Lab session of Image Analysis

BE 1. Image resizing and color enhancement

Data Duration: 2h.
The material of this lab session can be found on **Chamilo**.

Instructions Submit a **report** for each group (binome) of the session in a unique **pdf** , name it **`LabX_Name1_Name2`**, with **`X`** denoting the number of the lab session and **`Name1,2`** your surnames. Upload it in the folder corresponding to your group and lab in **Chamilo**

Deadline submission The material report should be submitted within a week from the lab work. The preparation has to be done individually and will be collected at the **beginning** of the lab.

Note Do it yourself! Do not use built-in functions of Matlab like `imresize`, `rgb2hsv`, `imhiststretch`, etc. although those may be useful to provide a comparison to your results

Useful commands To load an image: `I=double(imread('barbara.tif'));`
To show an image: `imshow(I, [])` or `imagesc(I, []); colormap gray; axis image`
Note: Empty brackets automatically define the intensity range of the image. Otherwise, if `I` variable type is a `uint8`, the default intensity range of `imshow` for the visualization is $[0, 255]$ while if it is a `double` the range is $[0, 1]$
Size of an image: `[H,W]=size(I);`
An image of zeros with the same size as I : `J=zeros(size(I));`
Threshold `I` at 100: `J=double(I>=100);`
To filter an image `I` with a spatial filter `f`: `imfilter(I,f,'conv','replicate')`

Objectives The objectives of this lab work are to understand
- how to **resample an image** using filtering and interpolation
- how to **manipulate the contrast and colors** for enhancing the aspect of an image

Figure 1: The well known barbara image

Preparation

Resampling

- We want to reduce an image by a factor of two, that is, to transform an image of size $N \times N$ to a smaller image of size $N/2 \times N/2$ pixels. Briefly explain what are the different intuitive methods that you could apply.
- We consider in this work the simple operation of sub-sampling. This implies selecting for example every second line and every second column to produce the new image. Consider the Fig.1, what kind of artifacts could appear? Why? How could you improve the results?

Color space

- We consider the transformation of the image I from the red, green, blue basis to the luminance, yellow-blue chrominance and red-green chrominance as follows:
  $IL = \frac{I(:,:,1)+I(:,:,2)+I(:,:,3)}{\sqrt{3}}$
  $IC1 = \frac{I(:,:,1)+I(:,:,2)-2*I(:,:,3)}{\sqrt{6}};$
  $IC2 = \frac{I(:,:,1)-I(:,:,2)}{\sqrt{2}};$
- What is the initial color space and the final one?
- Show how to reconstruct **I** from **IL**, **IC1** and **IC2**.

  Hint: the new basis is orthonormal, so that the matrix P is orthogonal: its inverse is its transpose where P is defined by

$$\begin{matrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{6}} & \frac{-2}{\sqrt{6}} \\ \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} & 0 \end{matrix}$$

Histograms

In the context of real imaging sensors, acquisitions are provided as quantization of physical parameters, such as luminance, which may have wildly different dynamics in the probability distribution of intensity values. Additionally, we may focus on just considering a subset of the intensity range.

- Think about how to estimate these probability distributions with a frequentist approach. How may different clusters of intensities be grouped?
- Think about strategies on how to stretch such distributions to cover the whole range of intensity for visualization.
- What are the advantages and disadvantages of a linear transformation for such stretching?

1 Resampling

1.1 Downsampling

Apply the operation of subsampling on the image barbara

- Is the result satisfying?
- What kind of artifacts appears?

Apply different strategies to improve the results.

- Explain what is the impact on the image and if it seems satisfying

One of the correct way of reducing an image is to perform lowpass filtering before subsampling.

- Based on the Shannon theorem, explain why lowpass filtering is required.

Apply the lowpass filter `filter1=[-1/32,0,9/32,1/2,9/32,0,-1/32]` to the image. Do it horizontally, vertically and in both directions, before subsampling.

- Explain why you need to apply this method before subsampling.
- Discuss the results of the experiment and the most efficient approach.

Visualize the Fourier transform of the filter using `plot(abs(fftshift(fft([filter1,zeros(1,92)]))));`

- From this Fourier transform, explain why this filter is appropriate for lowpass filtering before subsampling by a factor of 2.

1.2 Upsampling

We want to enlarge an image by a factor of two; that is, to transform an image of size $N \times N$ to a larger image of size $2N \times 2N$ pixels. Apply the different operation that you had imagine in the preparation.

- Discuss the results

Upsample the image barbara by inserting zeros between the pixels and then we apply the lowpass filter `2*filter1` to the image, both horizontally and vertically.

- Comment on the result.
- The proposed lowpass filter is one of many possible choices for an interpolation filter. Is there a best possible choice (hint: consider the Fourier domain)? What are the issues that arise by implementing such a filter in practice in the discrete domain?

1.3 Do it as a function

The code `image-rotation.m` can be used to rotate the image. Your goal is to create a similar procedure performing image enlargement of an image with an arbitrary factor $f > 1$, not necessarily an integer.

- Understand how the function work.
- Modify `image-enlargement.m` with the approach bring by `image-rotation.m`
- Comment the results with Fig.1 and the **cameraman** image.
- Compare the results with the previous approach.
- What does it happen if $f < 1$ and why ?

2 Color spaces

2.1 Saturation

Open the image `imcolor1.tif` and visualize it. The saturation is not satisfying: the colors are washed out, as if the image had been scanned from an old photograph.

- Explain what will be the impact of increasing the saturation

Our target here is to switch domain from RGB to the luminance/chrominance; we will define `IL` as the luminance component, `IC1` as the yellow-blue chrominance and `IC2` as the red-green chrominance (the transformation is described in the preparation section). We can define the saturation as $\sqrt{(IC1^2 + IC2^2)}$ and the hue as $atan2(IC1, IC2)$. This may be viewed as a Cartesian to polar change of coordinates.

Let us double the saturation of the image; to this end, you can just multiply by two the images `IC1` and `IC2`, then performing an inverse transform to return to the RGB basis.

- Show the new image, comment it.
- In your opinion, is the chosen saturation value you chose the best available?

2.2 Hue

We want to modify the hue of an image to make some artistic effect. From the images `IC1` and `IC2`, we can define the saturation as $\sqrt{(IC1^2 + IC2^2)}$ and the hue as $atan2(IC1, IC2)$. This may be viewed as a Cartesian to polar change of coordinates. Consequently, we can reconstruct `IC1` and `IC2` from the hue and saturation by $IC1 = saturation \times sin(hue)$ and $IC2 = saturation \times cos(hue)$. Load the image `IM088.tif` and modify the image.

- Play with hue by adding or substracting some hue. Show the most satisfying result(s)

3 Histograms

3.1 Contrast stretching

Open the image `SUDCH1.tif` and visualize it. We want to enhance the contrast of the details in a zone which not covered by the clouds.

- Crop an appropriate area from the image and visualize the histogram by the instruction `imhist`
- Select an appropriate range of the histogram section with an high amount of occurrences of the pixel levels and enhance the visualization of this range by using the function `Contraststretch.m`, which linearly maps a certain intensity input range `[a,b]` to a certain output `[va,vb]`.
- Try different parameters for different effects, such as clipping (linear transformation with saturation of values out of scale) or thresholding; is a piecewise linear transformation sufficient in this case?

3.2 Histogram matching

Open the standard MatLAB image $\{\mathbf{M}_i\}_{i=1,2,3}$ from `concordaerial.png`. Notice there is no visual consistency in the color image as their histograms are not well calibrated among each other. A possible solution to this issue is to match the histogram to another reference one, in our case taken from a standard image $\mathbf{I}_{ref}$ loaded from `concordorthophoto.png`.

- Show the histograms of each color band and the reference one
- As very rough approximation, you may consider the histograms to be Gaussian distributions. In this case, matching may be performed by shifting and scaling the histograms of the color image according to the reference one
- Calculate mean μ_i and standard deviation σ_i of each band $\mathbf{M}_i$ and similarly calculate μ_{ref} and σ_{ref} for $\mathbf{I}_{ref}$
- Match the histogram of each band by performing the operation $(\mathbf{M}_i - \mu_i)\sigma_{ref}/\sigma_i + \mu_{ref}$ and visualize the results