Image Processing (Computer Vision)  
“Inverse Photography”  

World  

Photography  

Images/Video  

Images/Video  

Processing  

Computer Vision  

Something  

Stages in Computer Vision  

- Physics: Image Formation (Light, Reflectance)  
- Physics: Cameras: Optics (Lens), Sensors (CCD, CMOS)  
- Image Processing: Coding (Transmission, Compression)  
- Image Processing: Enhancement (Noise Cleaning, Colors)  
- IP-CV: Feature Detection (Objects, Actions, Motion)  
- Computer Vision: Scene recovery (3D, Reflectance)  
- Computer Vision: Object Recognition  
- Robotics: Control Action (autonomous driving)  

Vision in Nature = Smart, Moving  

- Only smart and moving organisms see!  
  - Plants do not have eyes  
- Visual recognition at early development  
  - Babies recognize and track the mother very early  
- Most of the brain is involved in vision processing  

Application: Recognition  

1984  

National Geographics: “Afghan Girl”  

2000  

Panoramic Stereo Mosaics  
(Last Exercise)  


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Textbook:  
Gonzalez & Woods, Digital Image Processing (2nd Ed.),  
Addison Wesley, 2002.  
Jain, Pratt, Rosenfeld,....  

Expected Work:  
- 4 Written Exercises  
- 4 individual computer exercises (MATLAB)  

Grading:  
- Exam: 60-70%; Exercises: 30-40%
Relevant Computer Vision Courses

- Image Processing (Peleg)
- Computer Vision Seminar (Sundays 10-12)
- Computer Graphics (Sun 12-14, Wed 16-18, Lischinski)
- Introduction to Machine Learning (Mon 10-12, Tue 12-14, Shashua)
- Computer Vision (Werman)
- Image Sequence Analysis (Peleg)
- Issues in Computational & Biological Vision (Weinshall)
- Human Vision: A Computation Approach (Weiss)

Image Formation

- Light is emitted by light source
- Light is reflected from objects
- Reflected light is sensed by eye or by camera

\[ I = L \cdot r \]

The Human Eye (2.1)

World to Retina Projection

The Retina

Colors - Electromagnetic Radiation

120 \times 10^6 \text{ Rods (B/W)}

7 \times 10^6 \text{ Cones (Color)}

\approx 10^4 \text{ Nerves}

- Visible Light Range: 350-780 nm
- Maximum Sun Energy: 450 nm
- Best Atmospheric Transmittance: Visible Range
Mach Bands (1)

Spatial Sensitivity

Response Curve

Mach Bands (2)

Visual Illusions

Dual Interpretations

What is That?

Image Digitization (2.3)

• Transforming the 3D world into 2D image
  – Perspective Projection (Optics)
• Sampling the Image Plane
  – Finite number of Pixels
• Quantizing the color/gray-level
  – Finite number of colors

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Perspective Projection (2.5.2)

- Transforming the 3D world into 2D image
  - Continuous Perspective Projection
  - optics

\[ x = \frac{f \cdot X}{Z}, \quad y = \frac{f \cdot Y}{Z} \]

Image Sampling

- Sampling the Image Plane
  - Finite number of Pixels

Color/Grey-level Quantization

- Quantizing the color/grayscale
  - Finite number of colors

Digital Pictures

- A Matrix of numbers (B/W)
- A Matrix of triplets (RGB Color, etc.)

Color Spaces (4.6)

| Y - Luminance | \( Y \) | 0.299 | 0.587 | 0.114 |
| ############## | --- | --- | --- | --- |
| \( I \) | 0.596 | -0.275 | -0.321 |
| \( Q \) | 0.212 | -0.523 | 0.311 |

CIE Chromaticity Diagram (1931)
The Histogram

- Frequency counting of gray levels

![Frequency counting of gray levels](image)

- In continuous intensities:
  a continuous probability distribution \( p(g) \)

Histogram Equalization

- Equal usage of all gray levels

![Equal usage of all gray levels](image)

- Normalizing to range 0..1

\[ s_i = \frac{1}{n} \sum_{j=1}^{n} n_i \]

Histogram Equalization (cont.)

N Pixels, Range 0..K-1

\[ n_i = \# \text{ pixels at } i \]

Normalized Cumulative Occurrence:

\[ s_i = \frac{1}{n} \sum_{j=1}^{n} n_i \]

- For every original level \( j \):
  - Change its gray level to \( S_j \cdot (K - 1) \)
  - Stretch gray levels back to [0..K-1]
Examples for Equalization

Adaptive Histogram Equalization

- Different regions in a single image
  - Example: Coin on white paper
- Poor result for Histogram Equalization
  - Do the coins and paper separately
  - How to segment?
- Compute histogram in local regions around each pixel