COMPUTER VISION
Lecture 2

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CONTENTS

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Chapter 1

Brief Summary

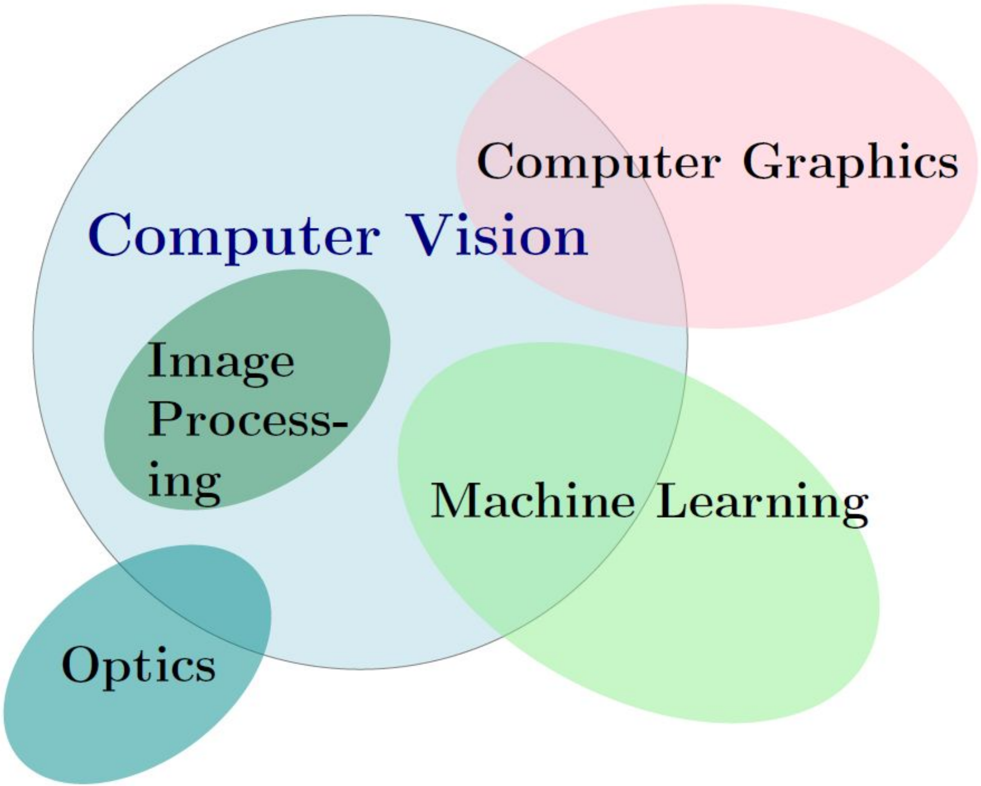
- Attendance not mandatory
- **Direct** correlation between attendance and passing the exam
- **Direct** correlation between attendance and grade of the exam

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

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

Image (or video)

Sensing device

Interpreting device

Interpretations

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

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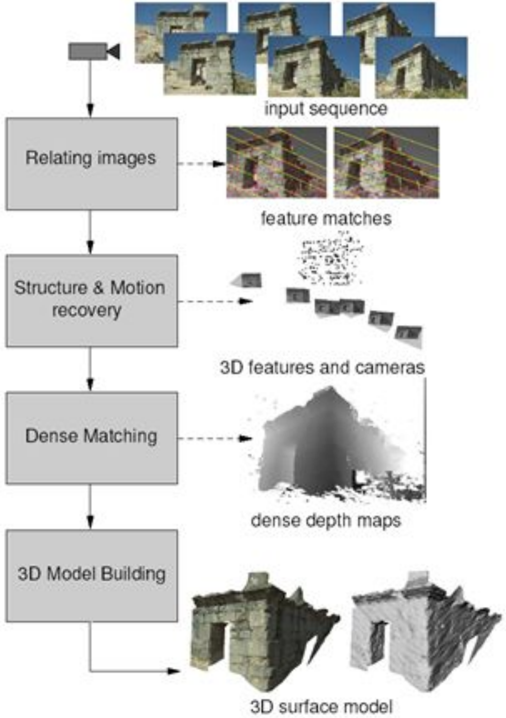
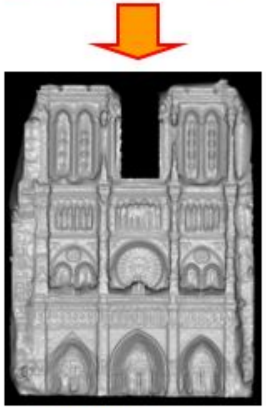
WHAT INFORMATION TO EXTRACT

- Metric 3D Information
- Semantics

VISION AS A MEAUREMENT DEVICE

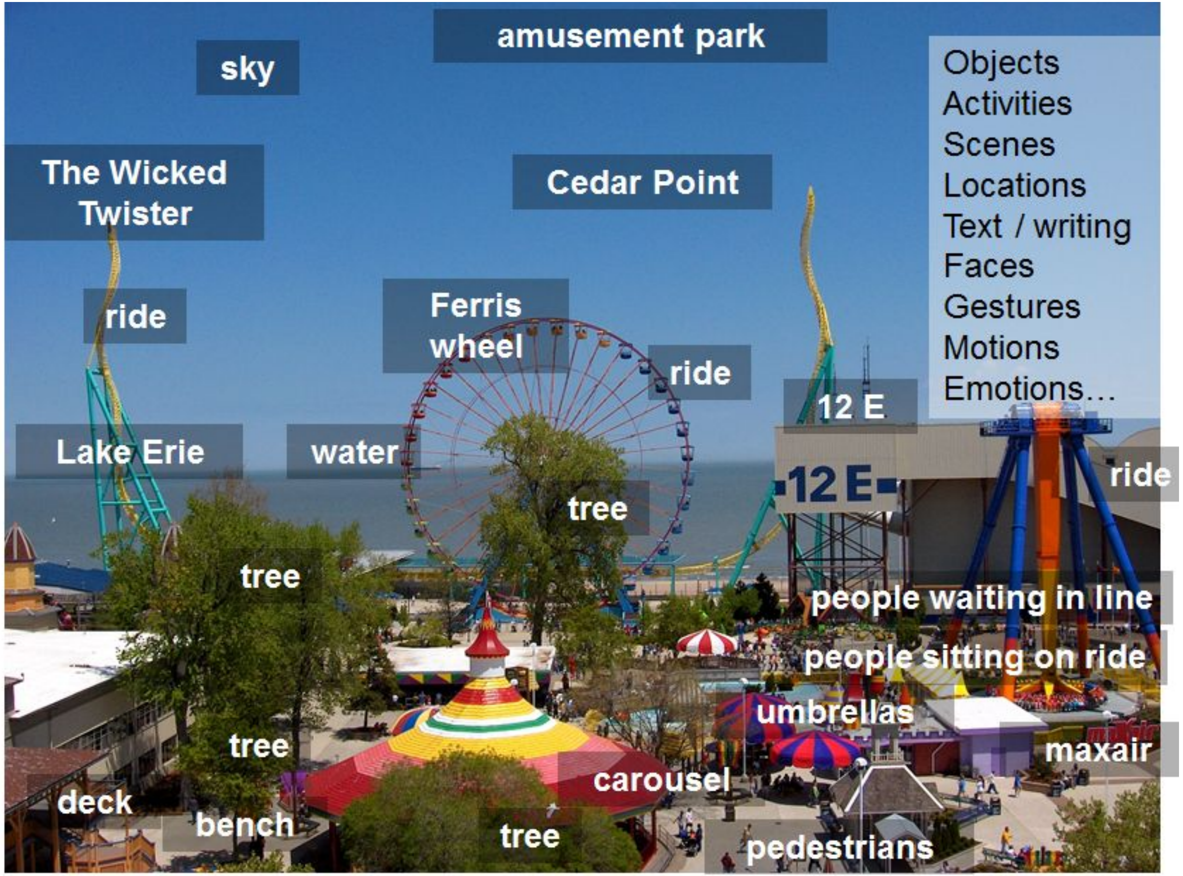


Pollefeys et al.



Goesele et al.

VISION AS A SOURCE OF SEMANTIC INFORMATION



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Chapter 2

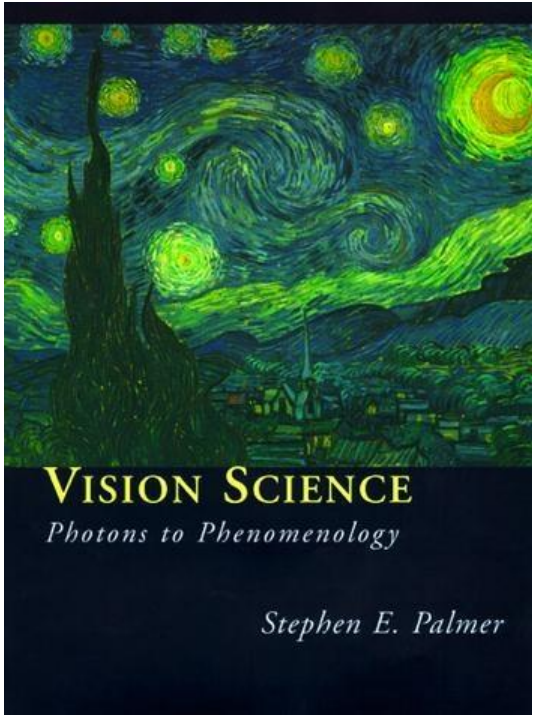
Light

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

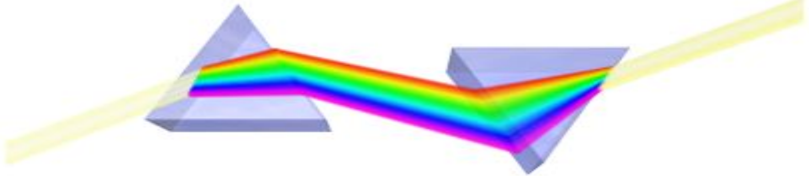
WHAT IS COLOR?

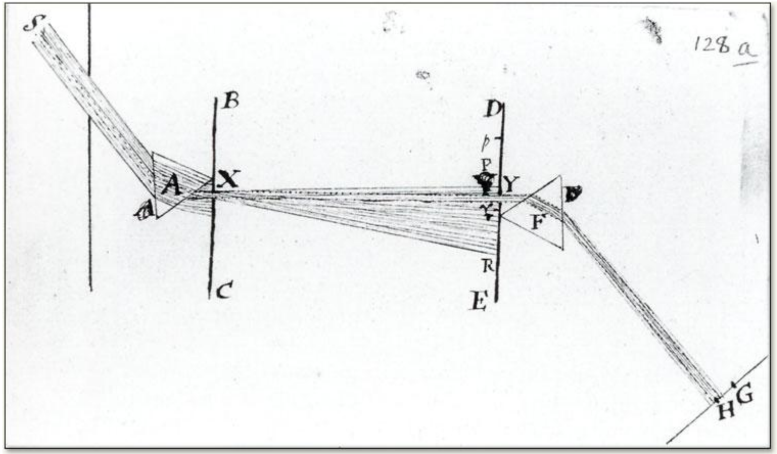
- The result of interaction between physical light in the environment and our visual system.

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



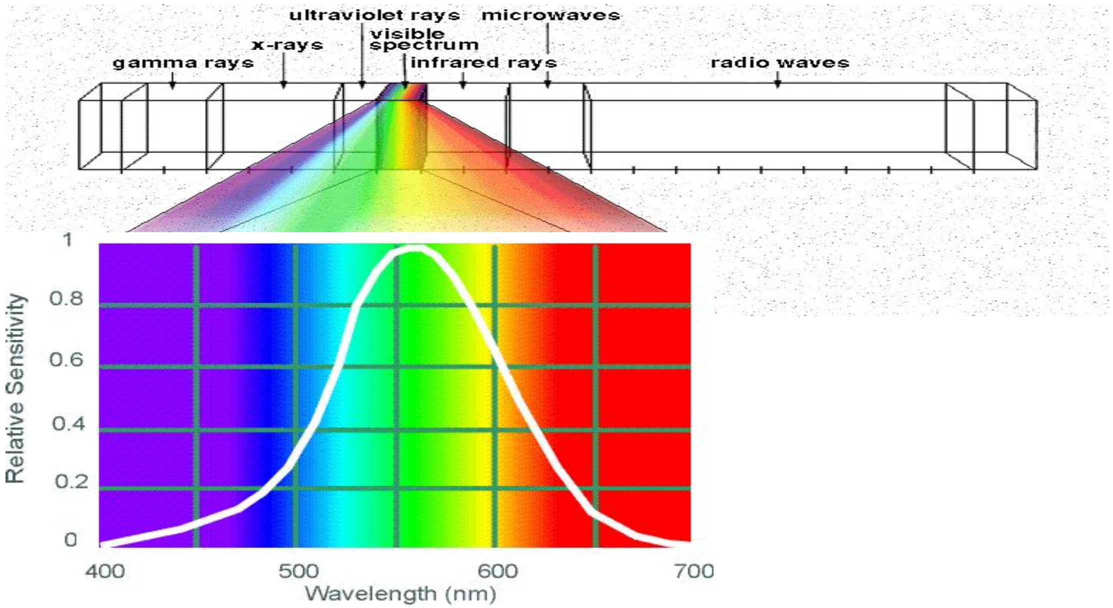
White light: composed of almost equal energy in all wavelengths of the visible spectrum





Newton 1665

ELECTROMAGNETIC SPECTRUM

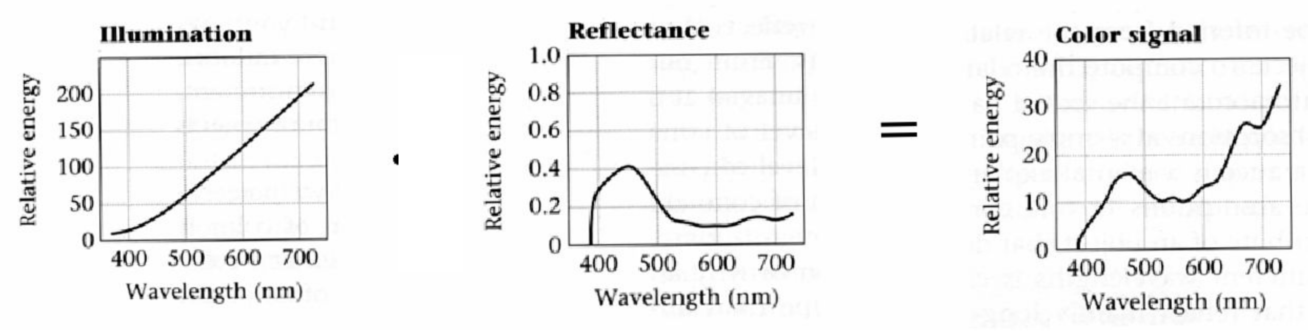


Human Luminance Sensitivity Function

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

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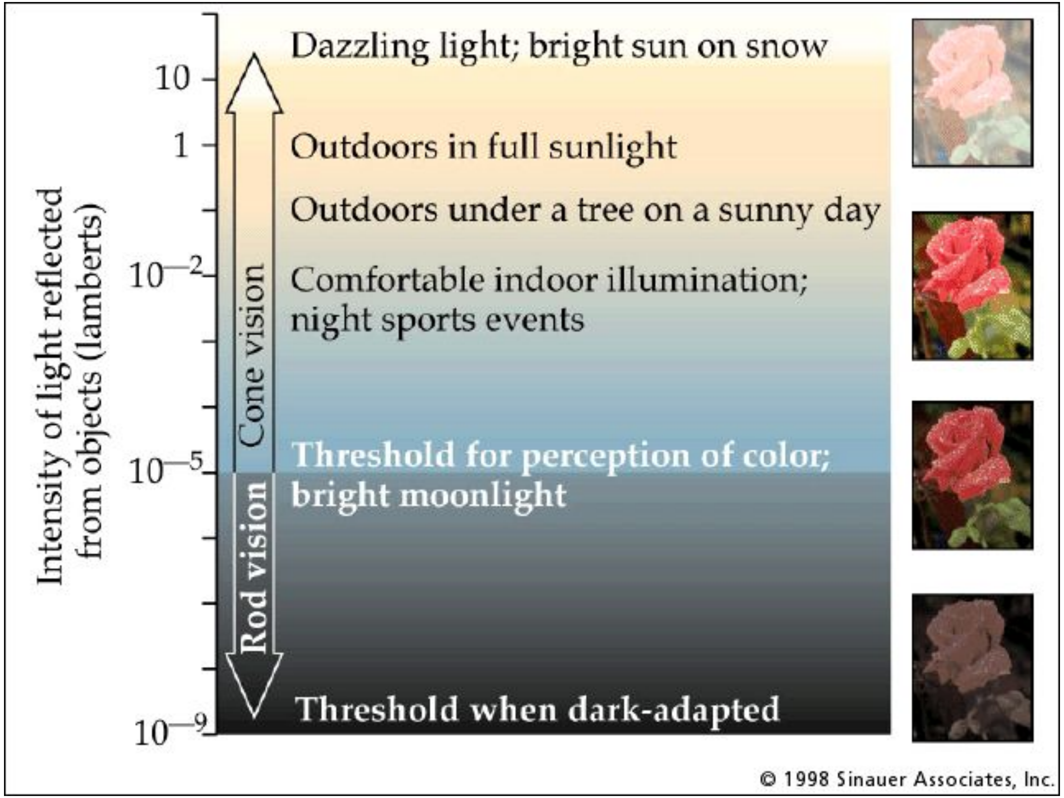
- Physics of color
- Human encoding of color
- Color spaces
- White balancing

TWO TYPES OF LIGHT-SENSITIVE RECEPTORS

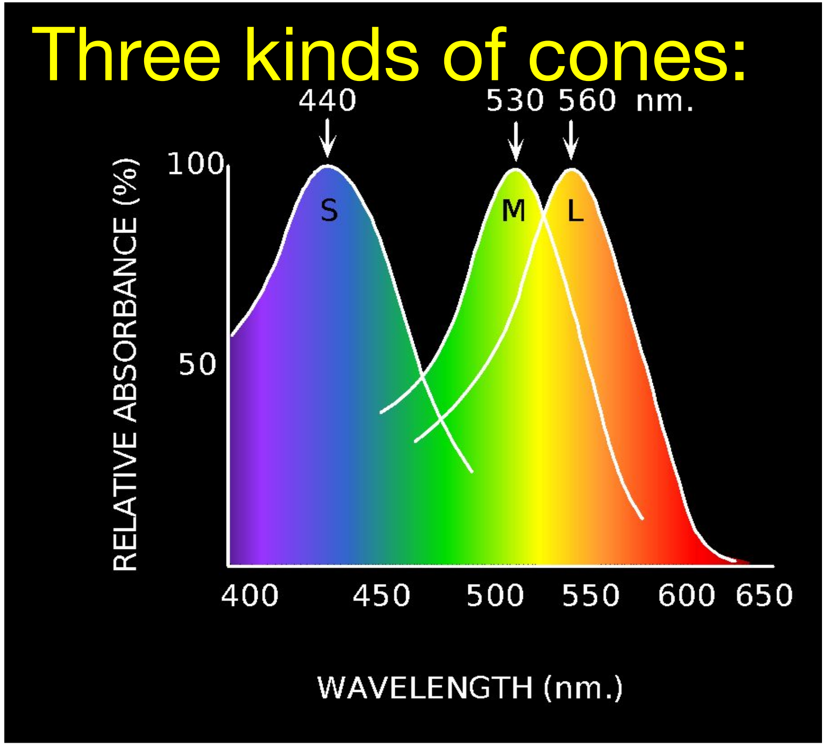
Cones
- cone-shaped
- less sensitive
- operate in high light
- color vision

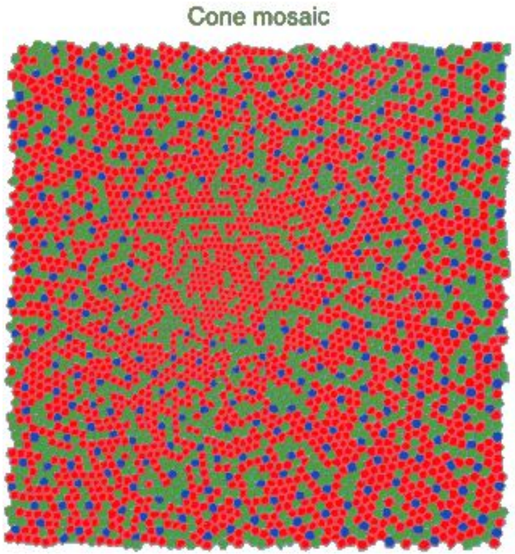
Rods
- rod-shaped
- highly sensitive
- operate at night
- gray-scale vision

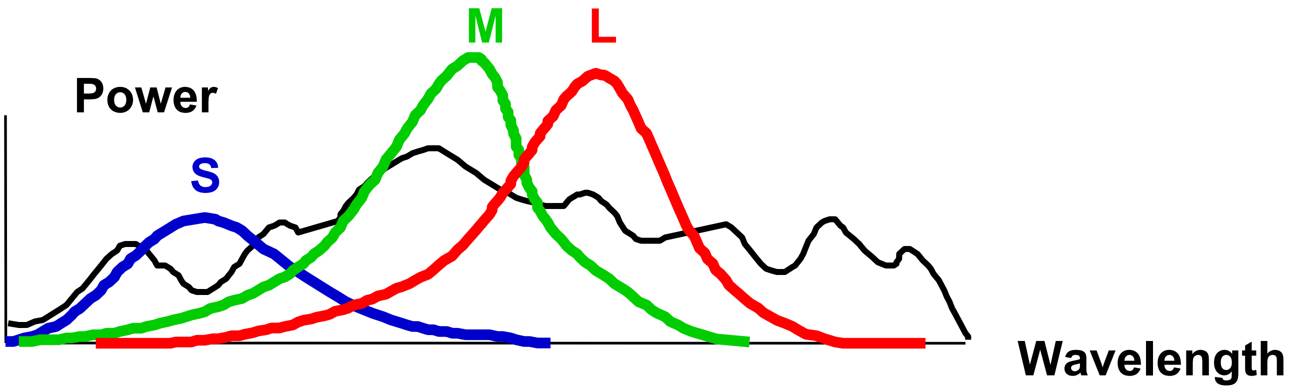
ROD / CONE SENSITIVITY



PHYSIOLOGY OF COLOR VISION







Rods and cones act as filters on the spectrum

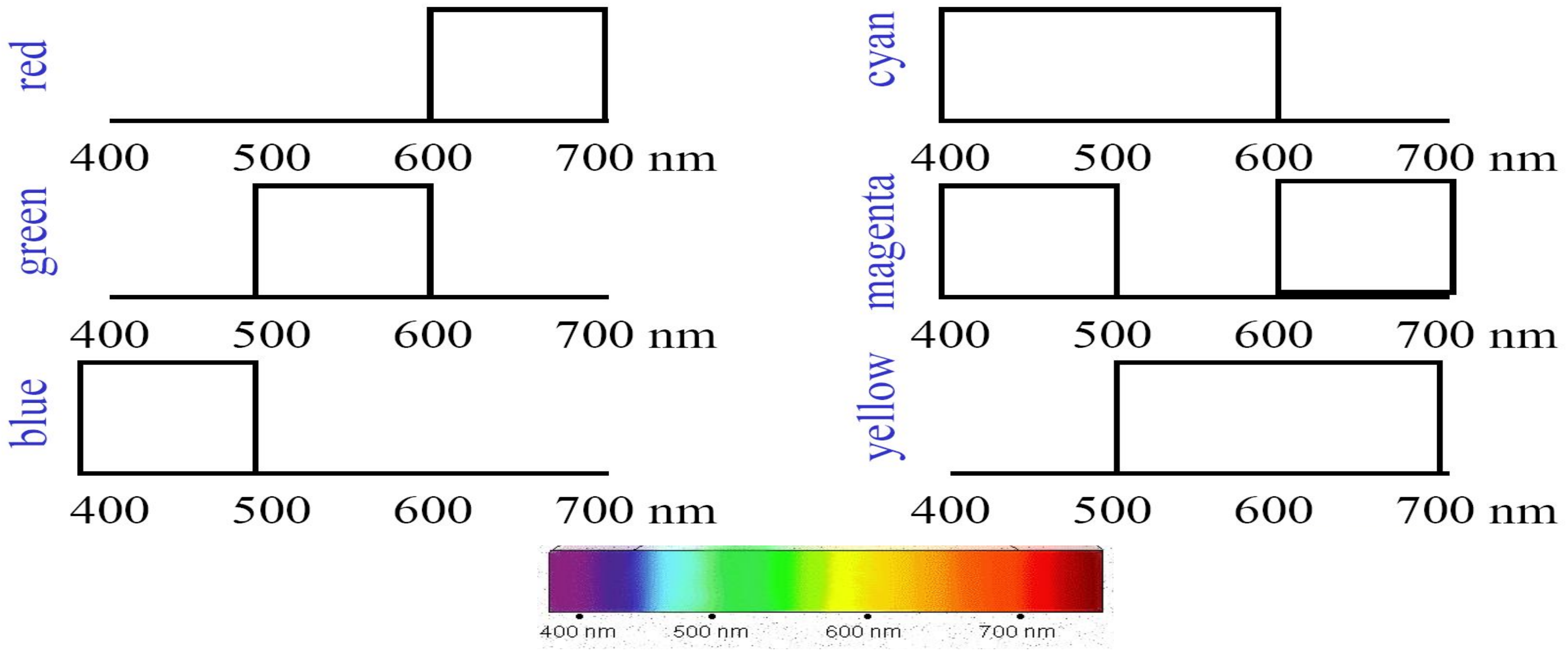
- To get the output of a filter, multiply its response curve by the spectrum, integrate over all wavelengths
  - Each cone yields one number

Q: How can we represent an entire spectrum with 3 numbers?

A: We can't! Most of the information is lost.

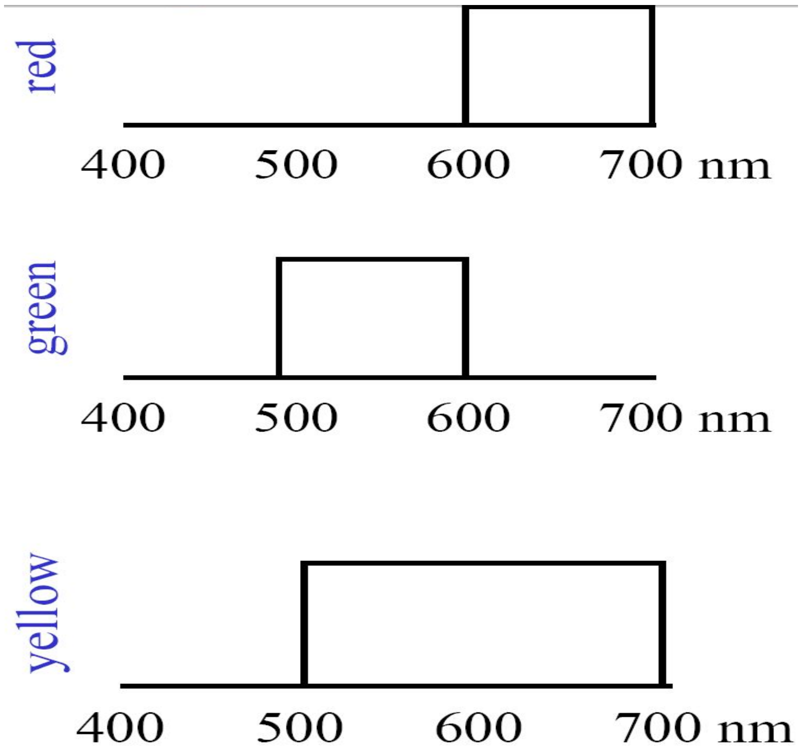
- As a result, two different spectra may appear indistinguishable
  - such spectra are known as **metamers**

COLOR MIXING

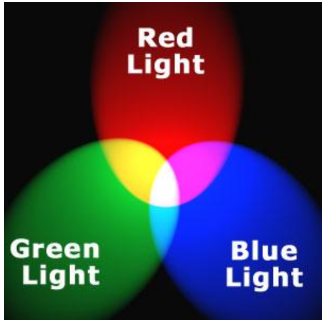


Source: W. Freeman

ADDITIVE COLOR MIXING



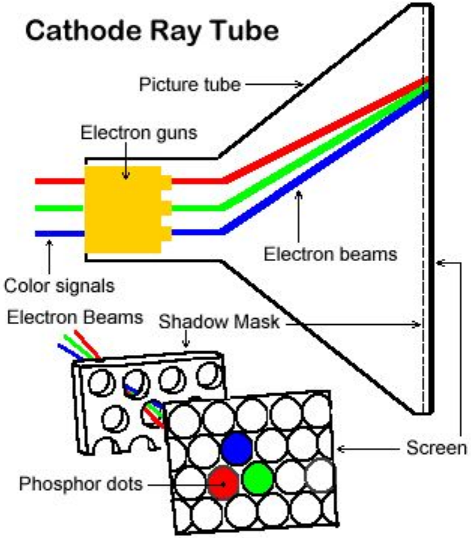
Colors combine by *adding* color spectra



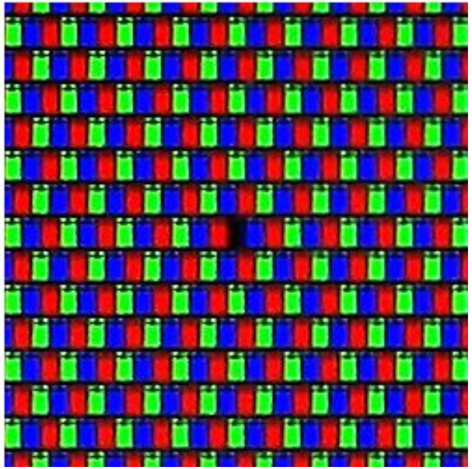
Light *adds* to existing black.

Source: W. Freeman

EXAMPLES OF ADDITIVE COLOR SYSTEMS

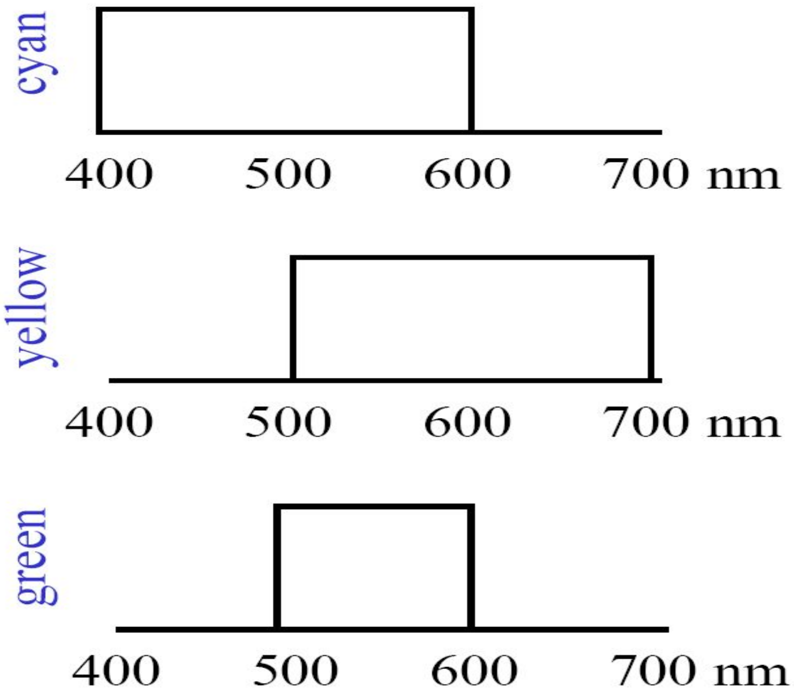


CRT phosphors

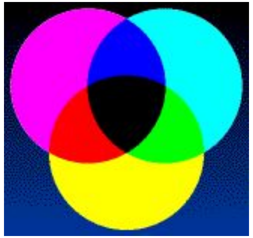


multiple projectors

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

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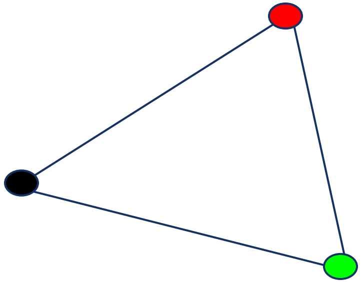
- Defined by a choice of three *primaries*
- The coordinates of a color are given by the weights of the primaries used to match it

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

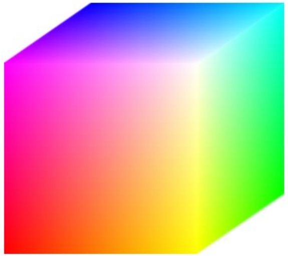


mixing three lights produces colors that lie within the triangle they define in color space

RGB SPACE

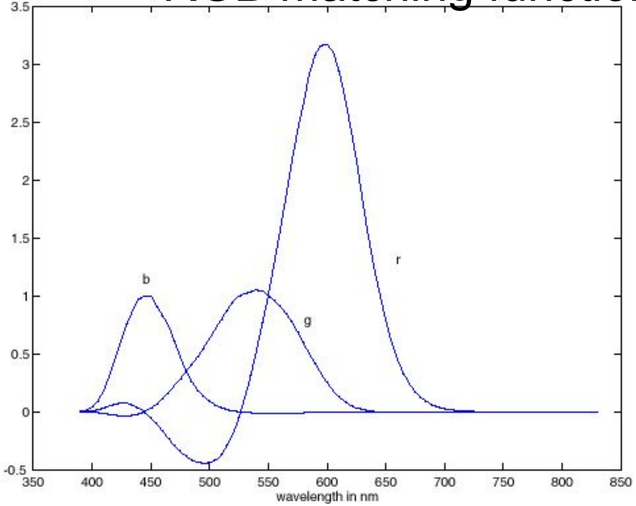
- Primaries are monochromatic lights (for monitors, they correspond to the three types of phosphors)
- *Subtractive matching* required for some wavelengths

RGB primaries

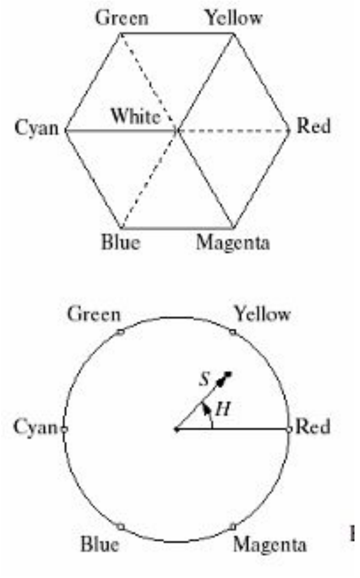


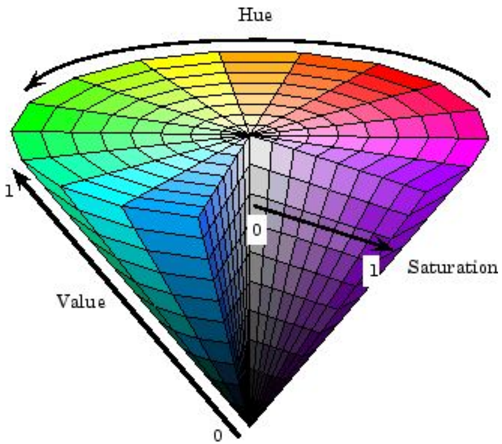
$p_1 = 645.2$ nm
$p_2 = 525.3$ nm
$p_3 = 444.4$ nm

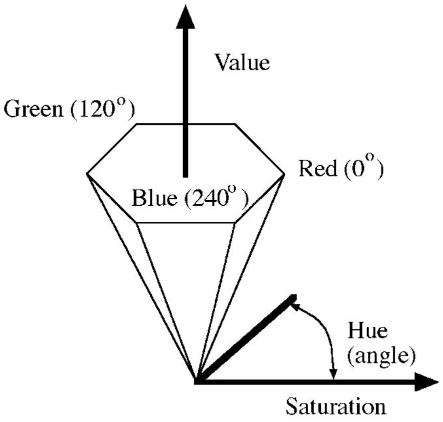
RGB matching functions



NONLINEAR COLOR SPACES: HSV







- Perceptually meaningful dimensions: Hue, Saturation, Value (Intensity)
- RGB cube on its vertex

Overview of Color

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

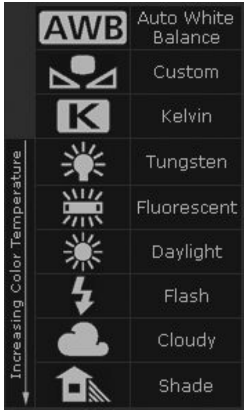
WHITE BALANCE

- 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 $1/r_w$, $1/g_w$, $1/b_w$

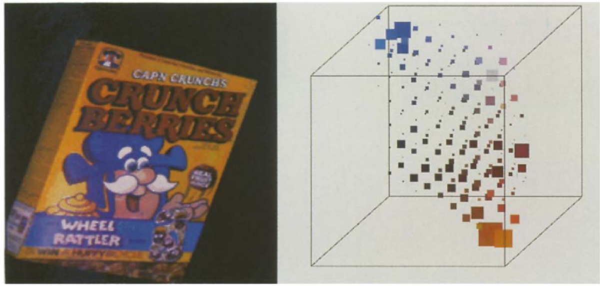
Slide: F. Durand

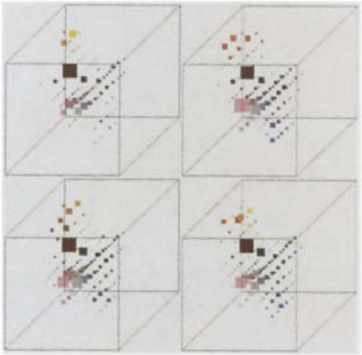
WHITE BALANCE

- 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

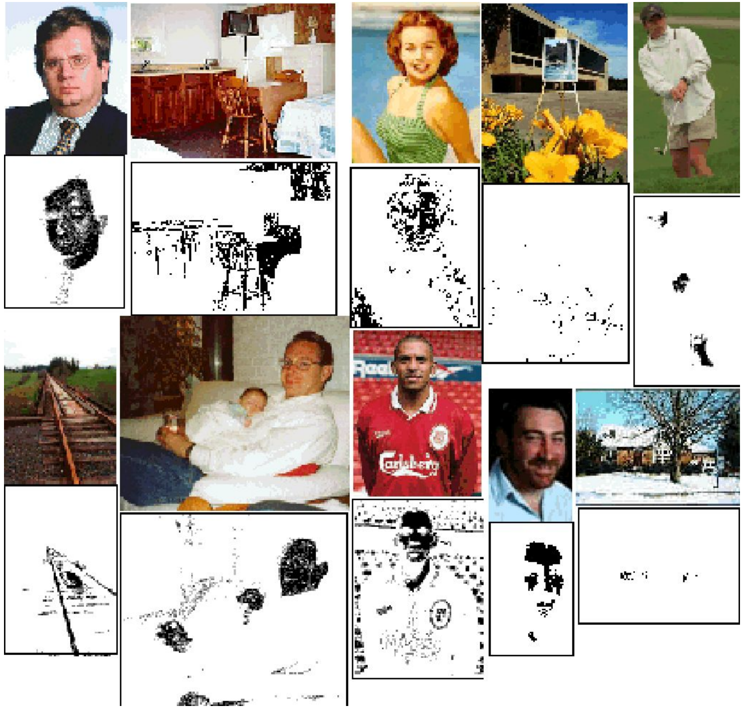
Color histograms for indexing and retrieval





Swain and Ballard, Color Indexing, IJCV 1991.

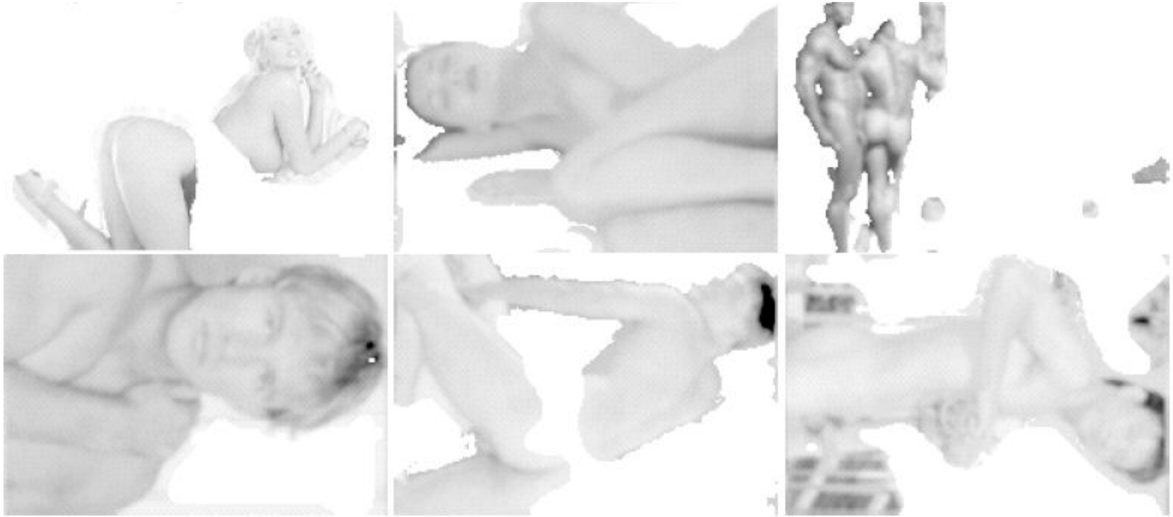
Skin detection



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

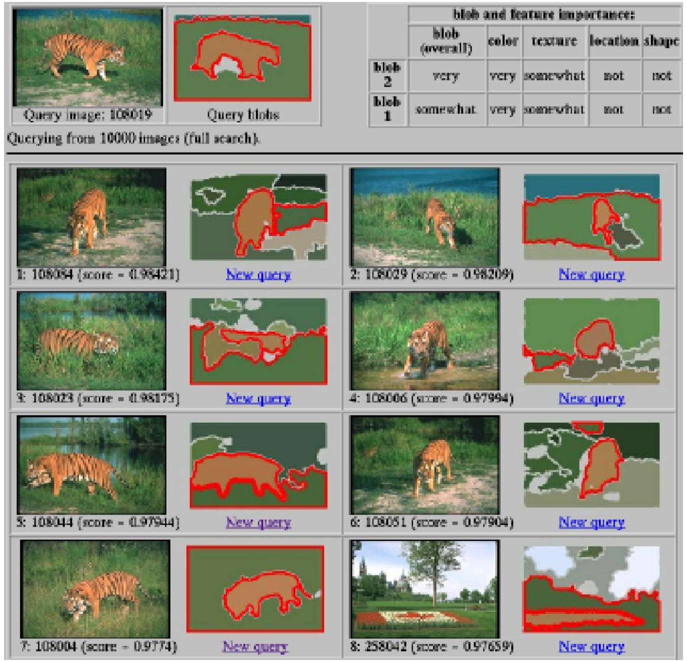
Source: S. Lazebnik

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

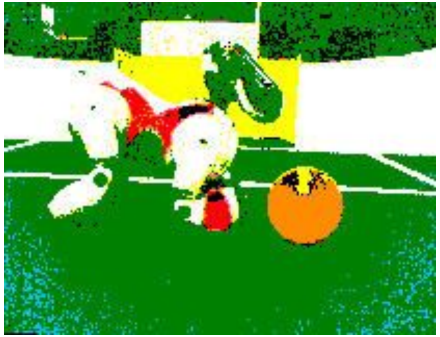
Image segmentation and retrieval



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

Robot soccer

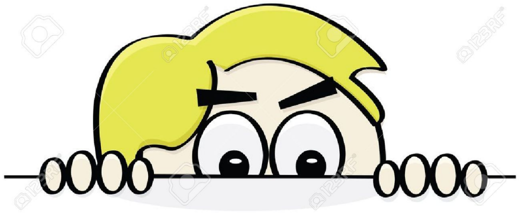
 

M. Sridharan and P. Stone, Towards Eliminating Manual Color Calibration at RoboCup. RoboCup-2005: Robot Soccer World Cup IX, Springer Verlag, 2006

Source: K. Grauman

Lecture 3

LET'S SNEAK A LOOK AT NEXT LECTURE



LINEARE ALGEBRA

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

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!