2D Signal Processing

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This lab accounts for 5% of the final 4C8 mark.

Instructions: You are required to compile a report that answers specific instructions included in the report. Include relevant code and output figures in your report.

Requirements: Labs Reports should be typed up and submitted electronically using the **PDF file format** via the module's blackboard page by the specified deadline. Remember to put your name and student number on the top of your reports.

You must have read and understood the plagiarism provisions in the General Regulations of the University Calendar for the current year, found at: https://www.tcd.ie/calendar.

Introduction

1 Low Pass Filter / Separable Filter

In this lab, we will consider a 2D filter h_0 with transfer function defined as follows:

$$H_0(z_1, z_2) = \frac{1}{20.25}\left(z_1^{-1}z_2^{-1} + 2.5z_1^{-1} + z_1^{-1}z_2 + 2.5z_2^{-1} + 6.25 + 2.5z_2 + z_1z_2^{-1} + 2.5z_1 + z_1z_2\right)$$

Q 1.1 *Write the 2D convolution mask for this transfer function.*

Q 1.2 *Load* `kodim19-256.png` *into* `I` *as double (in range [0-1]), and use* `conv2` *to apply this 2D filter to* `I` *and obtain* `I0`. *Show the results.*

Q 1.3 *Show that H_0 is separable and write down the two 1D convolutions masks.*

Q 1.4 *Show how you can apply* `conv2` *twice using these filters to obtain an image identical to* `I0`.

Q 1.5 *Show that the output is numerically identical to* `I0` *by computing the Mean Absolute Error between the two images.*

2 Image Gradient

We want now to find the horizontal and vertical edges of the image gradient.

Q 2.1 *The horizontal derivative I_x will be given by $H_x(z_1, z_2) = z_2 - z_2^{-1}$. Write the convolution mask for this transfer function and apply the filter for this 2D mask to* `I0` *and save the results in* `Ix`. *Show* `(Ix + 0.5)`.

Q 2.2 *The vertical derivative I_y will be given by $H_y(z_1, z_2) = z_1 - z_1^{-1}$. Write the convolution mask for this transfer function and apply the filter for this 2D mask to* `I0` *and save the results in* `Iy`. *Show* `(Iy + 0.5)`.

Q 2.3 *Combine both I_x and I_y to form the image gradient magnitude $I_x^2 + I_y^2$. Save the output to* `grad_mag` *and show it by rescaling values to the range 0-1.*

3 Downsampling

Q 3.1 *Downsample* `I` *by half. Show the results.*

Q 3.2 *Explain how H_0 can be used to avoid aliasing in downsampling. Show the corresponding improved results.*

4 Unsharp Masking

It is possible to use a low pass filter to generate high pass information by subtracting the output of the low pass filter from the input signal.

Q 4.1 *Using the low pass filter H_0 as defined above, implement the unsharp masking described in the handout-03 of the lecture notes. The fraction of high pass information (gain) that is added back into the image is α.*

Apply the unsharp masking on `I`. *Pick a value of α that gives the sharpest results, without visible artefacts. Write the value of α and show the results. The exact value of α does not need to be precise.*