 Th	2 Su	2 Mo	2 Th	2 Sa	2 Tu	2 Th	2 Su	2 We
3 Tu	3 Th	3 Su	3 Tu	3 Fr	3 Mo classes begin	3 Tu	3 Fr	3 Su	3 We grades due: graduation	3 Fr	3 Mo	3 Th
4 We	4 Fr	4 Mo	4 We	4 Sa	4 Tu	4 We	4 Sa	4 Mo	4 Th	4 Sa	4 Tu	4 Fr
5 Th	5 Sa	5 Tu	5 Th	5 Su	5 We	5 Th	5 Su	5 Tu	5 Fr	5 Su	5 We	5 Sa
6 Fr	6 Su	6 We	6 Fr classes end	6 Mo	6 Th	6 Fr	6 Mo	6 We	6 Sa	6 Mo	6 Th	6 Su
7 Sa	7 Mo	7 Th	7 Sa reading day	7 Tu	7 Fr	7 Sa	7 Tu SPRING	7 Th	7 Su	7 Tu	7 Fr	7 Mo
8 Su	8 Tu	8 Fr	8 Su reading day	8 We	8 Sa	8 Su	8 We BREAK	8 Fr	8 Mo	8 We	8 Sa	8 Tu
9 Mo	9 We	9 Sa	9 Mo exam	9 Th	9 Su	9 Mo	9 Th	9 Sa	9 Tu	9 Th	9 Su	9 We
10 Tu	10 Th	10 Su	10 Tu period	10 Fr break ends	10 Mo	10 Tu	10 Fr Good Friday	10 Su	10 We	10 Fr	10 Mo	10 Th
11 We	11 Fr	11 Mo	11 We	11 Sa	11 Tu	11 We	11 Sa	11 Mo	11 Th	11 Sa	11 Tu	11 Fr
12 Th	12 Sa	12 Tu	12 Th	12 Su	12 We	12 Th	12 Su	12 Tu	12 Fr graduation	12 Su	12 We	12 Sa
13 Fr	13 Su	13 We	13 Fr	13 Mo grades due/ intersession	13 Th	13 Fr	13 Mo Easter Monday	13 We	13 Sa	13 Mo	13 Th	13 Su
14 Sa	14 Mo	14 Th	14 Sa	14 Tu begins	14 Fr grades due make-ups	14 Sa	14 Tu	14 Th	14 Su	14 Tu	14 Fr diplomas & transcripts	14 Mo grades due make-ups
15 Su	15 Tu	15 Fr	15 Su	15 We	15 Sa	15 Su	15 We	15 Fr classes end	15 Mo	15 We	15 Sa due	15 Tu drop/add
16 Mo drop/ add	16 We	16 Sa	16 Mo	16 Th	16 Su	16 Mo	16 Th	16 Sa reading day	16 Tu	16 Th	16 Su	16 We
17 Tu	17 Th	17 Su	17 Tu	17 Fr	17 Mo drop / add	17 Tu	17 Fr	17 Su reading day	17 We	17 Fr	17 Mo	17 Th
18 We	18 Fr	18 Mo	18 We	18 Sa	18 Tu	18 We	18 Sa	18 Mo exam	18 Th	18 Sa	18 Tu	18 Fr
19 Th	19 Sa	19 Tu	19 Th	19 Su	19 We	19 Th	19 Su	19 Tu period	19 Fr	19 Su	19 We	19 Sa
20 Fr	20 Su	20 We	20 Fr	20 Mo	20 Th	20 Fr	20 Mo	20 We	20 Sa	20 Mo	20 Th	20 Su
21 Sa	21 Mo	21 Th	21 Sa	21 Tu	21 Fr	21 Sa	21 Tu	21 Th Christi Himmelfahrt	21 Su	21 Tu	21 Fr	21 Mo
22 Su	22 Tu	22 Fr	22 Su	22 We	22 Sa	22 Su	22 We	22 Fr	22 Mo	22 We	22 Sa make-up period	22 Tu
23 Mo	23 We	23 Sa	23 Mo break begins	23 Th make-up period	23 Su	23 Mo	23 Th	23 Sa	23 Tu	23 Th	23 Su	23 We
24 Tu	24 Th	24 Su	24 Tu	24 Fr	24 Mo	24 Tu	24 Fr	24 Su	24 We remaining grades due	24 Fr	24 Mo	24 Th
25 We	25 Fr	25 Mo	25 We Christmas Day	25 Sa	25 Tu	25 We	25 Sa	25 Mo	25 Th	25 Sa	25 Tu	25 Fr
26 Th	26 Sa	26 Tu	26 Th Boxing Day	26 Su	26 We	26 Th	26 Su	26 Tu	26 Fr	26 Su	26 We O-Week begins	26 Sa
27 Fr	27 Su	27 We	27 Fr	27 Mo	27 Th	27 Fr	27 Mo	27 We	27 Sa	27 Mo	27 Th	27 Su
28 Sa	28 Mo	28 Th	28 Sa	28 Tu	28 Fr	28 Sa	28 Tu	28 Th	28 Su	28 Tu	28 Fr	28 Mo
29 Su	29 Tu	29 Fr	29 Su	29 We	29 Sa	29 Su	29 We	29 Fr	29 Mo	29 We	29 Sa	29 Tu
30 Mo	30 We	30 Sa	30 Mo	30 Th		30 Mo	30 Th	30 Sa	30 Tu	30 Th	30 Su	30 We
	31 Th		31 Tu	31 Fr		31 Tu		31 Su summer recess		31 Fr	31 Mo O-Week ends	

RELATION TO OTHER AREAS

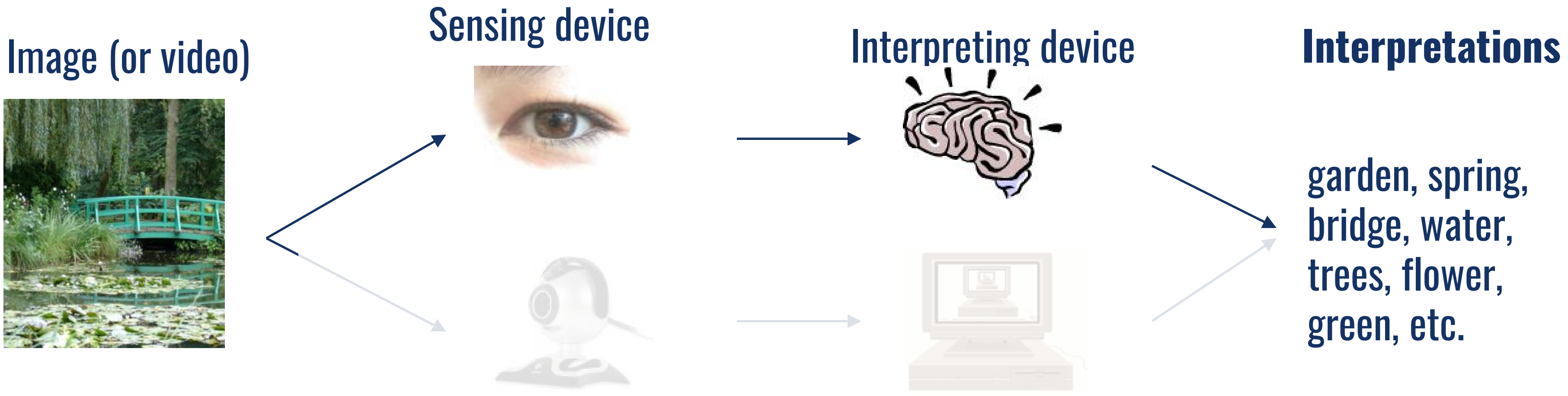


THE GOAL OF COMPUTER VISION

Bridging the gap between pixels and meaning

0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

WHAT IS (COMPUTER) VISION



WHAT IS (COMPUTER) VISION

Image (or video)

Sensing device

Interpreting device

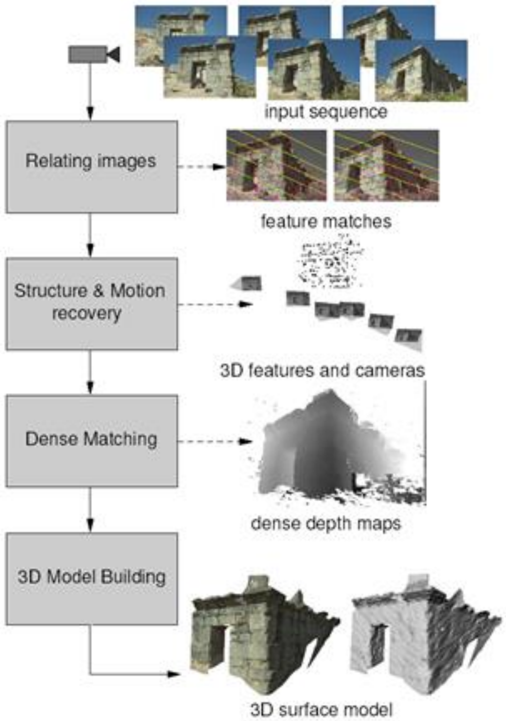
Interpretations

garden, spring, bridge, water, trees, flower, green, etc.

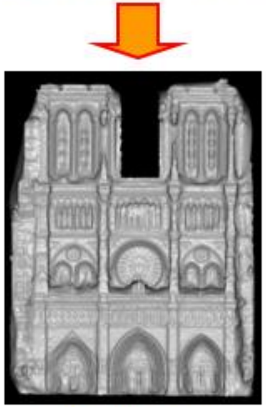
WHAT INFORMATION TO EXTRACT

- Metric 3D Information
- Semantics

VISION AS A MEAUREMENT DEVICE

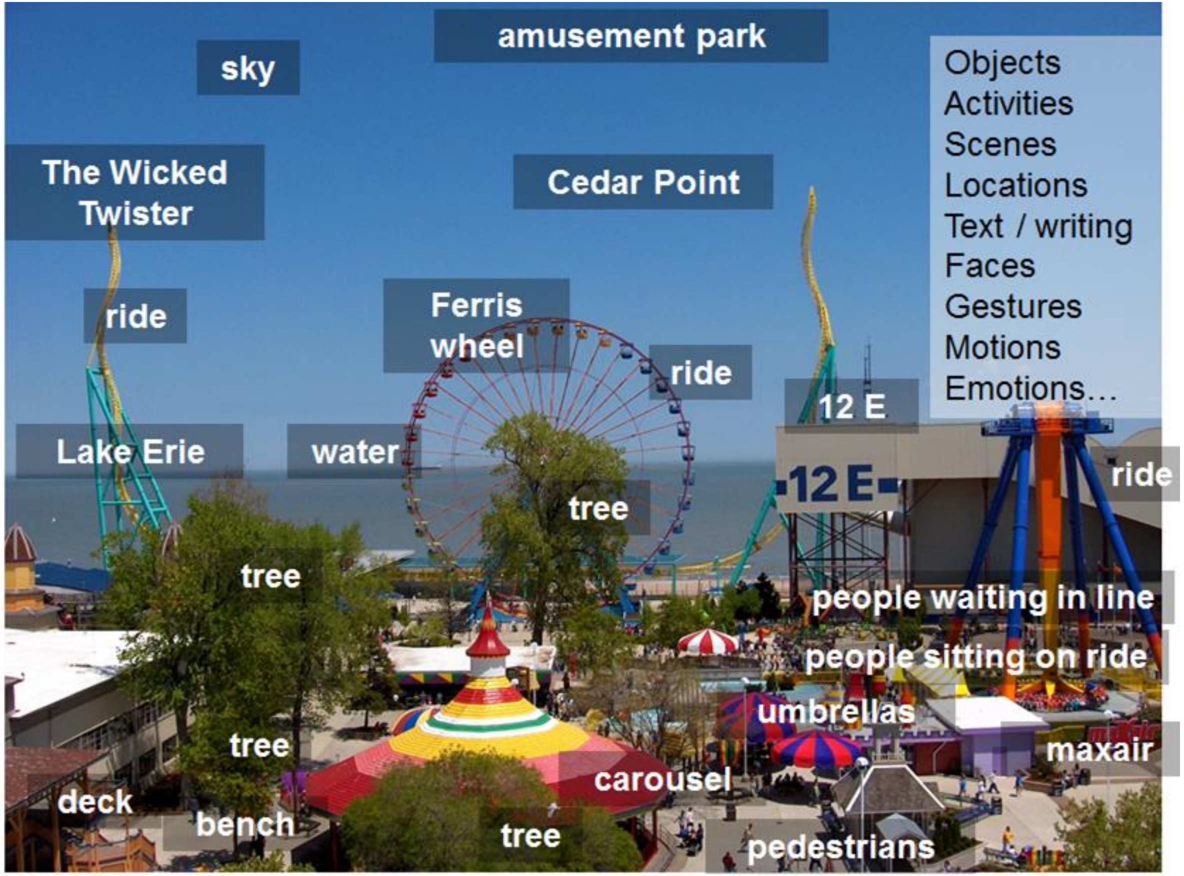


Pollefeys et al.



Goesele et al.

VISION AS A SOURCE OF SEMANTIC INFORMATION



Chapter 2

Light

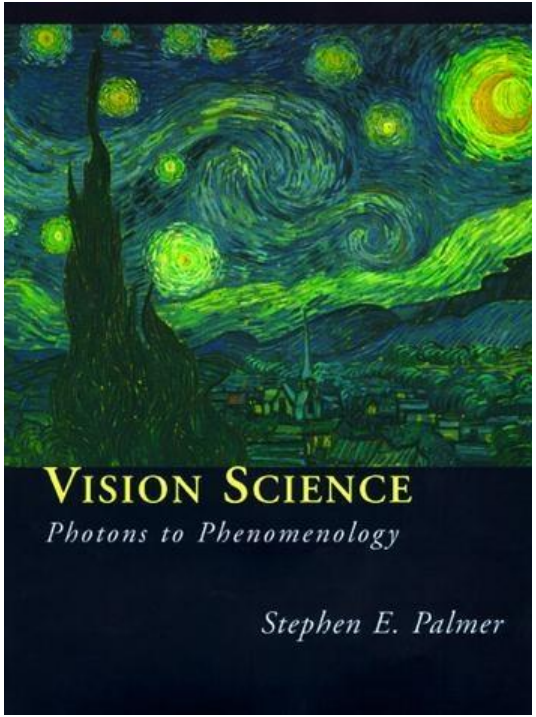
OVERVIEW OF COLOR

- Physics of color
- Human encoding of color
- Color spaces
- White balancing

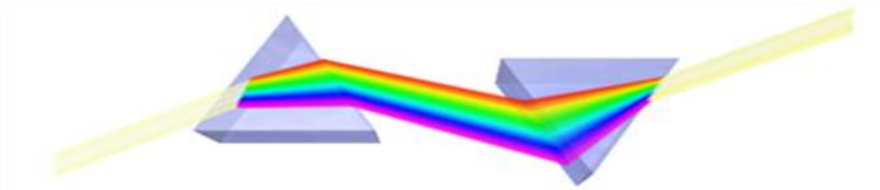
WHAT IS COLOR?

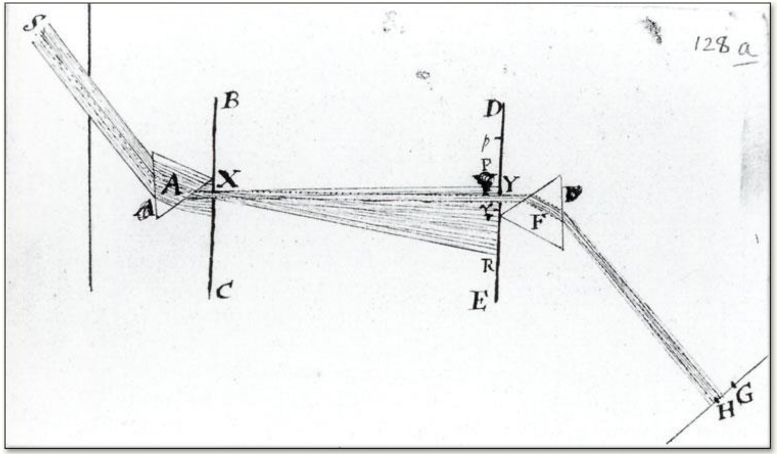
- The result of interaction between physical light in the environment and our visual system.

- A *psychological property* of our visual experiences when we look at objects and lights, *not a physical property* of those objects or lights.



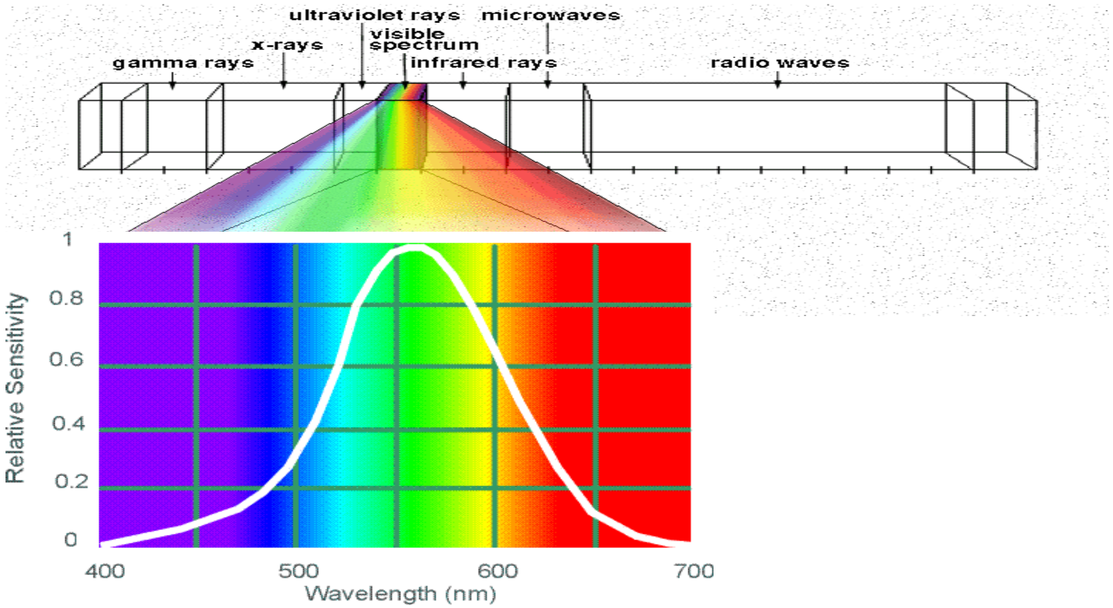
White light: composed of almost equal energy in all wavelengths of the visible spectrum





Newton 1665

ELECTROMAGNETIC SPECTRUM

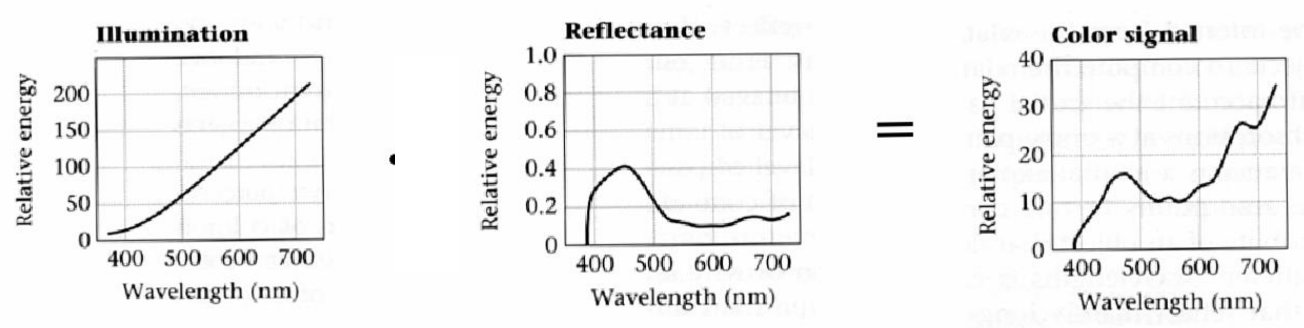


Human Luminance Sensitivity Function

Sun temperature makes it emit yellow light more than any other color.

INTERACTION OF LIGHT AND SURFACES

- Reflected color is the result of interaction of light source spectrum with surface reflectance
- Spectral radiometry
  - All definitions and units are now “per unit wavelength”
  - All terms are now “spectral”



From Foundation of Vision by Brian Wandell, Sinauer Associates, 1995

OVERVIEW OF COLOR

- Physics of color
- Human encoding of color
- Color spaces
- White balancing

TWO TYPES OF LIGHT-SENSITIVE RECEPTORS

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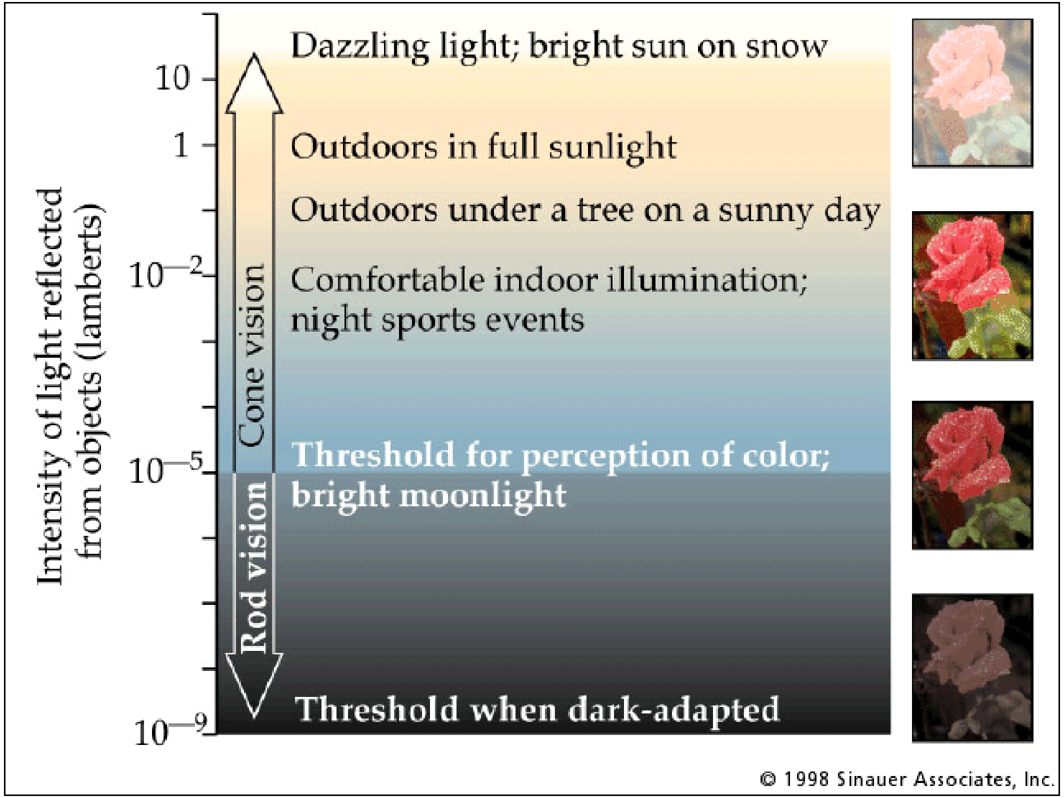
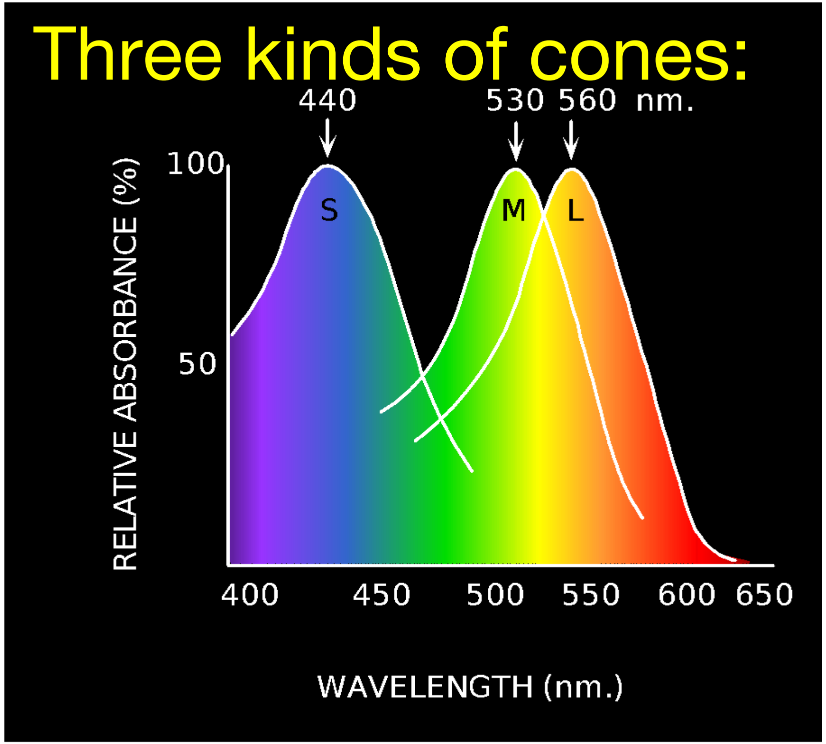
Cones
- cone-shaped
- less sensitive
- operate in high light
- color vision

Rods
- rod-shaped
- highly sensitive
- operate at night
- gray-scale vision

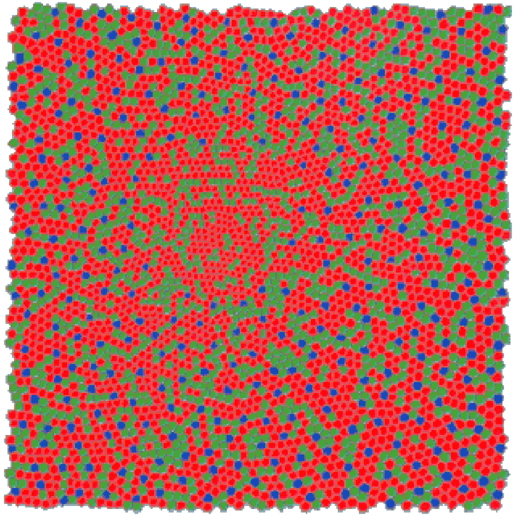
ROD / CONE SENSITIVITY

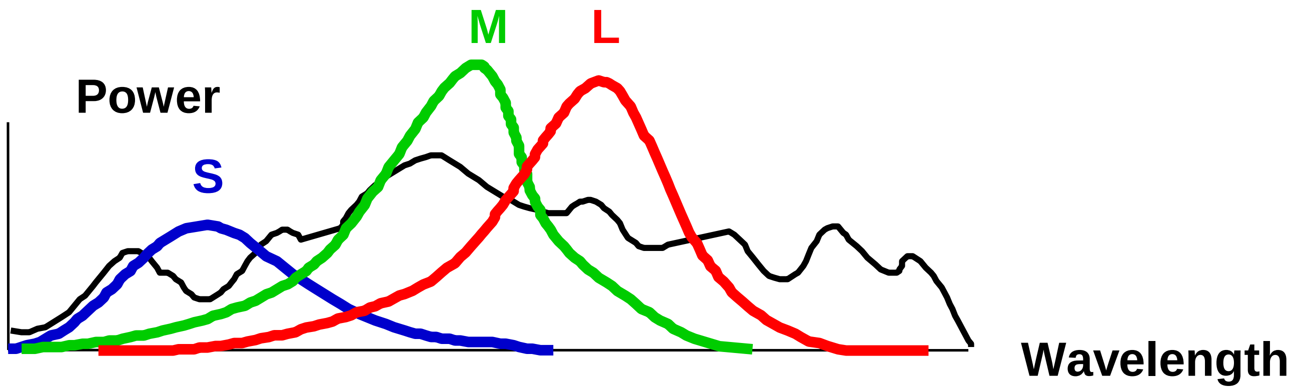


PHYSIOLOGY OF COLOR VISION



Cone mosaic





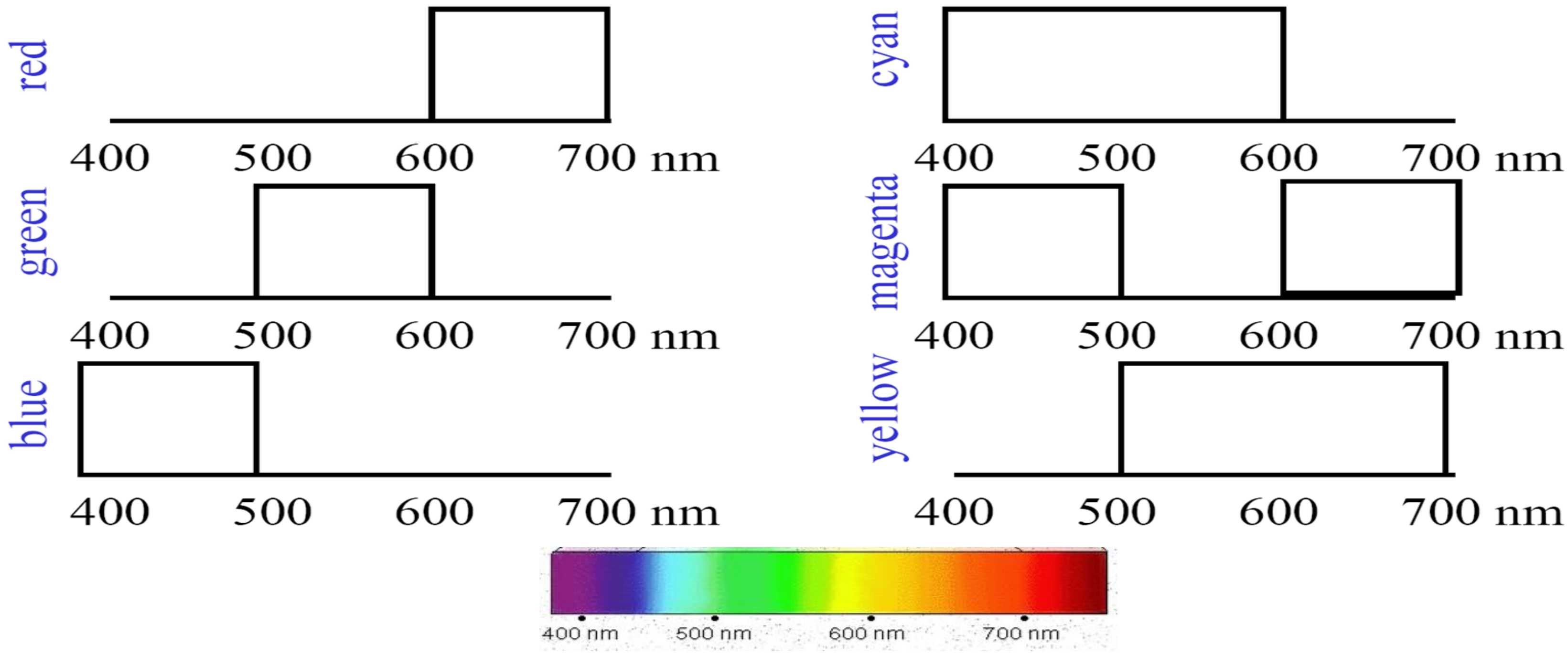
Rods and cones act as filters on the spectrum

- To get the output of a filter, multiply its response curve by the spectrum, integrate over all wavelengths
  - Each cone yields one number

Q: How can we represent an entire spectrum with 3 numbers?
A: We can't! Most of the information is lost.

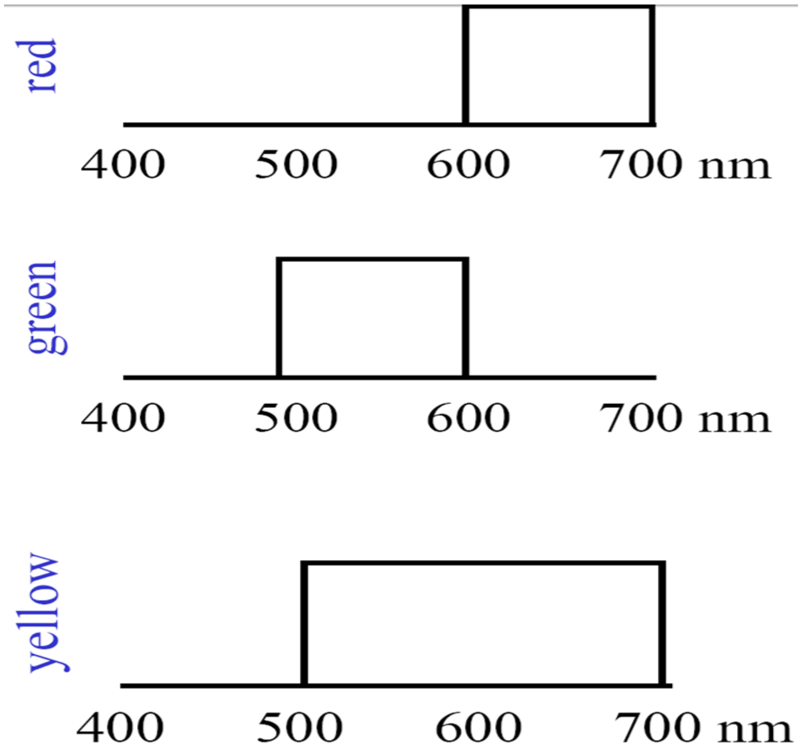
- As a result, two different spectra may appear indistinguishable
  - » such spectra are known as **metamers**

COLOR MIXING

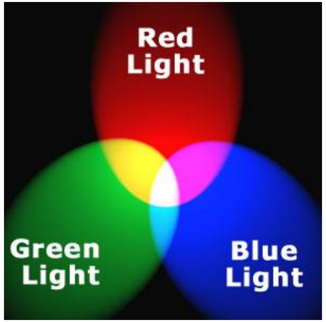


Source: W. Freeman

ADDITIVE COLOR MIXING



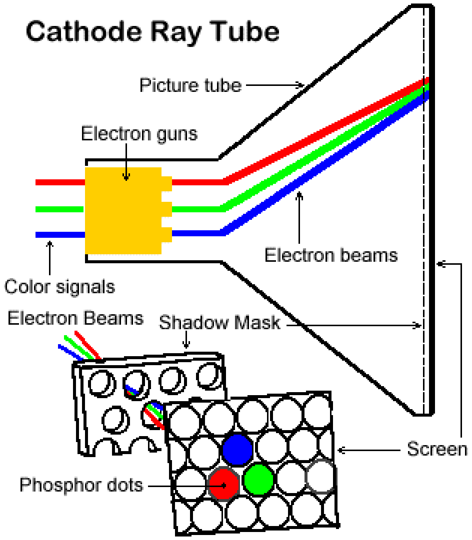
Colors combine by *adding* color spectra



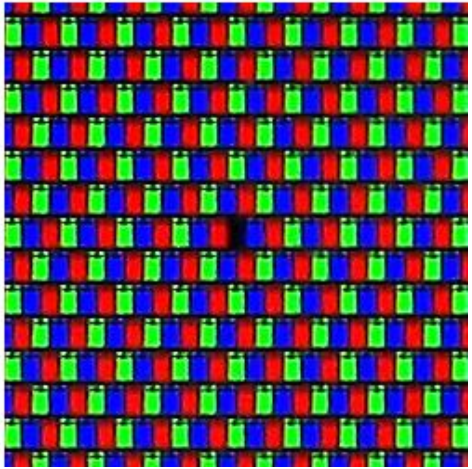
Light *adds* to existing black.

Source: W. Freeman

EXAMPLES OF ADDITIVE COLOR SYSTEMS

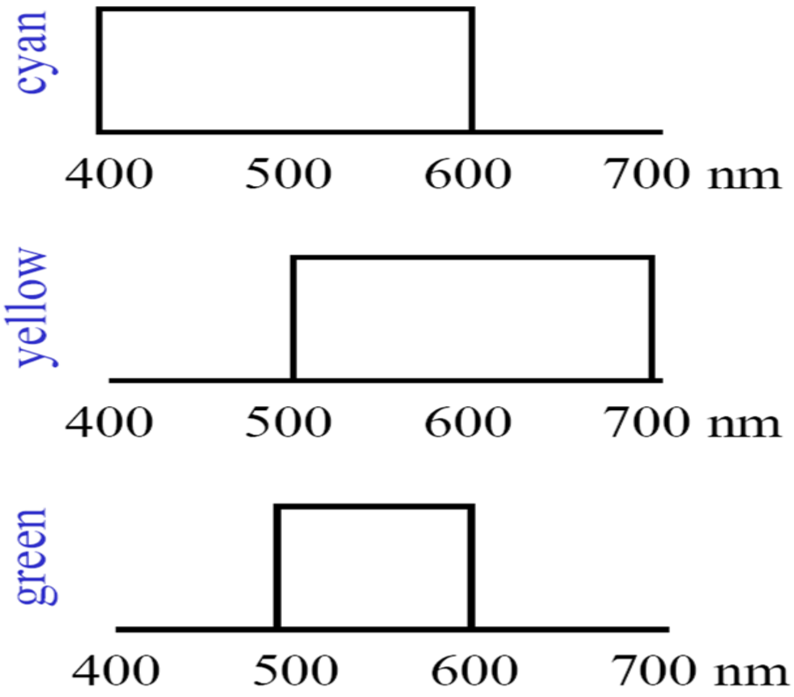


CRT phosphors

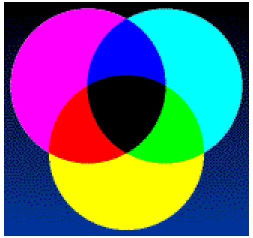


multiple projectors

SUBTRACTIVE COLOR MIXING



Colors combine by *multiplying* color spectra.



Pigments *remove* color from incident light (white).

Source: W. Freeman

EXAMPLES OF SUBTRACTIVE COLOR SYSTEMS

- Printing on paper
- Crayons
- Photographic film

TRICHROMACY

- -In color matching experiments, most people can match any given light with three primaries
  - Primaries must be *independent*

- For the same light and same primaries, most people select the same weights
  - Exception: color blindness

- Trichromatic color theory
  - Three numbers seem to be sufficient for encoding color
  - Dates back to 18th century (Thomas Young)

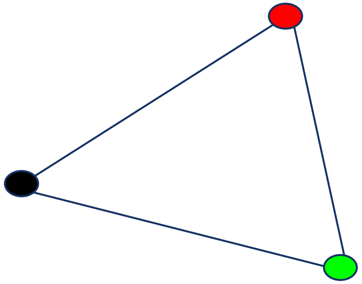
OVERVIEW OF COLOR

- Physics of color
- Human encoding of color
- Color spaces
- White balancing

LINEAR COLOR SPACES

- Defined by a choice of three *primaries*
- The coordinates of a color are given by the weights of the primaries used to match it

mixing two lights produces colors that lie along a straight line in color space

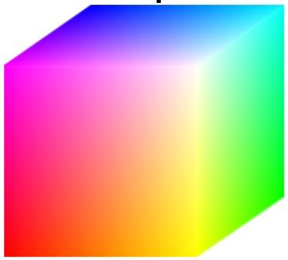


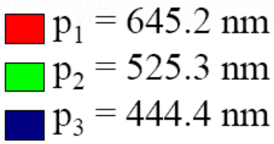
mixing three lights produces colors that lie within the triangle they define in color space

RGB SPACE

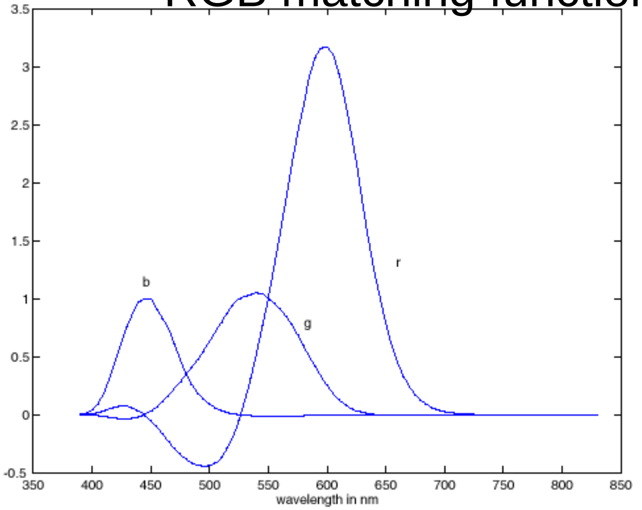
- Primaries are monochromatic lights (for monitors, they correspond to the three types of phosphors)
- *Subtractive matching* required for some wavelengths

RGB primaries

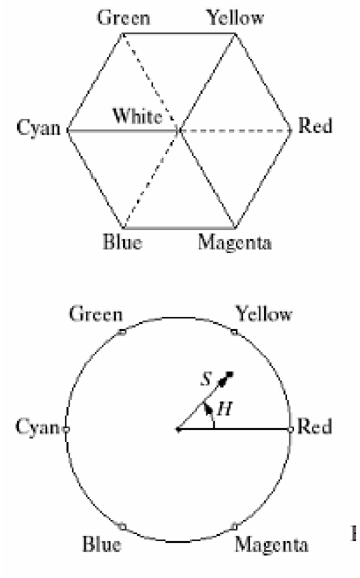


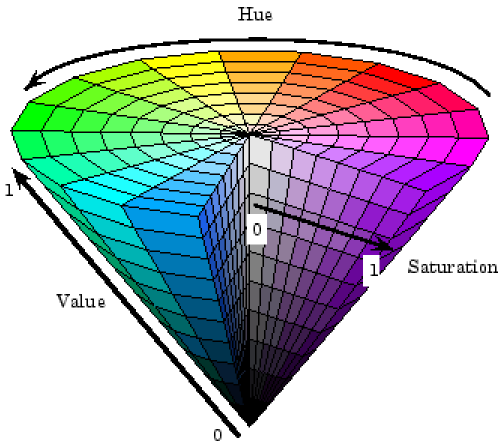


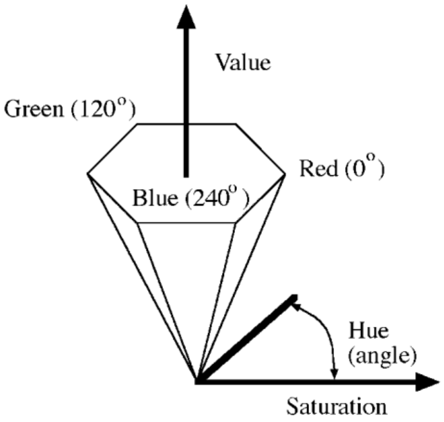
RGB matching functions



NONLINEAR COLOR SPACES: HSV







- Perceptually meaningful dimensions: Hue, Saturation, Value (Intensity)

Overview of Color

- Physics of color
- Human encoding of color
- Color spaces
- White balancing

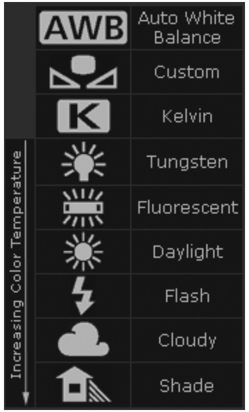
WHITE BALANCE

- It is the process of removing unrealistic color casts, so that objects which appear white in person are rendered white in your photo
- When the white balance is not correct, the picture will have an unnatural color "cast"

incorrect white balance

correct white balance

- Film cameras:
  - Different types of film or different filters for different illumination conditions
- Digital cameras:
  - Automatic white balance
  - White balance settings corresponding to several common illuminants
  - Custom white balance using a reference object



http://www.cambridgeincolour.com/tutorials/white-balance.htm

- Von Kries adaptation
  - Multiply each channel by a gain factor
  - A more general transformation would correspond to an arbitrary 3x3 matrix

- Best way: gray card
  - Take a picture of a neutral object (white or gray)
  - Deduce the weight of each channel
    - If the object is recoded as r_w, g_w, b_w use weights $1/r_w$, $1/g_w$, $1/b_w$

Slide: F. Durand

WHITE BALANCE

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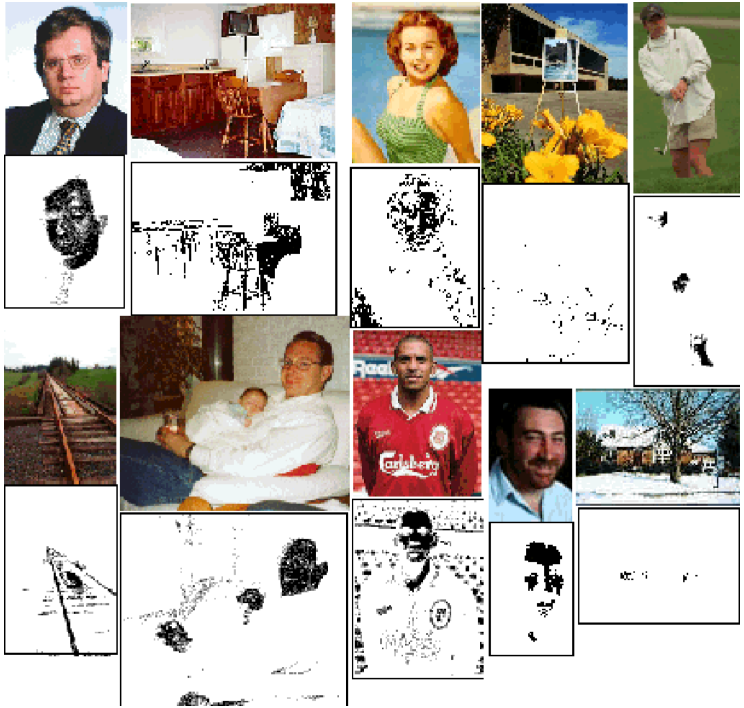
- Without gray cards: we need to “guess” which pixels correspond to white objects
- Gray world assumption
  - The image average r_{ave}, g_{ave}, b_{ave} is gray
  - Use weights $1/r_{ave}$, $1/g_{ave}$, $1/b_{ave}$
- Brightest pixel assumption (non-saturated)
  - Highlights usually have the color of the light source
  - Use weights inversely proportional to the values of the brightest pixels
- Gamut mapping
  - Gamut: convex hull of all pixel colors in an image
  - Find the transformation that matches the gamut of the image to the gamut of a “typical” image under white light
- Use image statistics, learning techniques

Slide: F. Durand

Color histograms for indexing and retrieval

Swain and Ballard, Color Indexing, IJCV 1991.

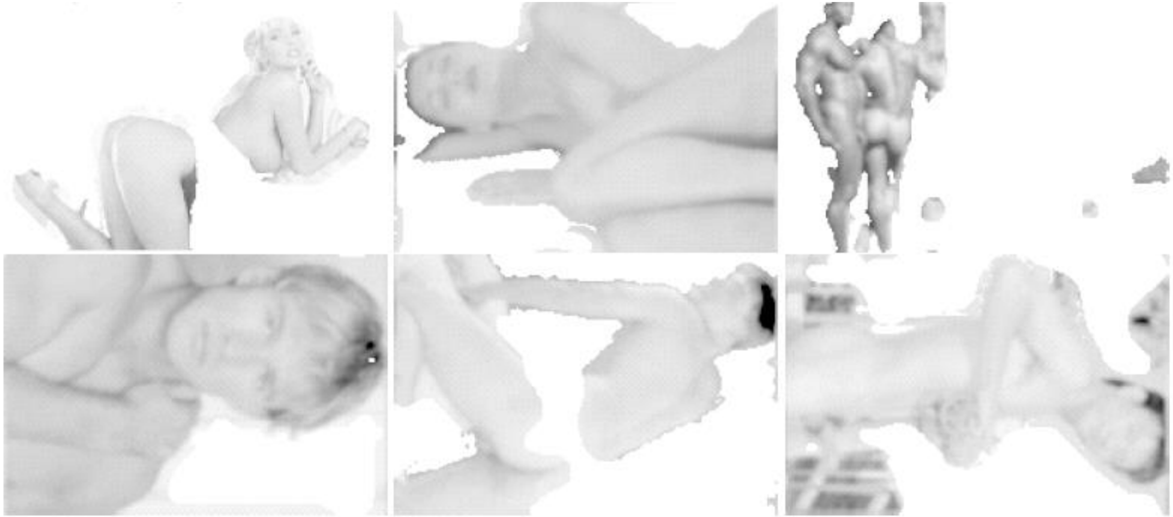
Skin detection



M. Jones and J. Rehg, Statistical Color Models with Application to Skin Detection, IJCV 2002.

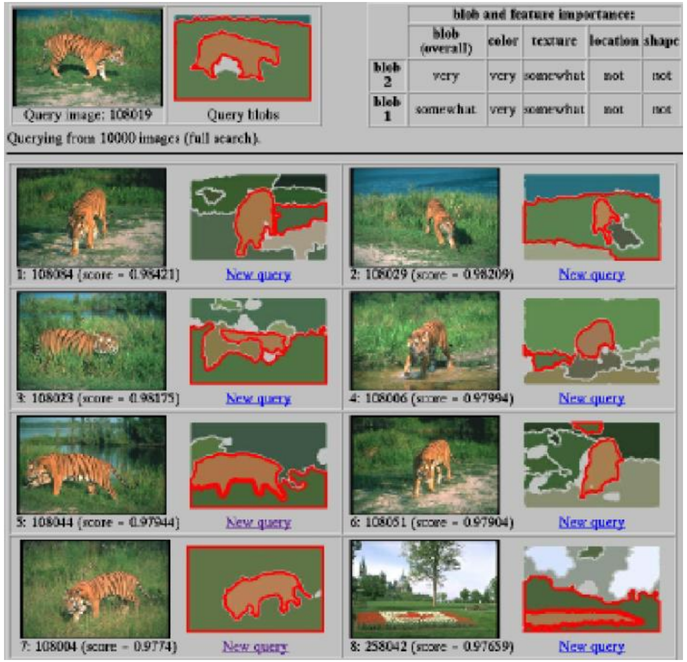
Source: S. Lazebnik

Nude people detection



Forsyth, D.A. and Fleck, M. M., “Automatic Detection of Human Nudes"
International Journal of Computer Vision , **32** , 1, 63-77, August, 1999

Image segmentation and retrieval



C. Carson, S. Belongie, H. Greenspan, and Ji. Malik, Blobworld: Image segmentation using Expectation-Maximization and its application to image querying, ICVIS 1999.

Source: S. Lazebnik

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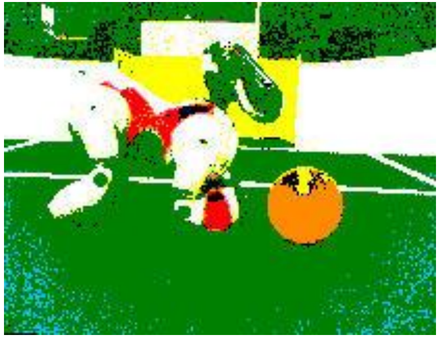
Robot soccer

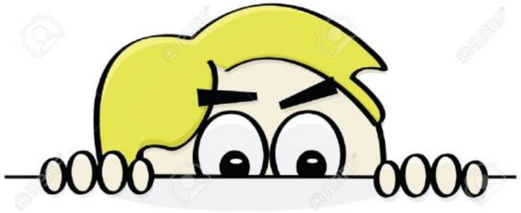


M. Sridharan and P. Stone, Towards Eliminating Manual Color Calibration at RoboCup. RoboCup-2005: Robot Soccer World Cup IX, Springer Verlag, 2006

Source: K. Grauman

Lecture 3

LET'S SNEAK A LOOK AT NEXT LECTURE



LINEARE ALGEBRA

$$\underbrace{\begin{bmatrix} a & b \\ c & d \end{bmatrix}}_{A} \times \underbrace{\begin{bmatrix} e & f \\ g & h \end{bmatrix}}_{B} = \underbrace{\begin{bmatrix} ae + bg & af + bh \\ ce + dg & cf + dh \end{bmatrix}}_{C}$$

A, B and C are square metrices of size N x N
a, b, c and d are submatrices of A, of size N/2 x N/2
e, f, g and h are submatrices of B, of size N/2 x N/2

SEE YOU ON TUESDAY!