CS7.404. Digital Image Processing
Monsoon-2022
Assignment-2
Posted on: 02/09/2022
Due on: 13/09/2022, 23:59 Hrs IST

- All your code should be in the `src` directory and images in `imgs` directory.
- Do not use any external library other than **`numpy`** for implementing any of the tasks. You can however use external libraries for I/O operations and plotting. If you are not sure if a library is allowed for a particular task, clarify with your TAs.
- You will be evaluated on correctness and how vectorized your code is - with correctness being the priority.
- Write modular code with relevant docstrings and comments for you to be able to use functions you have implemented in future assignments.
- All theory questions and observations must be written in a markdown cell of your jupyter notebook.
- All academic integrity policies apply. Check the course web page for more clarity.
- Start the assignment early, push your code regularly and enjoy learning!

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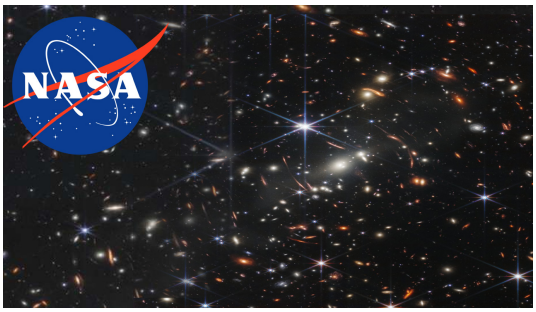
1 Blurry Moments

Michael Scott being the World's Best Manager knows how much precious moments mean to his employees. However, not every perfect moment can be captured perfectly, which can be disheartening. To fix this, Micheal came across some Image Processing Techniques in order to sharpen the blurry images that one might come across. As good as he is at selling papers, Micheal is equally bad at coding. He needs your help to implement two of those techniques namely, **Unsharp Masking** and **High Boost Filtering**.

1. Implement both the functions and test the implementation on `Jam.jpg` so that Michael can gift two of his best employees something special.
2. Choose any three different filter sizes. Compare the two methods for each filter size and report your observations along with the result images for the input `webb.jpg`

(a) Jam.jpg



(b) webb.jpg

2 Intentionally Blurry Moments

Detailing in an image is not always desirable especially when it results in Jim having wrinkles of Creed. However, the basic low pass filters while doing their job of smoothing, do not take into account that smoothing across edges is undesirable at times. However, Bilateral filter is a filter that smoothens the image while taking into account the presence of the edges. As usual, Michael is keen to see this into affect on the images he took on his trip to the lakeside but needs your help with it.

Implement Bilateral Filter and test it on `lakeside.jpg`. Report your observations and explain the results with different combination of domain and range parameters.

Figure 2: lakeside.jpg

3 Pam and Graphic Design

Pam's recently acquired taste in Graphic Design, got her thinking is there a faster way to make a cartoon of an image instead of starting from scratch?

During her *graphic-design* course in New Your city, she heard from her professor that - *"In order to achieve a basic cartoon effect, all you need is essentially - a bilateral filter and some edge detection. The bilateral filter will reduce the color palette,necessary for the cartoon look, and edge detection will allow production of bold silhouettes."* While she is excited to hear about this technique, she really does not know how to implement it. You are her classmate and a programming genius. Show her how you would generate cartoons by performing the following steps.

1. Given any color image, apply bilateral filtering to the color image. Keep this filtered image for future (last step).

2. Now, take a copy of the original color image and convert it to gray scale.

3. Apply blurring on this gray scale image to reduce noise. You can try different variants of blurring(box filter, gaussian filter, repeated gaussian filter,..) with different filter sizes and see the performance.

4. Now, create an edge mask from this `blurred, gray-scale` image. An edge mask can be obtained using **adaptive-thresholding**. (Read about adaptive thresholding from here and here.)

5. Now, combine the bilateral, filtered image from step 1 with edge mask (by taking `bitwise-AND` of both the images at each pixel location).

Help Pam to implement the above procedure and plot images obtained at every step in order for her to understand the entire process in a better way. Try the procedure for **images of your choice.** Feel free to experiment with different filters/methods to generate even better cartoons. (You may want to replicate Pam's own cartoon drawing of the office building to amaze her). **Note: This question has to be done on RGB images only.**

Figure 3: `Cartoon.jpg` : Sample result

4 Dwight for Promotion

Dunder Mifflin recently got acquired by `Sabre`. And the one thing that Dwight noticed is that, Jo Bennett, the CEO of Saber is giving promotion to anyone who has good ideas. Dwight has long being trying so hard to compete with his *all-time-friend*, Jim, to get promoted. This is his chance to come up with some great ideas. He however realizes that in order to compete with Jim, he would have to step up his game. He comes to you to learn about processing in frequency domain. Teach him about it by implementing the following and explaining your observations in your jupyter notebook:

1. Implement `2D DFT`.
2. Implement `1D FFT` and use it to implement `2D FFT`.
3. Compare the runtimes of your version of `DFT` and `FFT` on different sized images of your choice and plot them.
4. Implement `2D Inverse FFT`.
5. Apply Fourier transform on the Fourier transform of any image of your choice and show it.

After seeing your results, Dwight wonders how is the Fourier transform of image different from original image and what changes can be made to it in frequency domain so that after applying inverse you can get the original image back. **Note: You can use numpy.fft.fftshift for plotting**

5 Focused Dwight

After successfully learning frequency domain filtering from you, Dwight wants to understand frequency domain processing in more depth. He asks you to implement the following:

1. Apply ideal lowpass filter having a cutoff radius, D = 30 in the frequency domain for image `lakeside.png`. Also try for D = 15 and 50. Include the original image and all three ideal lowpass filtered images. Briefly discuss your results to help Dwight understand what is going on.
2. Apply Gaussian lowpass filter in the **frequency domain** for image `lakeside.png`. Try for D_0 values = 30, 15 and 50 (D_0 refers to the measure of spread in a Gaussian curve).Include the original image and all three Gaussian low-pass filtered images and briefly discuss your result to help Dwight understand what is going on (again? Yes).
3. Discuss the difference between your results for Gaussian lowpass filtering and ideal lowpass filtering.

6 The Broken Scanner and Smart Jim

Recently the customers of Sabre started to complain about the company's scanners. Jo Bennett is worried about the reputation of Sabre because of the faulty scanners. To give an example of the issue with the scanner, `cart.jpg` is the result of scanning `originalCart.jpg` using Sabre's scanner. It might take time to replace the faulty scanners. You are Jim and have found the right opportunity to out-do Dwight. You tell Jo Bennnett that all you need to do is to add a piece of code to the scanner's driver that post-processes the image that the scanner outputs and minimizes the noise. All that the customers have to do then is to download the latest driver. In particular the piece of code should transform `cart.jpg` to `originalCart.jpg`. Jo Bennett has given you the nod to go ahead with the plan. Implement the function.

(a) `cart.jpg`

(b) `originalCart.jpg`

Jo Bennett is amazed. This is her *wow* moment! She says, "Congratulations, you are our new CTO". You are thrilled, and just cannot contain yourself seeing Dwight being outsmarted yet again.