TNM087 - Image Processing and Analysis

Task 8 – Auto Focus

Background:

Fourier theory can be used to analyze an ideal optical system (basically a lens). This is the topic of Fourier Optics (see Goodman, Introduction to Fourier Optics). The variation of the optical properties of an optical system when the focus setting is varied is modelled in optics (see Born & Wolf, Principles of Optics). Efficient autofocus algorithms are essential in many optical systems from consumer cameras to automated microscopy.

Intuitively a blurred image has a lower high-frequency content than a focused image. In this exercise we measure the mean frequency content of an image and investigate how it changes in a focus sequence. The image with the highest mean frequency should be in focus which can be verified by visual inspection.

Read Chapter 4 in Gonzalez-Woods or Chapter 3.4 in Szeliski, Computer Vision for basic facts about the Fourier transform

Task:

From an image sequence defining a focus stack compute the Fourier based sharpness function

Syntax:

```
function sfunction = AutoFocus(FStack)
```

Hints:

The input is in the mat-file FStack with 192 image patches of size 32x32 pixels. If you want to see them you can use monims = reshape(FStack,32,32,1,192); montage(monims)

Read the description of fft2 and fftshift to understand which coordinate system is used by the fft functions in Matlab. Read especially the description where the origin of the Fourier domain is located. This point gives the center of the rings.

The first step is to generate a series of rings with center at the origin of the Fourier domain (check your vignette code to see how to construct circles, disks and rings)

You have to decide how many rings you want to use (8 is a reasonable choice since the images are small but you can play around with other choices)

Use only rings that are completely located within the Fourier domain (ignore corners)

Compute the number of grid points in each ring and save them for later use in a vector

For each slice in the stack compute the **magnitude of the Fourier transform** (don't forget the datatype)

Compute the sum of the magnitude values in a ring, then normalize this sum using the number of grid points in the ring. This gives you a description of the frequency content in the ring. Now you have one normalized frequency content per slice, per ring.

The mean intensities of the slices are all different (some are lighter and some are darker). This influences the value of the magnitude of the Fourier transform. If the mean intensity in one slice S1 is twice as high (for example because there are more light pixels in this slice) as the mean intensity in slice S2 then the magnitude value of the Fourier transform for S2 are twice as high as the magnitude values for slice S1. Global (mean) differences of intensities have no effect on the sharpness of the two slices. Therefore, it is a good idea to compensate the effect of global intensity differences first. See comment below.

The last step is to combine the frequency content values for the rings in one slice to one number: the value of the mean frequency of that slice. How do you weight the contributions of the different rings?

You can try to generate a full-sized image where all pixels are in focus using the images I*.jpg in the zip-file I100-150.zip.

Some comments:

1. **Compensate mean intensity differences since they are not important for focus computations**

You first compute for every image in the sequence the Fourier transform and then you add up the absolute values in every ring and for every ring you divide the sum by the number of points in the ring. For ring k in image m you this gives you a number A_{km}.

Now consider what happens if you want to compare the results from two different images: If image number m has a mean intensity M_m and image number n has mean intensity M_n then the values of A_{km} and A_{kn} are also related with approximately the same factors:

$$A_{km}/A_{kn} \approx M_m/M_n$$

if they have approximately the same structure.

The conclusion is that you have to compensate first for varying mean intensity before you compare the frequency contents. You can find the mean intensity by computing the DC-component which is the Fourier coefficient at position (0,0) (or from the original image, how?).

2. **Computing the mean frequency content**

After the computation of the A_{km} you have to compute the mean frequency content MF which is given by

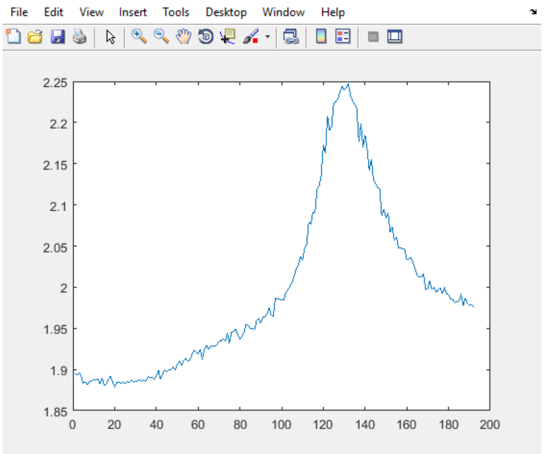
$$MF = \sum_k A_{km} w_k$$

For a fixed image m you can think of the sequence A_{km} (k = 1…K) as an (unnormed) probability distribution. Then the MF is the mean value of the weight vector $w_1 \ldots w_K$.

The weights w_k are usually not critical; you can use $w_k=k$

3. **Typical result**

What you should get with this approach should look like (focus around image 140)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