

CSE252A_FA23_assignment_0

October 5, 2023

1 CSE 252A Computer Vision I, Fall 2023 - Assignment 0

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Assignment due: Wed, Oct 11, 11:59 PM

Name:

PID:

1.1 Prior knowledge + certification of commencement of academic activity

In every course at UC San Diego, per the US Department of Education, we are now required to certify whether students have commenced academic activity for a class to be counted towards eligibility for Title IV federal financial aid. This certification must be completed during the first two weeks of instruction.

For CSE 252A, this requirement will be fulfilled via an ungraded prior knowledge quiz, which will assist the instructional team by providing information about your background coming into the course. In [Canvas](#), go to the CSE 252A course and navigate to Quizzes. Then, click on the “First Day Survey: Prior Knowledge #FinAid”

1.2 Instructions

Please answer the questions below using Python in the attached Jupyter notebook and follow the guidelines below:

- This assignment must be completed **individually**. For more details, please follow the Academic Integrity Policy and Collaboration Policy on [Canvas](#).
- All the solutions must be written in this Jupyter notebook.
- You may use basic algebra packages (e.g. NumPy, SciPy, etc) but you are not allowed to use the packages that directly solve the problems. Feel free to ask the instructor and the teaching assistants if you are unsure about the packages to use.
- It is highly recommended that you begin working on this assignment early.
- You must submit this notebook exported as a pdf. You must also submit this notebook as an .ipynb file.
- Your code and results should remain inline in the pdf.

- **You must submit 3 files on Gradescope - .pdf , .ipynb and .py file where the .py file is the conversion of your .ipynb to .py file . You must mark each problem on Gradescope in the pdf.** To convert the notebook to PDF, you can choose one way below:
 1. You can print the web page and save as PDF (e.g. Chrome: Right click the web page → Print... → Choose “Destination: Save as PDF” and click “Save”).
 2. You can find the export option in the header: File → Download as → “PDF via LaTeX”

To convert the notebook (.ipynb) to .py file use the following command:

```
jupyter nbconvert --to script filename.ipynb --output output_filename.py
```

- Please make sure the content in each cell (e.g. code, output images, printed results, etc.) are clearly visible and are not cut-out or partially cropped in your final PDF file.
- While submitting on gradescope, please make sure to assign the relevant pages in your PDF submission for each problem.

Late Policy: Assignments submitted late will receive a 15% grade reduction for each 12 hours late (i.e., 30% per day). Assignments will not be accepted 72 hours after the due date. If you require an extension (for personal reasons only) to a due date, you must request one as far in advance as possible. Extensions requested close to or after the due date will only be granted for clear emergencies or clearly unforeseeable circumstances.

1.3 Introduction

Welcome to **CSE 252A Intro to Computer Vision!**

This course provides a comprehensive introduction to computer vision providing broad coverage including low level vision (image formation, photometry, color, image feature detection), inferring 3D properties from images (shape-from-shading, stereo vision, motion interpretation) and object recognition.

We will use a variety of tools (e.g. some packages and operations) in this class that may require some initial configuration. To ensure smooth progress, we will setup the majority of the tools to be used in this course in this **Assignment 0**. You will also practice some basic image manipulation techniques.

1.4 Piazza, Gradescope and Python

Piazza

All students are automatically added to the class in [Piazza](#) once enrolled in this class. You can get access to it from [Canvas](#). You’ll be able to ask the professor, the TAs and your classmates questions on Piazza. Class announcements will be made using Piazza, so make sure you check your email or Piazza frequently.

Gradescope

All students are automatically added to the class in [Gradescope](#) once enrolled in this class. You can also get access to it from [Canvas](#). All the assignments are required to be submitted to Gradescope for grading. Make sure that you mark each page for different problems.

Python

We will use the Python programming language for all assignments in this course, with a few popular libraries (NumPy, Matplotlib). Assignments will be given in the format of web-based Jupyter notebook that you are currently viewing. We expect that many of you have some experience with Python and NumPy. And if you have previous knowledge in MATLAB, check out the [NumPy for MATLAB users](#) page. The section below will serve as a quick introduction to NumPy and some other libraries.

1.5 Getting Started with NumPy

NumPy is the fundamental package for scientific computing with Python. It provides a powerful N-dimensional array object and functions for working with these arrays. Some basic use of this packages is shown below. This is **NOT** a problem, but you are highly recommended to run the following code with some of the input changed in order to understand the meaning of the operations.

1.5.1 Arrays

```
[ ]: import numpy as np          # Import the NumPy package

v = np.array([1, 2, 3])         # A 1D array
print(v)
print(v.shape)                 # Print the size / shape of v
print("1D array:", v, "Shape:", v.shape)

v = np.array([[1], [2], [3]])  # A 2D array
print("2D array:", v, "Shape:", v.shape) # Print the size of v and check the
↳ difference.

# You can also attempt to compute and print the following values and their size.

v = v.T                        # Transpose of a 2D array
m = np.zeros([3, 4])           # A 2x3 array (i.e. matrix) of zeros
v = np.ones([1, 3])           # A 1x3 array (i.e. a row vector) of ones
v = np.ones([3, 1])           # A 3x1 array (i.e. a column vector) of ones
m = np.eye(4)                  # Identity matrix
m = np.random.rand(2, 3)      # A 2x3 random matrix with values in [0, 1]
↳ (sampled from uniform distribution)
```

1.5.2 Array Indexing

```
[ ]: import numpy as np

print("Matrix")
m = np.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]]) # Create a 3x3 array.
print(m)

print("\nAccess a single element")
print(m[0, 1])                 # Access an element
m[1, 1] = 100                  # Modify an element
```

```

print("\nModify a single element")
print(m)

print("\nAccess a subarray")
m = np.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]]) # Create a 3x3 array.
print(m[1, :]) # Access a row (to 1D array)
print(m[1:2, :]) # Access a row (to 2D array)
print(m[1:3, :]) # Access a sub-matrix
print(m[1:, :]) # Access a sub-matrix

print("\nModify a subarray")
m = np.array([[1,2,3], [4,5,6], [7,8,9]]) # Create a 3x3 array.
v1 = np.array([1,1,1])
m[0] = v1
print(m)
m = np.array([[1,2,3], [4,5,6], [7,8,9]]) # Create a 3x3 array.
v1 = np.array([1,1,1])
m[:,0] = v1
print(m)
m = np.array([[1,2,3], [4,5,6], [7,8,9]]) # Create a 3x3 array.
m1 = np.array([[1,1],[1,1]])
m[:2,:2] = m1
print(m)

print("\nTranspose a subarray")
m = np.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]]) # Create a 3x3 array.
print(m[1, :].T) # Notice the difference of the
↳dimension of resulting array
print(m[1:2, :].T)
print(m[1:, :].T)
print(np.transpose(m[1:, :], axes=(1,0))) # np.transpose() can be used to
↳transpose according given axes list.

print("\nReverse the order of a subarray")
print(m[1, ::-1]) # Access a row with reversed
↳order (to 1D array)

# Boolean array indexing
# Given a array m, create a new array with values equal to m
# if they are greater than 2, and equal to 0 if they less than or equal to 2
m = np.array([[1, 2, 3], [4, 5, 6]])
m[m > 2] = 0
print("\nBoolean array indexing: Modify with a scaler")
print(m)

# Given a array m, create a new array with values equal to those in m

```

```

# if they are greater than 0, and equal to those in n if they less than or
↳ equal 0
m = np.array([[1, 2, -3], [4, -5, 6]])
n = np.array([[1, 10, 100], [1, 10, 100]])
n[m > 0] = m[m > 0]
print("\nBoolean array indexing: Modify with another array")
print(n)

```

1.5.3 Array Dimension Operation

```

[ ]: import numpy as np

print("Matrix")
m = np.array([[1, 2], [3, 4]]) # Create a 2x2 array.
print(m, m.shape)

print("\nReshape")
re_m = m.reshape(1,2,2) # Add one more dimension at first.
print(re_m, re_m.shape)
re_m = m.reshape(2,1,2) # Add one more dimension in middle.
print(re_m, re_m.shape)
re_m = m.reshape(2,2,1) # Add one more dimension at last.
print(re_m, re_m.shape)

print("\nStack")
m1 = np.array([[1, 2], [3, 4]]) # Create a 2x2 array.
m2 = np.array([[1, 1], [1, 1]]) # Create a 2x2 array.
print(np.stack((m1,m2)))

print("\nConcatenate")
m1 = np.array([[1, 2], [3, 4]]) # Create a 2x2 array.
m2 = np.array([[1, 1], [1, 1]]) # Create a 2x2 array.
print(np.concatenate((m1,m2)))
print(np.concatenate((m1,m2), axis=0))
print(np.concatenate((m1,m2), axis=1))

```

1.5.4 Math Operations on Array

Element-wise Operations

```

[ ]: import numpy as np

a = np.array([[1, 2, 3], [4, 5, 6]], dtype=np.float64)
print(a * 3) # Scalar multiplication
print(a / 2) # Scalar division
print(np.round(a / 2))
print(np.power(a, 2))

```

```

print(np.log(a))
print(np.exp(a))

b = np.array([[1, 1, 1], [2, 2, 2]], dtype=np.float64)
print(a + b)           # Elementwise sum
print(a - b)           # Elementwise difference
print(a * b)           # Elementwise product
print(a / b)           # Elementwise division
print(a == b)          # Elementwise comparison

```

Broadcasting

```

[ ]: # Note: See https://numpy.org/doc/stable/user/basics.broadcasting.html
#      for more details.
import numpy as np
a = np.array([[1, 1, 1], [2, 2, 2]], dtype=np.float64)
b = np.array([1, 2, 3])
print(a*b)

```

Sum and Mean

```

[ ]: import numpy as np

a = np.array([[1, 2, 3], [4, 5, 6]])
print("Sum of array")
print(np.sum(a))           # Sum of all array elements
print(np.sum(a, axis=0))   # Sum of each column
print(np.sum(a, axis=1))   # Sum of each row

print("\nMean of array")
print(np.mean(a))         # Mean of all array elements
print(np.mean(a, axis=0)) # Mean of each column
print(np.mean(a, axis=1)) # Mean of each row

```

Vector and Matrix Operations

```

[ ]: import numpy as np

a = np.array([[1, 2], [3, 4]])
b = np.array([[1, 1], [1, 1]])
print("Matrix-matrix product")
print(a.dot(b))           # Matrix-matrix product
print(a.T.dot(b.T))

x = np.array([3, 4])
print("\nMatrix-vector product")
print(a.dot(x))           # Matrix-vector product

x = np.array([1, 2])

```

```

y = np.array([3, 4])
print("\nVector-vector product")
print(x.dot(y))                # Vector-vector product

```

1.5.5 Matplotlib

Matplotlib is a plotting library. We will use it to show the result in this assignment.

```

[ ]: %config InlineBackend.figure_format = 'retina' # For high-resolution.
      %matplotlib inline

import numpy as np
import matplotlib.pyplot as plt

x = np.arange(-2., 2., 0.01) * np.pi
plt.plot(x, np.sin(x))
plt.xlabel('x')
plt.ylabel('$\sin(x)$ value') # '$...$' for a LaTeX formula.
plt.title('Sine function')

plt.show()

```

This brief overview introduces many basic functions from NumPy and Matplotlib, but is far from complete. Check out more operations and their use in documentations for [NumPy](#) and [Matplotlib](#).

1.6 Problem 1: Image Operations and Vectorization (15 points)

Vector operations using NumPy can offer a significant speedup over doing an operation iteratively on an image. The problem below will demonstrate the time it takes for both approaches to change the color of quadrants of an image.

The problem reads an image `geisel.jpg` that you will find in the assignment folder. Two functions are then provided as different approaches for doing an operation on the image.

The function `iterative()` demonstrates the image divided into 4 parts:

(Top Left) The original image. (Top Right) Red channel image. (Bottom Left)
 (B,G,R) colored image. (Bottom Right) Grayscale image.

For your implementation:

- (1) For the red channel image, write your implementation to extract a single channel from a colored image. This means that from the $H \times W \times 3$ shaped image, you'll get three matrices of the shape $H \times W$ (Note that it's 2-dimensional).
- (2) For the (B,G,R) colored image, write your implementation to merge those single channel images back into a 3-dimensional colored image in the reversed channels order (B,G,R).
- (3) For the grayscale image, write your implementation to conduct operations with the extracted channels. You may use the following equation for computing the grayscale value from (R,G,B) channels.

$$gray = 0.21263903 * R + 0.71516871 * G + 0.072192319 * B$$

Note: In a grayscale image, a pixel has the same grayscale value for its red (R), green (G), and blue (B) channels.

Your task is to follow through the code and fill the blanks in `vectorized()` function and compare the speed difference between `iterative()` and `vectorized()`. Make sure your final generated image in the `vectorized()` is the same as the one generated from `iterative()`.

```
[ ]: import numpy as np
import matplotlib.pyplot as plt

img = plt.imread('geisel.jpg') # Read an image
print("Image shape:", img.shape) # Print image size and color depth.
↳The shape should be (H,W,C).

plt.imshow(img) # Show the original image
plt.show()
```

```
[ ]: import copy
import time
def iterative(img):
    """ Iterative operation. """
    image = copy.deepcopy(img) # Create a copy of the image matrix
    for y in range(image.shape[0]):
        for x in range(image.shape[1]):
            #Top Right
            if y < image.shape[0]/2 and x >= image.shape[1]/2:
                image[y,x] = image[y,x] * np.array([1,0,0]) # Keep the red
↳channel
            #Bottom Left
            elif y >= image.shape[0]/2 and x < image.shape[1]/2:
                image[y,x] = [image[y,x][2], image[y,x][1], image[y,x][0]]
↳#(B,G,R) image
            #Bottom Right
            elif y >= image.shape[0]/2 and x >= image.shape[1]/2:
                r,g,b = image[y,x]
                image[y,x] = 0.21263903 * r + 0.71516871 * g + 0.072192319 * b
    return image

def get_channel(img, channel):
    """ Function to extract 2D image corresponding to a channel index from a
↳color image.
    This function should return a H*W array which is the corresponding channel
↳of the input image. """
    img = copy.deepcopy(img) # Create a copy so as to not change the
↳original image
    ##### Write your code here. #####
```



```

def merge_channels(img0, img1, img2):
    """ Function to merge three single channel images to form a color image.
    This function should return a H*W*3 array which merges all three single
    ↪channel images
    (i.e. img0, img1, img2) in the input."""
    ##### Write your code here. #####
    # Hint: There are multiple ways to implement it.
    #     1. For example, create a H*W*C array with all values as zero and
    #         fill each channel with given single channel image.
    #         You may refer to the "Modify a subarray" section in the brief
    ↪NumPy tutorial above.
    #     2. You may find np.stack() / np.concatenate() / np.reshape() useful
    ↪in this problem.

def vectorized(img):
    """ Vectorized operation. """
    image = copy.deepcopy(img)
    a = int(image.shape[0]/2)
    b = int(image.shape[1]/2)
    # Please also keep the red / green / blue channel respectively in the
    ↪corresponding part of image
    # with the vectorized operations. You need to make sure your final
    ↪generated image in this
    # vectorized() function is the same as the one generated from iterative().

    ##### Write your code here. #####
    #Top Right: keep the red channel
    image[:a,b:] =

    #Bottom Left: (B,G,R) image
    image[a,:b] =

    #Bottom Right: Grayscale image
    image[a:,b:] =

    return image

```

Now, run the following cell to compare the difference between iterative and vectorized operation.

```

[ ]: import time

def compare():
    img = plt.imread('geisel.jpg')
    cur_time = time.time()
    image_iterative = iterative(img)

```

```

print("Iterative operation (sec):", time.time() - cur_time)

cur_time = time.time()
image_vectorized = vectorized(img)
print("Vectorized operation (sec):", time.time() - cur_time)

return image_iterative, image_vectorized

# Test your implemented get_channel()
assert len(get_channel(img, 0).shape) == 2 # Index 0

# Run the function
image_iterative, image_vectorized = compare()

# Plotting the results in sepearate subplots.
plt.figure(figsize=(12,4)) # Adjust the figure size.
plt.subplot(1, 3, 1) # Create 1x3 subplots, indexing from 1
plt.imshow(img) # Original image.

plt.subplot(1, 3, 2)
plt.imshow(image_iterative) # Iterative operations on the image.

plt.subplot(1, 3, 3)
plt.imshow(image_vectorized) # Vectorized operations on the image.

plt.show() # Show the figure.

# Note: The shown figures of image_iterative and image_vectorized should be
↳ identical!

```

1.7 Problem 2: Coordinates vs Row-col (5 points)

We have already loaded the `geisel.jpg` image. Get the color values `[r, g, b]` for - 1. the pixel at coordinate $(x, y) = (100, 250)$ 2. the pixel on the 100th row and 250th column.

Now call the `show_color` method for these pixels. Are the values/colors the same? Explain the reason for your observation.

```

[ ]: import matplotlib.pyplot as plt
import copy

def show_color(pixel):
    """ Function to show the color of a pixel.
    This function takes a 1D array of 3 elements (i.e. a pixel) as input. """
    plt.imshow(pixel.reshape(1,1,3))
    plt.show()

### Write your code here. ###

```

1.8 Problem 3: More Image Manipulation (35 points)

In this problem you will use the image `world_map.png`. Being a color image, this image has three channels, corresponding to the primary colors of red, green and blue.

- (1) Read the image.
- (2) Write a function to flip the original image from left to right. For this function, please **only use Array Indexing** to implement this function. **DO NOT** use even a single for-loop and **DO NOT** directly use library functions (e.g. `np.flip()`) that directly flips the matrix.
- (3) Next, write another function to rotate the original image 90 degrees **clockwise**. For this function, please **only use Array Indexing** to implement this function. **DO NOT** use even a single for-loop and **DO NOT** directly use library functions (e.g. `np.rot90()`) that directly rotates the matrix. Display three images, by applying the rotation function once (i.e. 90-degree rotation), twice (i.e. 180-degree rotation) and thrice (i.e. 270-degree rotation). [**HINT**: Can you reuse the previous flip method you wrote?]
- (4) Read the `usa.png` image and the corresponding `usa_mask.png` binary mask image.
- (5) Given the `start_x` and `start_y` on the world map image indicating the starting position (top-left corner) of the USA image, you need to write a function to place just the cutout of the USA at the right position on the world map. (**Hint**: **Mask** pixel values of 1 indicate **image** pixels to show.)
- (6) Finally, consider **4 color images** you obtained: 1 original world map image, 1 from flipping (left to right), 1 from rotation (180-degree), and 1 after placing the USA cutout on the world map. Now, from the flipped image remove the red channel, from the rotated image, remove the green channel and from the final USA cutout image remove the blue channel. Using these 4 images, create one single image by tiling them together **without using loops**. The image will have 2×2 tiles making the shape of the final image $2H \times 2W \times 3$. The order in which the images are tiled does not matter. Show the tiled image.

```
[ ]: import numpy as np
import matplotlib.pyplot as plt
import copy
```

```
[ ]: # (1) Read the image.
#### Write your code here. ####
img =

plt.imshow(img) # Show the image after reading.
plt.show()
```

```
[ ]: # (2) Flip the image from left to right.
def flip_img(img):
    """ Function to mirror image from left to right.
    This function should return a H*W*3 array which is the flipped version of
    ↪ original image.
    """
    #### Write your code here. ####
```

```
plt.imshow(img)
plt.show()
flipped_img = flip_img(img)
plt.imshow(flipped_img)
plt.show()
```

```
[ ]: # (3) Rotate image.
def rotate_90(img):
    """ Function to rotate image 90 degrees clockwise.
        This function should return a W*H*3 array which is the rotated version of
        original image. """
    ##### Write your code here. #####

plt.imshow(img)
plt.show()
rot90_img = rotate_90(img)
plt.imshow(rot90_img)
plt.show()
rot180_img = rotate_90(rotate_90(img))
plt.imshow(rot180_img)
plt.show()
rot270_img = rotate_90(rotate_90(rotate_90(img)))
plt.imshow(rot270_img)
plt.show()
```

```
[ ]: # (4) Read the usa image and the binary mask image

##### Write your code here. #####

usa_img =
bi_mask_img =

print("Face Mask Image Size: ")
print(usa_img.shape)
print("Face Mask Binary Mask Image Size: ")
print(bi_mask_img.shape)

plt.imshow(usa_img)
plt.show()
plt.imshow(bi_mask_img)
plt.show()
```

```
[ ]: # (5) Put the face mask on the bear's face
start_x = 155
```

```
start_y = 310

final_img = copy.deepcopy(img)

#### Write your code here. ####

plt.imshow(final_img)
plt.show()
```

```
[ ]: # (6) Write your code here to tile the four images and make a single image.
# You can use the img, flipped_img, rot180_img, final_img to represent the four
↳ images.
# After tiling, please display the tiled image.
#### Write your code here. ####
```