CAP 4453
Robot Vision

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• Assignment Zero:
  • Due tomorrow

• Assignment 1:
  • Deadline: Next Friday
Questions?
Credits

• Some of this slides comes from:
  • Yogesh S Rawat (UCF)
  • Noah Snavely (Cornell)
  • Ioannis (Yannis) Gkioulekas (CMU)
  • Mubarak Shah (UCF)
  • S. Seitz
  • James Tompkin
  • Ulas Bagci
  • L. Lazebnik
Robot Vision

2. Basics of Images
Black Body radiation

![Graph showing the spectrum of black body radiation with different temperatures (3000 K, 4000 K, 5000 K, 6000 K) and indicating the maximum wavelength.](image-url)
LED lights

Day 1: Electromagnetic Radiation and Matter – Chemistry 109 (unizin.org)
From last class

How the spectrum appears to people and dogs

Human’s View

Dog’s View

Ultraviolet

Light Wavelength (nm)
From last class

Human View
(No UV Sensitivity)

Dog View
(Some UV Sensitivity)
From last class

Sensitivity to UV makes targets that block or reflect these short wavelengths visible (like a drawing in sunscreen lotion)

Dog Vision: What Colors Can Dogs See And Can They See In The Dark? (improveeyesighthq.com)
From last class

The ability to see ultraviolet (UV) helps guide bees to the pollen containing parts of flowers

Human View (No UV Sensitivity)  Bee View (UV Sensitivity)

A large list of visual sensors

- Monochrome cameras
- RGB cameras
- MultiSpectral cameras
- Lidar / Time of flight cameras
And beyond
Images using other bands

See the Whirlpool Galaxy Through the Eyes of NASA’s 'Great Observatories' - YouTube
Multispectral cameras

- **OPTICAL ELEMENTS**
- **FILTER WHEEL**
- **FILTER ON SENSOR**
MultiSpectral cameras

- PCB inspection
- Skin characterization
- Food inspection
- Agriculture
  - Analyzing crops
- Military

Multispectral Imaging: New Technology Resurrects Centuries-Old Texts (nbcnews.com)
Outline

• Image as a function
  • Sampling
  • Quantization

• Extracting useful information from Images
  • Histogram

• Color spaces
  • RGB
  • HUE
  • CIE

• Homework 1
Outline

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Traffic movie (2000)
You learn today
Digitization

- Computers use discrete form of the images
- The process transforming *continuous space* into *discrete space* is called *digitization*
Digitization

- Function
  \[ y = f(x) \]
- Domain of a function
- Range of a function
- Sampling
  - Discretization of domain
- Quantization
  - Discretization of range
Digitization of 1D function

one-dimensional

quantization

sampling

continuous signal → digitized signal

$y = f(t)$
Digitization of 2D function
Digitization of 3D function

three-dimensional

continuous image

digitized image
Digitization of an arc
Gray scale digital image

Brightness or intensity
Definition

• An image $P$ is a function defined on a (finite) rectangular subset $G$ of a regular planar orthogonal array.
• $G$ is called (2D) grid, and an element of $G$ is called a pixel.
• $P$ assigns a value of $P(p)$ to each $p \in G$
Definition

- Pictures are not only sampled
- They are also quantized
  - they may have only a finite number of possible values
  - i.e., 0 to 255, 0-1, ...
Digitization
Sampling
Quantization

Original (256 colors)  8 colors  4 colors
About the picture

Lena Forsen - playmate, who became the "mother" of JPEGs (fotoblogia.pl)
Resolution

- Also a display parameter
  - defined in dots per inch (DPI) or
  - measure of spatial pixel density
  - standard value for recent screen technologies is 72 dpi.
  - Recent printer resolutions are in 300 dpi and/or 600 dpi.
Gray scale image

- An image contains discrete number of pixels
  - A simple example
  - Pixel value:
    - "grayscale" (or "intensity"): [0, 255]
Color image

- An image contains discrete number of pixels
  - A simple example
  - Pixel value:
    - “grayscale” (or “intensity”): [0, 255]
    - “color”
      - RGB: [R, G, B]
      - Lab: [L, a, b]
      - HSV: [H, S, V]

[213, 60, 67]
[90, 0, 53]
[249, 215, 203]

Source: F.F. Li
RGB Channels
RGB Channels

How many pixels do you need to represent this image?
How many bytes do you need to represent this image?
RGB Color Space

Compression technique

- These are colours with different spectra but with same perceptual values
- RGB colour space is the basic colour space
- Device-dependant colour space
RGB Color Space

Compression technique

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RGB Color Space

Compression technique

Disadvantages

- a high correlation between its components
  - about 0.78 for rBR (cross correlation between the Band R channel)
  - 0.98 for rRG
  - 0.94 for rGB
- It is psychologically non-intuitive
- Perceptual non-uniformity (add a value have different effect for every color)
Phenomenal color spaces

• Most natural way for humans of describing colors
• Described by 3 attributes
  • Hue: the colour is red, green, yellow, blue, purple ...
  • Saturation: the level of non-whiteness
  • Brightness is a measure of the intensity of light.
• HSL color space. Hue, Saturation, Luminance
  • transformations from the RGB space.
  • inherit all the short-comings of RGB space.
  • There is usually a hue discontinuity around 360 degrees.
  • This makes difficult to make arithmetic operations in such a color space.
measure the spectral reflectance factors of an object

(23) What is the CIELAB color space, and how is it used to determine the quality of a surface? - Quora
CIE Colour Spaces

• CIE (Commission Internationale de l’Eclairage (illumination))
  • In 1931 laid down the CIE 1931 standard colorimetric observer.
  • CIE XYZ: CIE standardized the XYZ values as tristimulus values that can describe any color that can be perceived by an average human observer
    • XYZ are positives
    • It is device dependent
  • CIELuv and CIELab: proposed in 1976
  • Goal: provide a perceptually equal space
  • CIELab
    • \( L^* \) closely matches human perception of lightness (black at 0 and white at 100)
    • \( a^* \): green–red opponent colors, with negative values toward green and positive values toward red. Unbounded, usually bounded from -128 to 127
    • \( b^* \): blue–yellow opponents, with negative numbers toward blue and positive toward yellow. Unbounded
CIELAB

- L* measures whether the sample is light (high L*) or dark (low L*).
- The a* and b* values together represent the hue and chroma of the sample.

<table>
<thead>
<tr>
<th></th>
<th>std</th>
<th>bttx</th>
</tr>
</thead>
<tbody>
<tr>
<td>L*</td>
<td>56</td>
<td>58</td>
</tr>
<tr>
<td>a*</td>
<td>26</td>
<td>36</td>
</tr>
<tr>
<td>b*</td>
<td>3</td>
<td>9</td>
</tr>
</tbody>
</table>

the bttx is lighter, stronger and yellower than the std
CIELab
Cielab

LAB color enhancement in Photoshop. Normal Image
CieLAB transformation

```python
# -*- coding: utf-8 -*-

# Created on Wed Aug 24 19:10:31 2022

@author: gonzalez

import cv2
import numpy as np

img = cv2.imread('cvexposed.jpg')

imgcie = cv2.cvtColor(img, cv2.COLOR_BGR2LAB)

imgcie = imgcie.astype(np.float)

imgcie[:,:,0] = imgcie[:,:,0] - 80
imgcie[:,:,1] = imgcie[:,:,1] - 30
imgcie[imgcie<0] = 0

imgcie = imgcie.astype(np.uint8)

imgOut = cv2.cvtColor(imgcie, cv2.COLOR_LAB2BGR)

cv2.imshow('in', img)
cv2.imshow('out', imgOut)
cv2.waitKey(0)
```
A histogram is a graphic representation of numerical data that shows the data distribution. When the number of observations is large, and the bin's size is small, the histogram will be similar to the distribution density chart.

How to create a histogram?

1. Find the range of the numerical data, Range = Max - Min.
2. Choose the number of bins you prefer to present.
3. Calculate the bin size: Bin size = Range/number of bins.
4. For every bin count, the total number of observations falls in the bin.
5. Present the data as a column chart, where each column represents the number of observations in a bin.
Image Histogram
Histogram Example
Intensity profiles for selected (two) rows
Questions?
Coding homeworks

• Presented as a notebook using colab
  • https://colab.research.google.com/

• Homeworks are posted at webcourses as a link to:
  • gonzo1978/CAP4453: Colab notes for CAP 4453 (github.com)