Homework 1 Written Questions

Template Instructions

This document is a template with specific answer regions and a fixed number of pages. Given large class sizes and limited TA time, the template helps the course staff to grade efficiently and still focus on the content of your submissions. Please help us in this task:

- Make this document anonymous.
- Questions are in the orange boxes. Provide answers in the green boxes.
- Use the footer to check for correct page alignment.
- **Do NOT remove the answer box.**
- **Do NOT change the size of the answer box.**
- **Extra pages are not permitted unless otherwise specified.**
- **Template edits or page misalignment will lead to a 10 point deduction.**

Gradescope Submission

- Compile this document to a PDF and submit it to Gradescope.
- Pages will be automatically assigned to the right questions on Gradescope.

This Homework

- 5 questions **[12 + 6 + 13 + 14 + 7 = 52]**.
- Include code, images, and equations where appropriate.

Declaration of Generative AI Use

Reminder of Course Policy

- The use of GenAI tools (e.g., ChatGPT, Grammarly, Bard) for completing any part of this course is discouraged.
- Using these tools is not needed to be successful in the class and could be detrimental to your learning experience.
- If you use them, you must cite the tool you used and explain how you used it.
- If you do not cite the tool, it is an academic code violation.
- We will be using special tools to detect cases of unattributed GenAI use.

Student Declaration

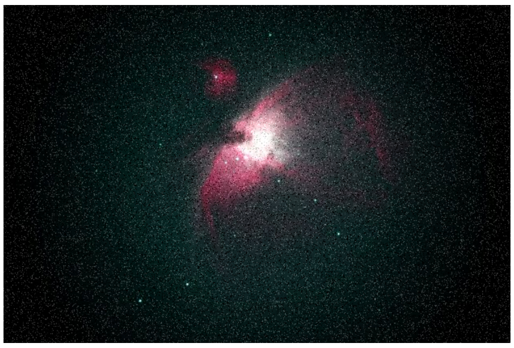
Have you used generative AI tools to complete this assignment:

YES ☐ [✓ NO ■]

If you answered YES above, describe what tools you used and what parts of the assignment you used them for below:

Example: I used ChatGPT to debug my convolution implementation

Q1: **[12 points]** We have been given special permission to use the telescope on the roof of Barus and Holley. Unfortunately, our fantastic image of the Orion nebula has noise caused by the imaging sensor: (orion-noise.png)



One way to deal with this noise is with image convolution. Convolution is a type of image filtering that is a fundamental image processing tool.

(a) *Explicitly describe* the input, transformation, and output components of 2D discrete convolution. Please be precise; define variables as need.

(i) **[2 points]** Input **[2–4 sentences]**

The image convolution would require two inputs. The first would be the image, which here is the noisy Orion image. We would also need a dimension for our median filter (which would have to be an odd integer).

(ii) **[2 points]** Transformation (how is the image transformed?) **[2–4 sentences]**

The image would be transformed by taking our original image and applying a 2D convolution. Pixel by pixel we would find a square with the specified dimensions and use the median value in that square as the pixel's new value. For pixels that would be out of the image's bounds, we could use reflection so we don't get a black border.

(iii) **[2 points]** Output **[2–4 sentences]**

The output would be an image that looks like the input image without the noise. The larger our kernel's dimensions are, the less detail is preserved but the smoother the overall output image is.

(b) **[4 points]**

Describe two filter kernels that we may use with convolution, and give an example computer vision application that each enables. **[4–8 sentences]**

One example of a filter kernal to be used with convolution is the Sobel filter. This allows us to do edge detection.
Another example of a filter kernel is the Gaussian filter. This allows us to blur an image while avoiding the artifacts of box filtering.

(c) **[2 point]**

What kind of filter might we use to de-noise our image of the Orion nebula, and why? **[2–3 sentences]**

The median filter could be helpful in denoising this image. It takes the median value of a certain radius, which means noisy values would be replaced by values that fit more in with the spaces around them. It also wouldn't end up as blurry as something like the mean filter would.

Q2: [6 points] Now that we've de-noised our image of the Orion nebula, let's explore filtering techniques more closely. Two kinds of linear filtering are correlation and convolution.

(a) **[3 points]**

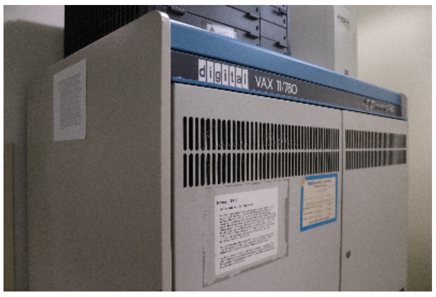
What is different between convolution and correlation? Include differences in their algebraic properties. When might we use each? **[5–6 sentences]**

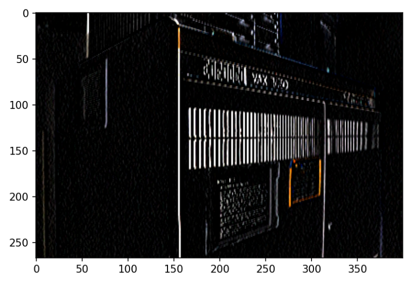
Convolution is useful when it comes to modifying an existing image, and correlation is useful for finding images within images. Though convolution is the same as correlation when rotated by 180 degrees, they have very different algebraic properties. Convolution is commutative, associative, and distributes over addition. Correlation has none of these. Convolution is very useful in Convolutional Neural Networks (hence the name).

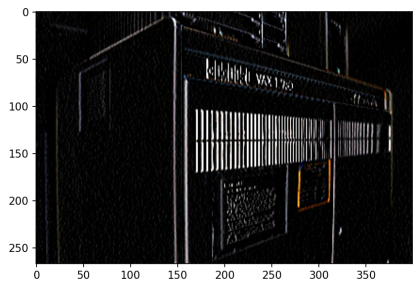
(b) **[3 points]** To solidify our understanding of the distinction between correlation and convolution, we will process another image.

Devise a scenario in which the output of correlation and convolution differ. Write code that loads an image and produces two distinct images, one from convolution and one from correlation on some kernel of your choice. Specify your kernel, and provide the input image and two output results. Then, use your understanding of convolution and correlation to explain the outputs. **[2–4 sentences]**

Consider $scipy.signal.convolve2d$ and $scipy.signal.correlate2d$ to experiment!

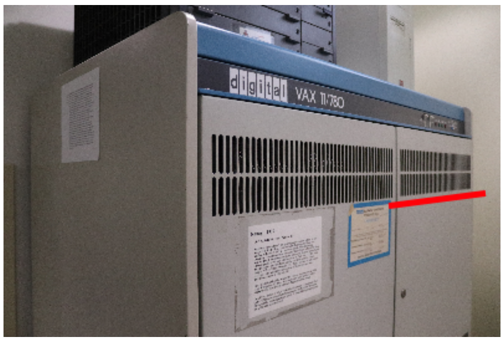




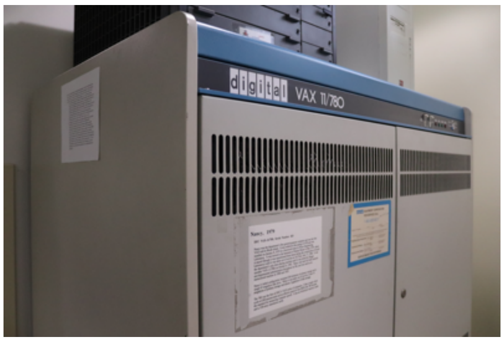


The reason the convoluted and correlated images are different here is because of convolution and correlation moving in opposite directions. The kernel for convolution is rotated 180 degrees from the kernel for correlation, and as the two move in different directions the pixels that are weighted more are different, resulting in different images. One is finding edges from the left, the other from the right.

Q3: [13 points] While exploring Brown CS's history in the halls of CIT, we happen upon Nancy: a DEC VAX 11/780. So struck by its beauty, we decide to take an artful photo with our camera. Modern digital sensors have many megapixels, so we resize it to make the file smaller.



Resized image



Depiction of original (*not original file*)

(a) **[3 points]** Oh no! What happened to Nancy? There are weird artifacts in the vents (above red line)—these definitely weren't there in the original photo. Plus, if we look closely, the white label text is less smooth and there are jagged lines.

What is this phenomenon called, and why did it happen? **[2–4 sentences]**

This is known as aliasing. This is the result of downsampling from our original image without using enough samples to accurately preserve the original signals. The way our downsampling sampled the original image meant that we sampled the image unevenly, resulting in jagged edges.

(b) **[3 points]**

How might we fix this issue with filtering? Describe the process, and explain why it works. **[2–4 sentences]**

Filtering is the process by which we use enough samples to get accurate information on what the downsampled image should look like. As we rescale, filtering uses a higher frequency of samples to pick what new pixels should be in the smaller image. This means that areas that aren't jagged in the intial image won't be jagged in the final one.

Only A3 (a) - (b) should be on this page

(c) **[3 points]**

Which of the following kernels is high pass, low pass, or neither?

Note: To fill in boxes, replace '\square' with '\blacksquare' for your answer.

(i) $\begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$

■ High pass
□ Low pass
□ Neither

(ii) $\begin{bmatrix} \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \\ \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \\ \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \end{bmatrix}$

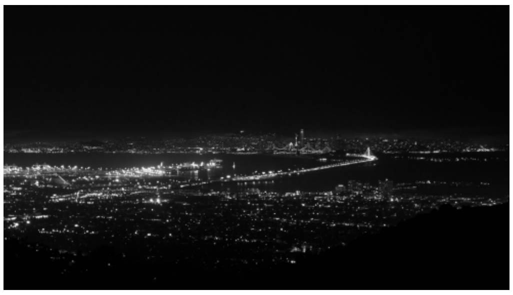
TODO: Select the appropriate answer.
□ High pass
■ Low pass
□ Neither

(iii) $\begin{bmatrix} -\frac{1}{9} & -\frac{1}{9} & -\frac{1}{9} \\ -\frac{1}{9} & \frac{8}{9} & -\frac{1}{9} \\ -\frac{1}{9} & -\frac{1}{9} & -\frac{1}{9} \end{bmatrix}$

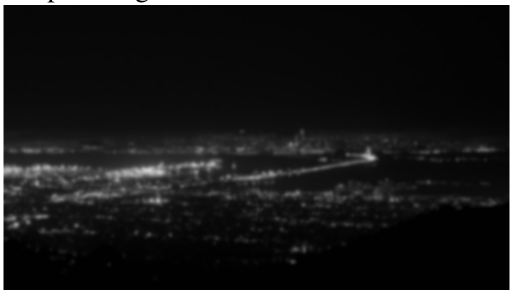
TODO: Select the appropriate answer.
■ High pass
□ Low pass
□ Neither

(d) **[2 points]** We decide to test if we can recognize which kind of filter has been used to achieve a target output image.

Given the input image below, identify the kind of filter.

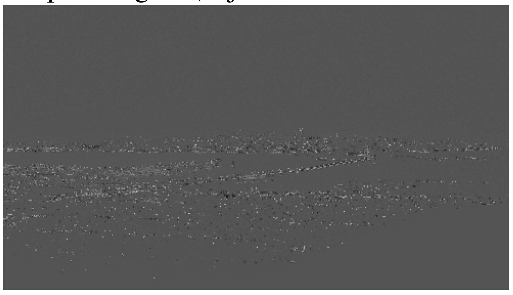


(i) Output image 1:



TODO: Select the appropriate answer.
☐ High pass
[✓ Low pass]

(ii) Output image 2 (adjusted for easier visualization):



TODO: Select the appropriate answer.
[✓ High pass]
☐ Low pass

(e) **[2 points]**

Which of the following statements are true? (Check all that apply).

TODO: Select all that apply.

- ■ High pass filter kernels will always contain at least one negative number
- ■ A Gaussian filter is an example of a low pass filter
- ☐ A high pass filter is the basis for most smoothing methods
- ☐ In a high pass filter, the center of the kernel must have the highest value

Q4: **[14 points]** With filtering, we can create *hybrid images* that depict different objects when viewed at different distances. They are inauthentic images of the natural world.

As technology advances, evaluating the authenticity of images becomes increasingly difficult. Please read this article by photography critic Andy Grundberg in the *New York Times* from August 1990.

Grundberg stated that: “In the future, readers of newspapers and magazines will probably view news pictures more as illustrations than as reportage, since they can no longer distinguish between a genuine image and one that has been manipulated.”

(a) **[4 points]**

When is Grundberg’s future, and why? **[4–6 sentences]**

Grundberg’s future will not come to pass. People still trust photographs to be the truth. This has lead to AI images that look like photographs to be mistaken as the truth, which is dangerous but also only works if readers believe photographs to be true. Grundberg is more optimistic than I am, because he believes that society will accept the new truth of how images are created, and I believe we’re going to be fooled as long as AI images still exist.

(b) **[4 points]**

For a news picture, are digital manipulations fine? How do we decide which ones? Use one ethical framework from the ethics primer. **[4–6 sentences]**

With a utilitarian framework, digital manipulations are permissable if they do not alter the impact of the image. The point of the news is to inform the viewer on what is going on in the world, and if the image that makes it to print accurately represents the truth modification is fine. Touching up a celebrity or making an image more legible are fine. However, ones that alter the meaning of the image (like removing protestors) are dishonest, as they get across an idea of the news that’s incongruous with reality.

Only A4 (a) - (b) should be on this page

(c) **[4 points]** The Coalition for Content Provenance and Authenticity (C2PA) has designed a technical specification to attach history to an image. Please watch this video for an overview; stop at 4 minutes and 40 seconds.

Describe one situation in which the C2PA system helps us in determining authenticity, and one situation in which it does not. Please explain why in each case. **[4–6 sentences]**

If someone takes a photograph of a mountain range and posts it. No matter where it is on the internet, people will know who took it. If someone scans an existing painting and that png is made with C2PA. We know that the photo is legitimate but we are not any closer to finding out the initial artist behind the painting.

(d) **[2 point]** Grundberg's article is titled "Ask It No Questions: The Camera Can Lie."

Does the C2PA system weaken Grundberg's argument? **[1–2 sentences]**

Not really because most people are not going to take the time to see if an image is legitimate or not and default back to it being legit. An image could also be screenshotted and then have that screenshot be enclosed with a C2PA wrapper (unless I'm misunderstanding how this works), which would disrupt finding out who made the image.

Q5: Technical practice — [7 points] In computer vision, each image is a matrix of pixels. The `numpy` library provides fast computation with large multi-dimensional vectors and matrices.

To familiarize yourself with the library, read through the following scenarios and complete the exercises. Write *one* `numpy` function to complete each of the following tasks.

With `numpy` imported as

```
import numpy as np
```

we can call functions with

```
np.function_name(<arguments>)
```

Test out your answers by creating your own python program. Some functions you might find useful are np.squeeze, np.expand_dims, np.clip, np.pad, and np.zeros.

Use operators like `[]` and `:`, but remember that each prompt can be completed with only *one* function/operator shorthand.

(a) **[1 point]** Create a black image `img` with all values in this matrix equal to 0.

Create `img` where `np.shape(img) == (320,640)`.

```python
import numpy as np
img = np.zeros((320,640))
print(np.shape(img))
```

(b) **[1 point]** A filtering operation seems to mess up the output dimensions, producing a variable `img_out` where `np.shape(img_out) == (1, 1, 320, 640)`.

Remove all 1-sized dimensions. Convert `img_out` to a new matrix `img_fixed` where `np.shape(img_fixed) == (320, 640)`.

```python
import numpy as np
imgOut = np.zeros((1,1,320,640))
img_fixed = np.squeeze(imgOut)
print(np.shape(img_fixed))
```

(c) **[1 point]** Color images are represented with three dimensions. The first dimension represents the number of color channels, and could help us to identify whether an image is color (RGB) or grayscale.

Say you have a grayscale image `img` where `np.shape(img) == (320, 640)`. Convert this to a new image `img_expanded` where `np.shape(img_expanded) == (1, 320, 640)`. In other words, add a 1-sized dimension to `img`.

```
import numpy as np
img = np.zeros((320,640))
img_expanded = np.expand_dims(img, axis=0)
print(np.shape(img_expanded))
```

(d) **[1 point]** Assume we have a 2D matrix `img` with values range [-1.0, 1.0].

Clip `img` so that all its values lie within the range [-0.5, 0.5].

```
import numpy as np
img = [[-1,1],[-1,1]]
img = np.clip(img, -0.5,0.5)
print(img)
```

(e) **[1 point]** Suppose we have an RGB image matrix, `img`, of shape (320, 640, 3). We call each color matrix a channel of information.

Retrieve the third blue channel of the image while preserving all of `img`'s dimensions and intensity values.

```
import numpy as np
img = np.zeros((320,640,3))
img = img[:,:,:2]
print(img.shape)
```

(f) **[1 point]** Suppose we have a second RGB image matrix, `img2`, also of shape (320, 640, 3).

Retrieve the red and blue channels of `img2` within a single variable of shape (320, 640, 2).

```
import numpy as np
img = np.zeros((320,640,3))
img = img[:,:,0:3:2]
print(img.shape)
```

(g) **[1 point]** Padding is a useful operation to help us produce a convolved image equal in size to an input image.

Given an RGB image, `img`, pad it with two columns of zeros on the left and right edges of the image, and three rows of zeros on the top and bottom edges of the image. Do not add zeros to the color dimension.

```
import numpy as np
img = np.full((320,640,3),255)
img = np.pad(img,((2,2),(3,3),(0,0)), 'constant')
print(img.shape)
```

Feedback? (Optional)

We appreciate your feedback on how to improve the course. You can provide anonymous feedback through this form which can be accessed using your Brown account (your identity will not be collected). If you have urgent non-anonymous comments/questions, please email the instructor.