CAP 4453
Robot Vision
Dr. Gonzalo Vaca-Castaño
gonzalo.vacacastano@ucf.edu
Administrative details

• AI group announcement
• Grader Email: robotvision.ucf@gmail.com
• 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
Why there are 2 greens at BAYER

• As a cost-effective alternative, many manufacturers produce cameras that coat the CCD elements of their area arrays with a Bayer filter, named after Bryce E. Bayer, a scientist at Eastman Kodak who patented the concept in 1976. In Bayer-based color imagers, pixels on the image sensor are covered with a mosaic of red, green, and blue transmissive filters. In the Bayer pattern, 50% of the pixels are green, 25% are red, and 25% are blue (see image).

• Bayer noticed that the human eye obtains most of its sharpness information from green light, which is why the pattern has more green pixels. By using two green-filtered pixels for every red or blue, the Bayer pattern is designed to maximize the perceived sharpness in the luminance channel, composed mostly of green data.

Cameras use Bayer filters to attain true color | Vision Systems Design (vision-systems.com)
From last class

How the spectrum appears to people and dogs

Human’s View

Dog’s View

Light Wavelength (nm)

Ultraviolet

Can Dogs See in Ultraviolet? | Psychology Today
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 sun screen 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

A large list of visual sensors

Monochrome cameras

MultiSpectral cameras

RGB cameras

Lidar / Time of flight cameras
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)
Computer Vision 2010 vs Today

In 2010
Applications

- Self Driving cars
- Biometric verification
- Healthcare (Gauss Surgical)
- Medical diagnostics
- Retail (amazon go)
- Industrial monitoring
- Agriculture (remove weeds)

Google’s DeepMind Beats Doctors at Detecting 50 Eye Diseases Just by Looking at Scans

By AL Cheung
Last Modified Date: May 27, 2020

Cargill brings facial recognition capability to farmers through strategic equity investment in Cainthus

Senators give farmers clear picture of animal health and well-being

Discovered (5/16): Cargill and Cainthus, a Denver-based machine vision company, are launching a joint venture to provide farmers with a new technology that uses facial recognition to identify sick animals on farms. The system, called FarmViz, uses computer vision technology to detect signs such as food and water intake, tail position and behavior patterns of animals. The software analyzes data from the animals to identify potential health issues, allowing farmers to take action to prevent disease spread.

Walmart Expands Use of Bossa Nova’s Robots from 50 to 350 Stores

It was recently announced that Walmart has expanded its use of autonomous mobile robots (AMRs) used for real-time, on-shelf product data. Walmart will use these AMRs in 350 stores to improve inventory management.

AI startup Gather uses drones and computer vision for warehouse inventory

Disney’s facial recognition AI watches you watch movies

Cargill brings facial recognition capability to farmers through strategic equity investment in Cainthus

Discovered (5/16): Cargill and Cainthus, a Denver-based machine vision company, are launching a joint venture to provide farmers with a new technology that uses facial recognition to identify sick animals on farms. The system, called FarmViz, uses computer vision technology to detect signs such as food and water intake, tail position and behavior patterns of animals. The software analyzes data from the animals to identify potential health issues, allowing farmers to take action to prevent disease spread.
What changed?

- Emergence of deep learning
- Advancement in hardware
- Availability of large-scale data
  - ImageNet
  - OpenImages
  - YFCC100M
  - Youtube-8M
  - Kinetics
  - AVA
  - ...

![Google Cloud](image)
![Microsoft Azure](image)
![NVIDIA](image)
![Amazon Web Services](image)
CPU vs GPU
Hardware

Train

- **CPU**
  - Small models
  - Small datasets
  - Useful for design space exploration

- **GPU**
  - Medium-to-large models, datasets
  - Image, video processing
  - Application on CUDA or OpenCL

- **TPU**
  - Matrix computations
  - Dense vector processing
  - No custom TensorFlow operations

- **FPGA**
  - Large datasets, models
  - Compute intensive applications
  - High performance, high perf./cost ratio

Inference

<table>
<thead>
<tr>
<th>Device</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>Cost effective, fit for general purpose, powerful cores, high memory capacity</td>
<td>Don’t fully exploit parallelism, low throughput performance</td>
</tr>
<tr>
<td>GPU</td>
<td>High throughput performance, a good fit for modern architectures (ConvNets)</td>
<td>Expensive, energy-hungry, has IO latency, memory limitations</td>
</tr>
<tr>
<td>Custom AI Chips (ASIC, SoC)</td>
<td>Potential to significantly boost inference performance</td>
<td>Expensive and hard to develop</td>
</tr>
<tr>
<td>FPGA</td>
<td>Chip, energy efficient, flexible</td>
<td>Extremely difficult to use, not always better than CPU/GPU</td>
</tr>
</tbody>
</table>
Outline

• Image as a function
  • Sampling
  • Quantization
• Extracting useful information from Images
  • Histogram
• Color spaces
  • RGB
  • HUE
  • CIE
• Homework 1
Outline

• Image as a function
  • Sampling
  • Quantization
• Extracting useful information from Images
  • Histogram
• Color spaces
  • RGB
  • HUE
  • CIE
• Homework 1
Outline

• Image as a function
  • Sampling
  • Quantization

• Extracting useful information from Images
  • Histogram

• Color spaces
  • RGB
  • HUE
  • CIE

• Homework 1
Digitization

- Computers use discrete form of the images
- The process transforming \textit{continuous space} into \textit{discrete space} is called \textit{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 continuous signal → digitized signal

quantization

sampling

$y = f(t)$

$y_1, y_2, y_3, \ldots$
Digitization of 2D function

two-dimensional
Digitization of 3D function

three-dimensional

continuous image

digitized image
Digitization of an arc
Gray scale digital image
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]

Source: F.F. Li
RGB Channels
RGB Channels

How many pixels do you need to represent this image?
RGB Channels

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

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

Compression technique

\[
R = \int_{500}^{830} S(\lambda) R(\lambda) \, d\lambda \\
G = \int_{500}^{830} S(\lambda) G(\lambda) \, d\lambda \\
B = \int_{500}^{830} S(\lambda) B(\lambda) \, d\lambda
\]

\(S(\lambda)\) is the light spectrum.
\(R(\lambda), G(\lambda)\) and \(B(\lambda)\) are the sensitivity function

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.
CIELAB

measure the spectral reflectance factors of an object
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>btx</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 btx is lighter, stronger and yellower than the std.
CIELab
Cielab

LAB color enhancement in Photoshop. Normal Image
Histogram

• 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 \( \text{Range} = \text{Max} - \text{Min} \).
  2. Choose the number of bins you prefer to present.
  3. Calculate the bin size: \( \text{Bin size} = \text{Range}/\text{number of bins} \).
  4. For every bin count, the total number of observations falls in the bin.
  5. Present the data s a column chart, where each column represents the number of observations in a bin.
Image Histogram
Histogram Example

![Histogram Example Image]
Intensity profiles for selected (two) rows
Questions?
Coding homeworks

• Presented as a notebook using colab
  • [https://colab.research.google.com/] (https://colab.research.google.com/)

• Homeworks are posted at webcourses as a link to: