KC_Tan_HW0

October 6, 2021

1 CSE 252A Computer Vision I Fall 2021 - Assignment 0

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- Assignment Published On: **Wed, September 29, 2021**.
- Due On: **Wed, October 6, 2021 11:59 PM (Pacific Time)**.

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.
- After finishing the assignment in the notebook, please export the notebook as a PDF and submit both the notebook and the PDF (i.e. the `.ipynb` and the `.pdf` files) on Gradescope.
- 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.

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 **CSE252A Computer Vision I**!

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

[1]:
```
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
print(v)
```

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

```
[1 2 3]
(3,)
1D array: [1 2 3] Shape: (3,)
2D array: [[1]
 [2]
 [3]] Shape: (3, 1)
[[1 2 3]]
[[0. 0. 0. 0.]
 [0. 0. 0. 0.]
 [0. 0. 0. 0.]]
[[1. 1. 1.]]
[[1.]
 [1.]
 [1.]]
[[1. 0. 0. 0.]
 [0. 1. 0. 0.]
 [0. 0. 1. 0.]
 [0. 0. 0. 1.]]
[[0.60650697 0.18604217 0.11111244]
 [0.11805996 0.69682329 0.81506842]]
```

1.5.2 Array Indexing

[2]:
```
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)
```

```
Matrix
[[1 2 3]
 [4 5 6]
 [7 8 9]]

Access a single element
2

Modify a single element
[[  1   2   3]
 [  4 100   6]
 [  7   8   9]]

Access a subarray
[4 5 6]
[[4 5 6]]
[[4 5 6]
 [7 8 9]]
[[4 5 6]
 [7 8 9]]

Modify a subarray
[[1 1 1]
 [4 5 6]
 [7 8 9]]
[[1 2 3]
 [1 5 6]
 [1 8 9]]
[[1 1 3]
 [1 1 6]
 [7 8 9]]

Transpose a subarray
[4 5 6]
[[4]
 [5]
 [6]]
[[4 7]
 [5 8]
 [6 9]]
[[4 7]
 [5 8]
 [6 9]]
```

```
Reverse the order of a subarray
[6 5 4]

Boolean array indexing: Modify with a scaler
[[1 2 0]
 [0 0 0]]

Boolean array indexing: Modify with another array
[[  1   2 100]
 [  4  10   6]]
```

1.5.3 Array Dimension Operation

[3]:
```
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)  # 1 big cell with a 2R x 2C array
print("--------------------")
re_m = m.reshape(2,1,2)  # Add one more dimension in middle.
print(re_m, re_m.shape)  # 2 big cells with 1R x 2C array
print("--------------------")
re_m = m.reshape(2,2,1)  # Add one more dimension at last.
print(re_m, re_m.shape)  # 2 big cells with 2R x 1C array

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)), np.stack((m1,m2)).shape) # 2 big cells with 2R x 2C␣
 ↪array

print("\nConcatenate")
m1 = np.array([[1, 2], [3, 4]]) # Create a 2x2 array.
m2 = np.array([[1, 1], [1, 1]]) # Create a 2x2 array.
# axis : [int, optional] The axis along which the arrays will be joined.
#        If axis is None, arrays are flattened before use. Default is 0.
print(np.concatenate((m1,m2)), np.concatenate((m1,m2)).shape)
print("--------------------")
print(np.concatenate((m1,m2), axis=0))
print("--------------------")
print(np.concatenate((m1,m2), axis=1))
print("--------------------")
print(np.concatenate((m1,m2), axis=None))
```

```
Matrix
[[1 2]
 [3 4]] (2, 2)

Reshape
[[[1 2]
  [3 4]]] (1, 2, 2)
--------------------
[[[1 2]]

 [[3 4]]] (2, 1, 2)
--------------------
[[[1]
  [2]]

 [[3]
  [4]]] (2, 2, 1)

Stack
[[[1 2]
  [3 4]]

 [[1 1]
  [1 1]]] (2, 2, 2)

Concatenate
[[1 2]
 [3 4]
 [1 1]
 [1 1]] (4, 2)
--------------------
[[1 2]
 [3 4]
 [1 1]
 [1 1]]
--------------------
[[1 2 1 1]
 [3 4 1 1]]
--------------------
[1 2 3 4 1 1 1 1]
```

1.5.4 Math Operations on Array

Element-wise Operations

[4]:
```
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
```

```
[[ 3.  6.  9.]
 [12. 15. 18.]]
[[0.5 1.  1.5]
 [2.  2.5 3. ]]
[[0. 1. 2.]
 [2. 2. 3.]]
[[ 1.  4.  9.]
 [16. 25. 36.]]
[[0.         0.69314718 1.09861229]
 [1.38629436 1.60943791 1.79175947]]
[[  2.71828183   7.3890561   20.08553692]
 [ 54.59815003 148.4131591  403.42879349]]
[[2. 3. 4.]
 [6. 7. 8.]]
[[0. 1. 2.]
 [2. 3. 4.]]
[[ 1.  2.  3.]
 [ 8. 10. 12.]]
[[1.  2.  3. ]
 [2.  2.5 3. ]]
[[ True False False]
 [False False False]]
```

Broadcasting

[5]:
```
# 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)
```

```
[[1. 2. 3.]
 [2. 4. 6.]]
```

Sum and Mean

[6]:
```
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
```

```
Sum of array
21
[5 7 9]
[ 6 15]

Mean of array
3.5
[2.5 3.5 4.5]
[2. 5.]
```

Vector and Matrix Operations

[7]:
```
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
```

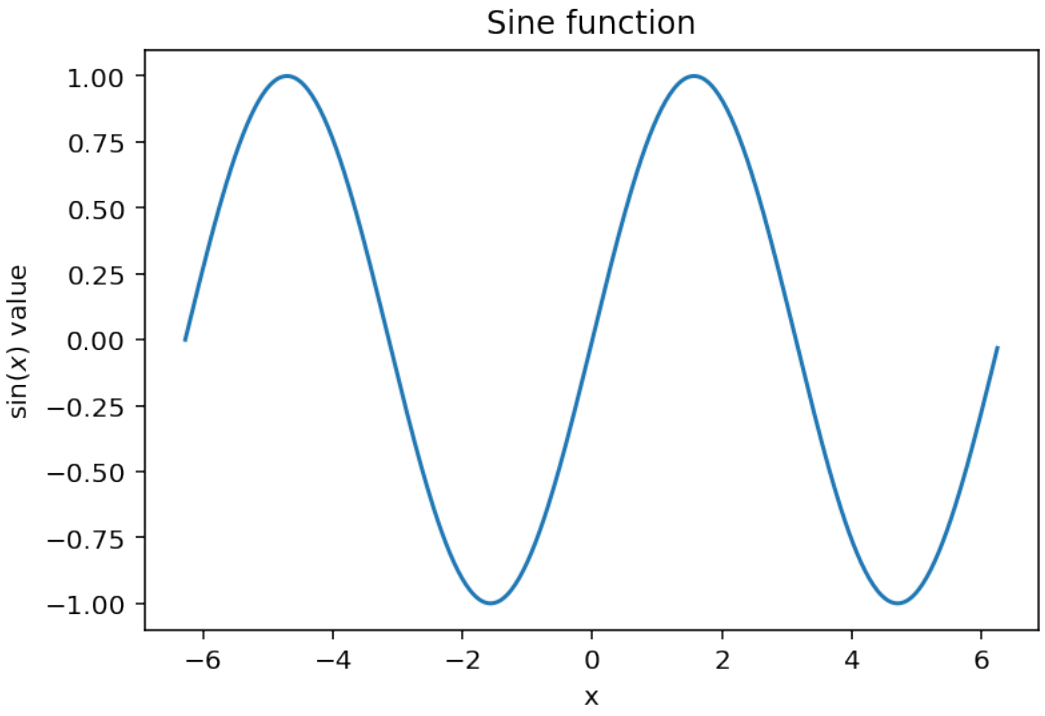
```
Matrix-matrix product
[[3 3]
 [7 7]]
[[4 4]
 [6 6]]
```

```
Matrix-vector product
[11 25]

Vector-vector product
11
```

1.5.5 Matplotlib

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

[8]:
```
%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 `ucsd-triton-statue.png` 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).

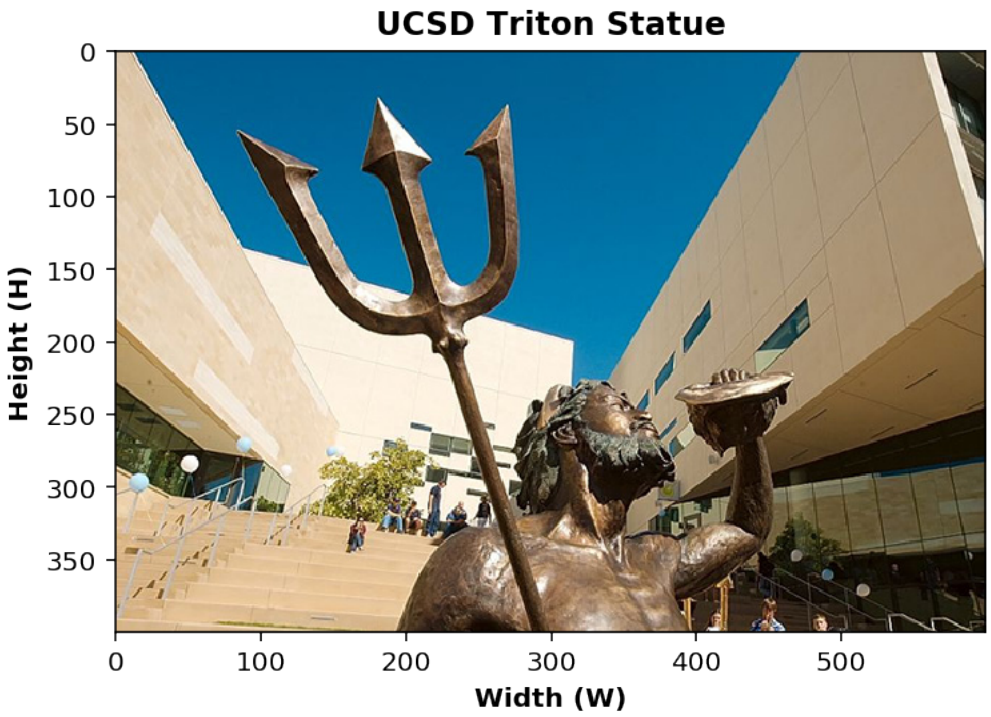
(2) For the (B,G,R) colored image, write a function to merge those single channel images back into a 3-dimensional colored image in the reversed channels order (B,G,R).

(3) For the grayscale image, write a function to conduct operations with the extracted 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()`.

[9]:
```
import numpy as np
import matplotlib.pyplot as plt

img = plt.imread('ucsd-triton-statue.jpg') # Read an image
print("Image shape:", img.shape)           # Print image size and color depth.␣
 ↪The shape should be (H,W,C).
# 400 cells with 600R x 3C array
# Each row stores the values of R, G, and B
# First Column is R value, Second Column is G value, Third Column is B value.

plt.title('UCSD Triton Statue', fontweight="bold")            # Title
plt.xlabel('Width (W)', fontweight="bold")                    # X-label
plt.ylabel('Height (H)', fontweight="bold")                   # Y-label
plt.imshow(img)                                               # Show the␣
 ↪original image
plt.show()
```

```
Image shape: (400, 600, 3)
```



[10]:
```
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: # height < 200 &␣
↪width >= 300
                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: # height >=␣
↪200 & width < 300
                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: # height >=␣
↪200 & width > 300
                r,g,b = image[y,x]
```

```
                image[y,x] = 0.2989 * r + 0.5870 * g + 0.1140 * 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. """
    image = copy.deepcopy(img)      # Create a copy so as to not change the original image

    #### Write your code here. ####
    return image[:,:,channel]       # Extract the intended channel that is input by the user.


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."""
    # 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.

    #### Write your code here. ####
    re_img0 = img0.reshape(img0.shape[0], img0.shape[1],1) # Reshape red channel from H x W  to H x W x 1
    re_img1 = img1.reshape(img1.shape[0], img1.shape[1],1) # Reshape green channel from H x W  to H x W x 1
    re_img2 = img2.reshape(img2.shape[0], img2.shape[1],1) # Reshape blue channel from H x W  to H x W x 1

    return np.concatenate((re_img0, re_img1, re_img2), axis=2) # merge them to H x W x 3


def vectorized(img):
    """ Vectorized operation. """
    image = copy.deepcopy(img)
```

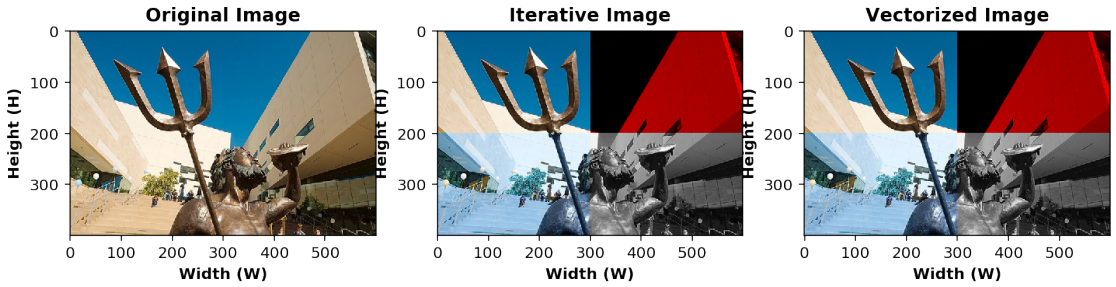
```
    a = int(image.shape[0]/2)
    b = int(image.shape[1]/2)
    # Please also keep the red / green / blue channel respectively in the␣
↪corresponding part of image
    # with the vectorized operations. You need to make sure your final␣
↪generated image in this
    # vectorized() function is the same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

    #### Write your code here. ####
    #Top Right: keep the red channel
    image[:a,b:] = image[:a, b:] * np.array([1, 0, 0])

    #Bottom Left: (B,G,R) image
    r_chnl = get_channel(image[a:,:b],0)
    g_chnl = get_channel(image[a:,:b],1)
    b_chnl = get_channel(image[a:,:b],2)
    image[a:,:b] = merge_channels(b_chnl,g_chnl, r_chnl)
    #image[a:,:b] = image[a:, :b, [2,1,0]] # Convert from rgb to bgr, switch␣
↪columns.

    #Bottom Right: Grayscale image
    graysc = image[a:,b:,:3].dot(np.array([0.299, 0.587, 0.114])) # H x W
    image[a:, b:] = merge_channels(graysc, graysc, graysc) # Merge to become H␣
↪x W x 3

    return image
```

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

[11]:
```
import time

def compare():
    img = plt.imread('ucsd-triton-statue.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.title('Original Image', fontweight="bold")  # Title
plt.xlabel('Width (W)', fontweight="bold")      # X-label
plt.ylabel('Height (H)', fontweight="bold")     # Y-label
plt.imshow(img)                                 # Original image.

plt.subplot(1, 3, 2)
plt.title('Iterative Image', fontweight="bold") # Title
plt.xlabel('Width (W)', fontweight="bold")      # X-label
plt.ylabel('Height (H)', fontweight="bold")     # Y-label
plt.imshow(image_iterative)                     # Iterative operations on the␣
 ↪image.

plt.subplot(1, 3, 3)
plt.title('Vectorized Image', fontweight="bold")# Title
plt.xlabel('Width (W)', fontweight="bold")      # X-label
plt.ylabel('Height (H)', fontweight="bold")     # Y-label
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!
```

```
Iterative operation (sec): 0.7362229824066162
Vectorized operation (sec): 0.003535032272338867
```



1.7 Problem 2: More Image Manipulation (35 points)

In this problem you will use the image `bear.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 top to bottom. For this function, please only use **Array Indexing** to implement this function and **do not** directly use the functions (e.g. `np.flip()`) that directly flips the matrix.

(3) Next, write another function to rotate the original image 90 degrees counterclockwise. For this function, please only use **Array Indexing** to implement this function and **do not** directly use the functions (e.g. `np.rot90()`) that directly rotates the matrix. Try to apply the rotation function once (i.e. 90-degree rotation) and twice (i.e. 180-degree rotation)

(4) Read the `face-mask.png` image and the corresponding `face-mask-binary.png` binary mask image.

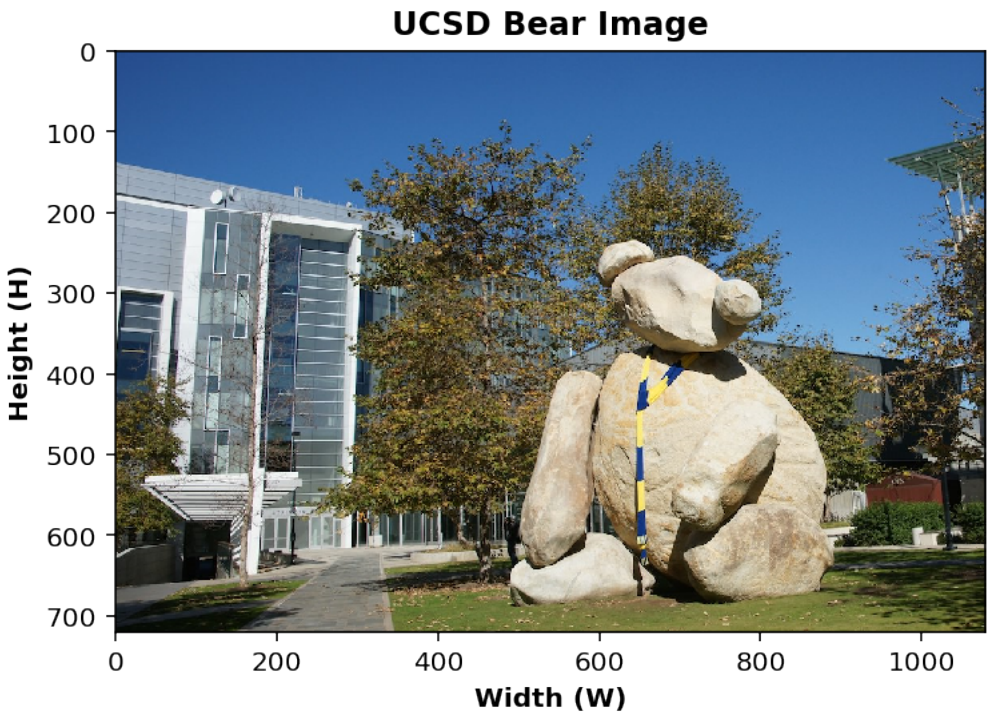
(5) Given the `start_x` and `start_y` on the bear image indicating the starting position(top-left corner) of the face mask, you need to write a function to help the bear put on the face mask. (Hints: **Mask** pixel values of 1 indicate **image** pixels to show.)

(6) Finally, consider **4 color images** you obtained: 1 original bear image, 1 from flipping (top to bottom), 1 from rotation (180-degree), and 1 for bear wearing the face mask. 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.

[12]:
```
import numpy as np
import matplotlib.pyplot as plt
import copy
```

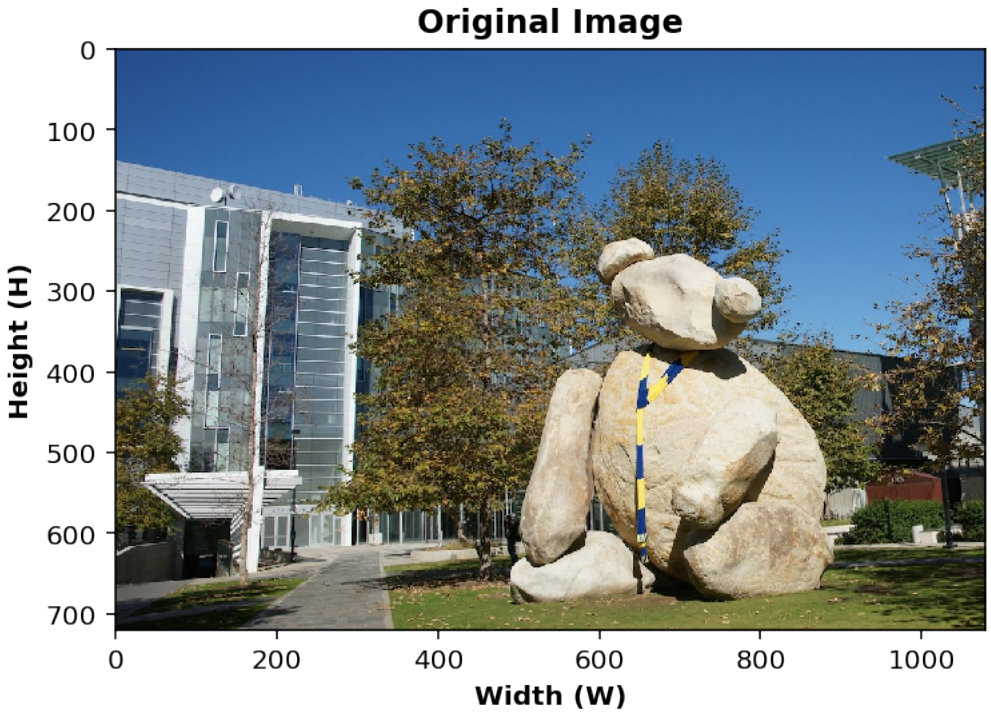
[13]:
```
# (1) Read the image.
#### Write your code here. ####
img = plt.imread('bear.png') # Read an image
print(img.shape)

plt.imshow(img)                                  # Show the image after reading.
plt.title('UCSD Bear Image', fontweight="bold") # Title
plt.xlabel('Width (W)', fontweight="bold")      # X-label
plt.ylabel('Height (H)', fontweight="bold")     # Y-label
plt.show()
```

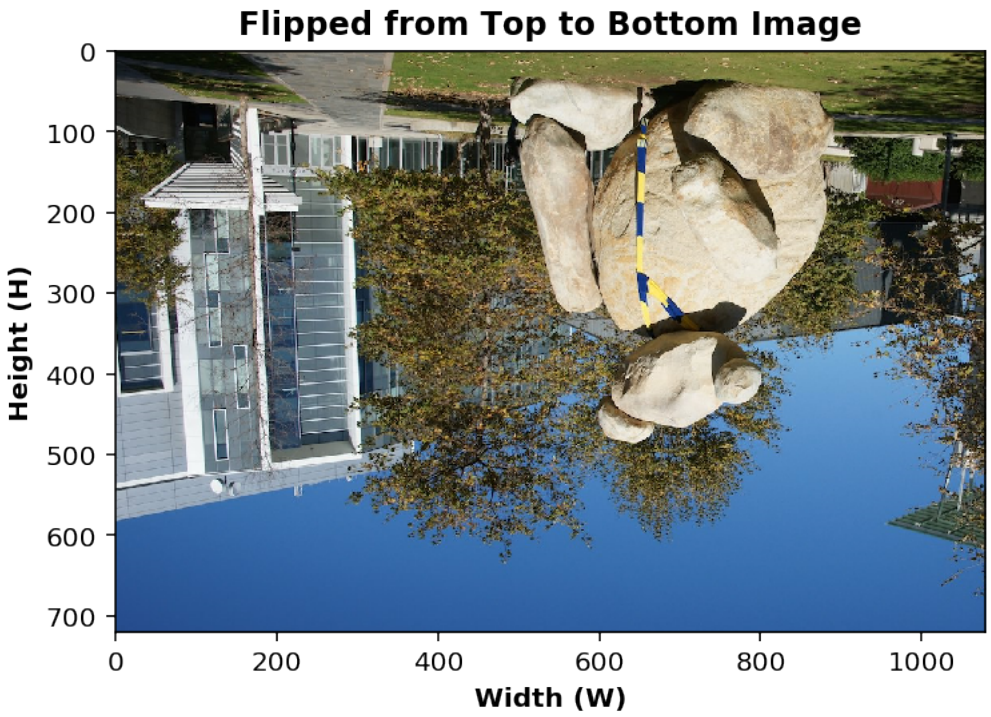
```
(720, 1080, 3)
```



[14]:
```
# (2) Flip the image from top to bottom.
def flip_img(img):
    """ Function to mirror image from top to bottom.
    This function should return a H*W*3 array which is the flipped version of␣
 ↪original image.
    """
    #### Write your code here. ####
    image = copy.deepcopy(img)                                                #␣
 ↪Create a copy of the image matrix
    flip_img = copy.deepcopy(img)                                             #␣
 ↪Create a copy for flipped image

    for y in range(int(img.shape[0]/2)):                                      #␣
 ↪Half of the height
        for x in range(img.shape[1]):
            top_pix = image[y,x]                                              #␣
 ↪Save top part of the image
            bottom_pix = image[img.shape[0] - y - 1, x]                       #␣
 ↪Save bottom part of the image

            # The flipping begins!
            flip_img[flip_img.shape[0] - y - 1, x], flip_img[y, x] = top_pix,␣
 ↪bottom_pix
```

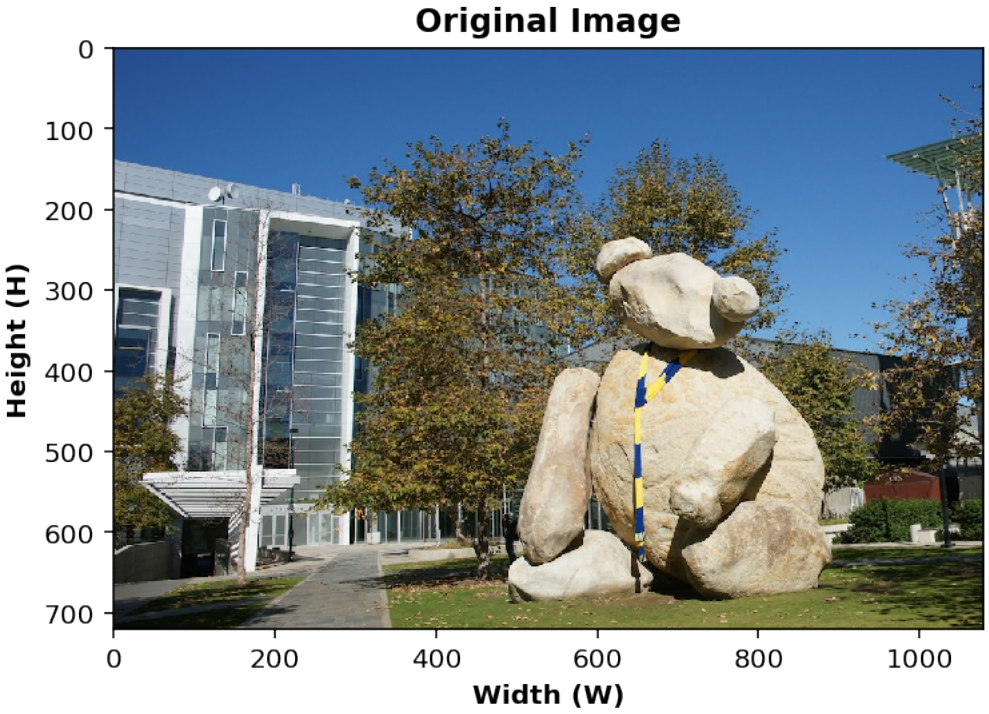
```
    return flip_img

plt.imshow(img)
plt.title('Original Image', fontweight="bold")                          # Title
plt.xlabel('Width (W)', fontweight="bold")                              # X-label
plt.ylabel('Height (H)', fontweight="bold")                             # Y-label
plt.show()
flipped_img = flip_img(img)
plt.imshow(flipped_img)
plt.title('Flipped from Top to Bottom Image', fontweight="bold")  # Title
plt.xlabel('Width (W)', fontweight="bold")                              # X-label
plt.ylabel('Height (H)', fontweight="bold")                             # Y-label
plt.show()
```

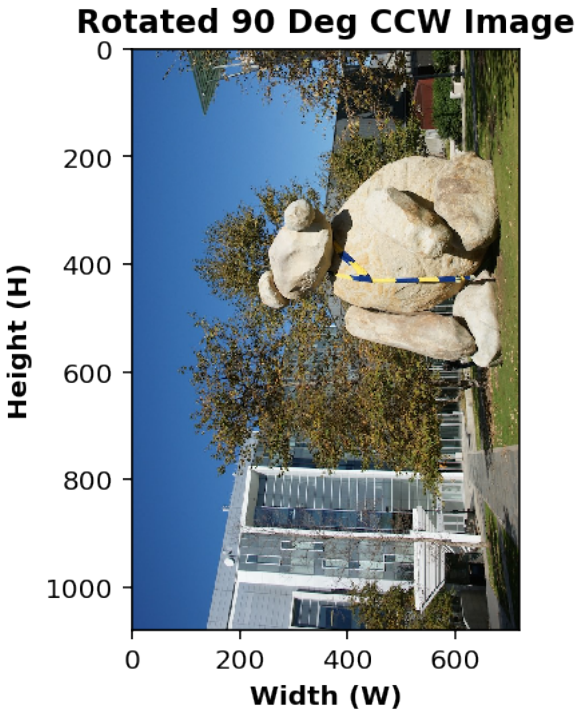


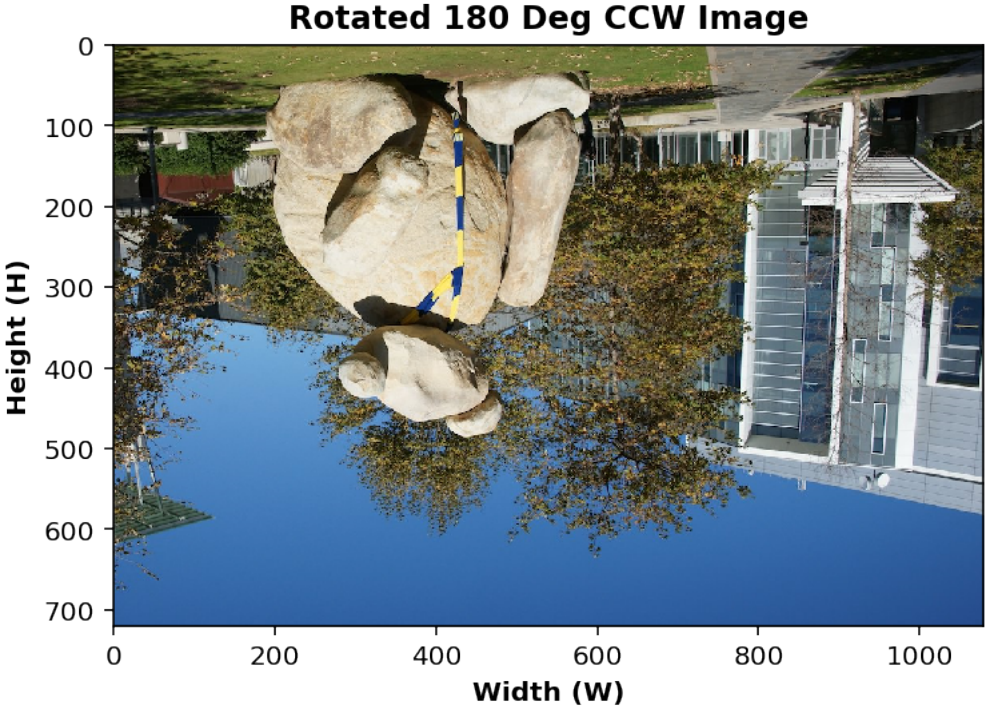


[15]:
```
# (3) Rotate image.
def rotate_90(img):
    """ Function to rotate image 90 degrees counter-clockwise.
    This function should return a W*H*3 array which is the rotated version of␣
 ↪original image. """
    #### Write your code here. ####
    image = copy.deepcopy(img)
    height, width, channel = image.shape[0], image.shape[1], image.shape[2] #␣
 ↪Store the image dimensions

    transpose_image = np.zeros([width, height, channel])     # Define and␣
 ↪initialize transpose matrix

    # Transpose the matrix
    for y in range(height):
        for x in range(width):
            transpose_image[x, y] = image[y, x]

    # Reverse the order of the rows on each channel to rotate the original␣
 ↪image by 90 deg ccw
    ccw90_image = transpose_image[::-1, :]

    return ccw90_image
```

```
plt.imshow(img)
plt.title('Original Image', fontweight="bold")                    # Title
plt.xlabel('Width (W)', fontweight="bold")                        # X-label
plt.ylabel('Height (H)', fontweight="bold")                       # Y-label
plt.show()

rot90_img = rotate_90(img)
plt.imshow(rot90_img)
plt.title('Rotated 90 Deg CCW Image', fontweight="bold")          # Title
plt.xlabel('Width (W)', fontweight="bold")                        # X-label
plt.ylabel('Height (H)', fontweight="bold")                       # Y-label
plt.show()

rot180_img = rotate_90(rotate_90(img))
plt.imshow(rot180_img)
plt.title('Rotated 180 Deg CCW Image', fontweight="bold")         # Title
plt.xlabel('Width (W)', fontweight="bold")                        # X-label
plt.ylabel('Height (H)', fontweight="bold")                       # Y-label
plt.show()
```

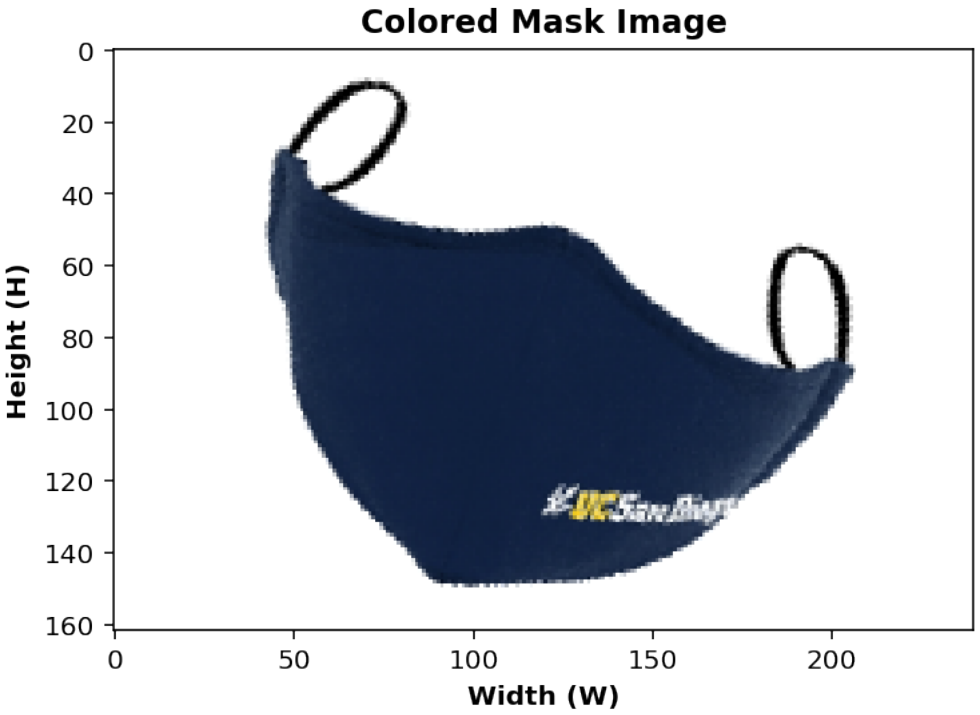


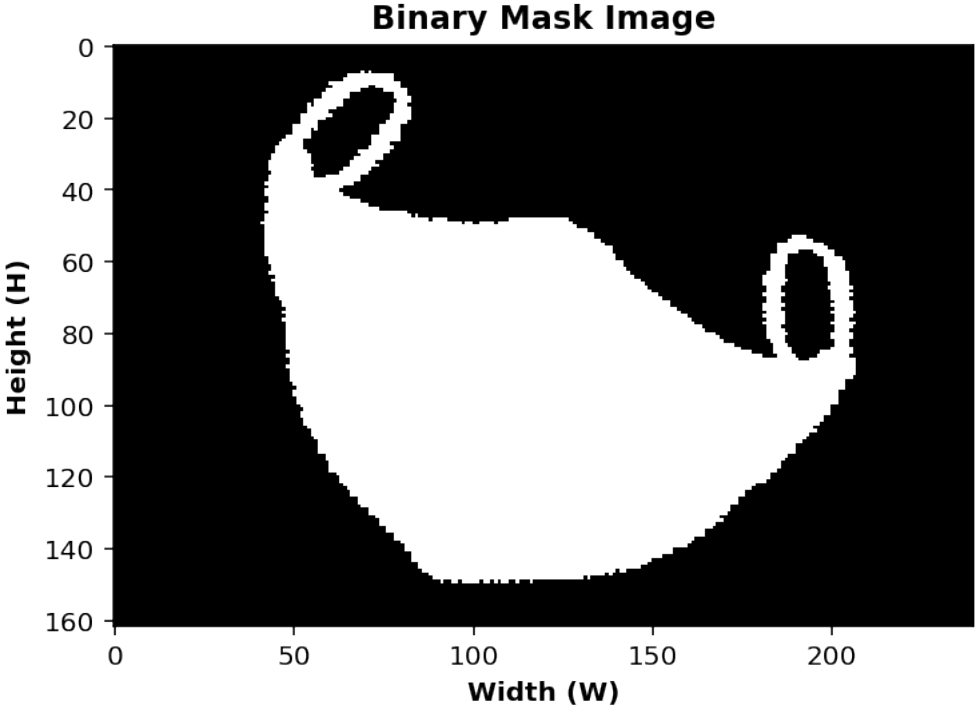

Rotated 90 Deg CCW Image
Height (H)
Width (W)
0
200
400
600
800
1000
0
200
400
600


Rotated 180 Deg CCW Image
Height (H)
Width (W)
0
100
200
300
400
500
600
700
0
200
400
600
800
1000

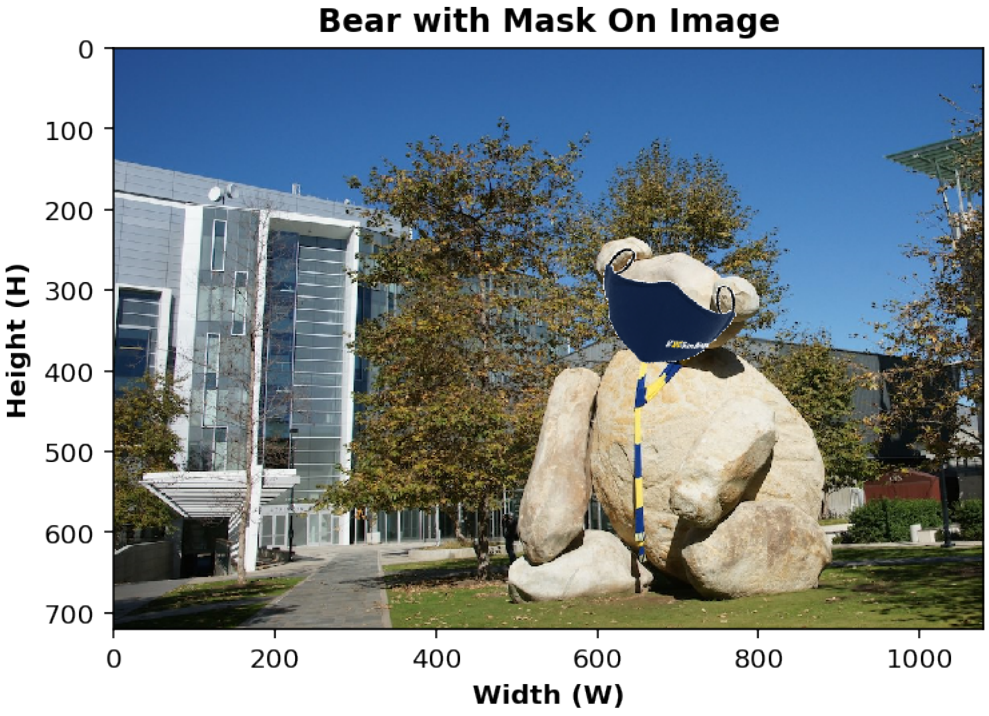
[16]:
```
# (4)Read the face mask image and the face mask binary image

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

mask_img = plt.imread('face-mask.png')            # Read 'face-mask.png' image
bi_mask_img = plt.imread('face-mask-binary.png') # Read 'face-mask-binary.png'␣
 ↪image

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

plt.imshow(mask_img)
plt.title('Colored Mask Image', fontweight="bold")                # Title
plt.xlabel('Width (W)', fontweight="bold")                        # X-label
plt.ylabel('Height (H)', fontweight="bold")                       # Y-label
plt.show()

plt.imshow(bi_mask_img)
plt.title('Binary Mask Image', fontweight="bold")                 # Title
plt.xlabel('Width (W)', fontweight="bold")                        # X-label
plt.ylabel('Height (H)', fontweight="bold")                       # Y-label
plt.show()
```

```
Face Mask Image Size:
(162, 240, 3)
Face Mask Binary Mask Image Size:
(162, 240, 3)
```

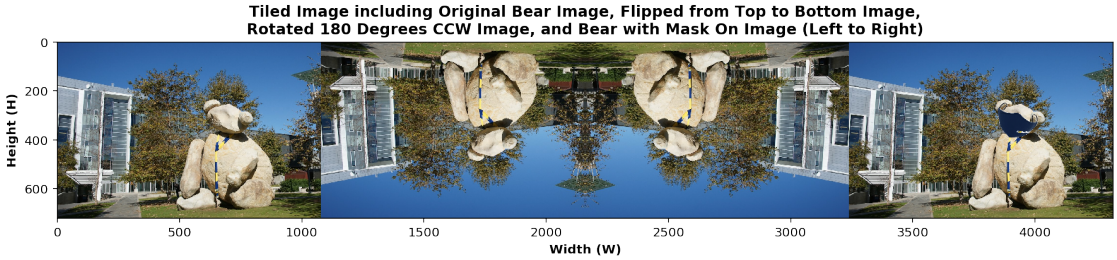

Colored Mask Image
Height (H)
Width (W)
0
20
40
60
80
100
120
140
160
0
50
100
150
200


Binary Mask Image
Height (H)
Width (W)
0
20
40
60
80
100
120
140
160
0
50
100
150
200

[17]:
```
# (5) Put the face mask on the bear's face
start_x = 565
start_y = 240

maskon_img = copy.deepcopy(img)

#### Write your code here. ####
height, width, channel = bi_mask_img.shape[0], bi_mask_img.shape[1],␣
↪bi_mask_img.shape[2] # Store the image dimensions

for y in range(start_y, start_y + height):
    for x in range(start_x, start_x + width):
        if np.all(bi_mask_img[y-start_y, x-start_x]) == True: # If the pixel is␣
↪white/non-zero
            maskon_img[y, x] = mask_img[y-start_y, x-start_x] # swap the bear␣
↪image pixel with the mask image.

# Display the masked image
plt.imshow(maskon_img)
plt.title('Bear with Mask On Image', fontweight="bold")            # Title
plt.xlabel('Width (W)', fontweight="bold")                         # X-label
plt.ylabel('Height (H)', fontweight="bold")                        # Y-label
plt.show()
```



[18]:
```
# (6) Write your code here to tile the four images and make a single image.
# You can use the img, flipped_img, rot180_img, maskon_img to represent the␣
 ↪four images.
# After tiling, please display the tiled image.
#### Write your code here. ####
# Tile images
tiled_image = np.concatenate((img, flipped_img, rot180_img, maskon_img),axis =␣
 ↪1)

# Display tiled images
plt.figure(figsize=(15, 5))   # Adjust the figure size.
plt.imshow(tiled_image)
# Title
plt.title('Tiled Image including Original Bear Image, Flipped from Top to␣
 ↪Bottom Image,\nRotated 180 Degrees CCW Image, and Bear with Mask On Image␣
 ↪(Left to Right)',fontweight="bold")
plt.xlabel('Width (W)', fontweight="bold")                    # X-label
plt.ylabel('Height (H)', fontweight="bold")                   # Y-label
plt.show()
```



1.7.1 Submission Instructions

Remember to submit **both** the Jupyter notebook file and the PDF version of this notebook to Gradescope. Please make sure the content in each cell is clearly shown in your final PDF file. 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"