CPSC 425: Assignment 1
Name: Terence Chen
Student number: 42602136

Part 1: Gaussian Filtering

1)

Code:

```python
# Question 1
def boxfilter(n):

    # Checks that n is odd
    assert n % 2 == 1, "Dimension must be odd"

    # Ensures filter sums to 1
    return np.ones((n, n))/(n*n)

```

Output:

```
In [3]: boxfilter(3)
Out[3]:
array([[ 0.11111111,  0.11111111,  0.11111111],
       [ 0.11111111,  0.11111111,  0.11111111],
       [ 0.11111111,  0.11111111,  0.11111111]])

In [4]: boxfilter(4)

AssertionErrorTraceback (most recent call last)
<ipython-input-4-65de769d965e> in <module>()
----> 1 boxfilter(4)

/Users/Terence/Desktop/Assignment 1.py in boxfilter(n)
     11
     12     # Checks that n is odd
---> 13     assert n % 2 == 1, "Dimension must be odd"
     14
     15     # Ensures filter sums to 1
AssertionError: Dimension must be odd

In [5]: boxfilter(5)
Out[5]:
array([[ 0.04,  0.04,  0.04,  0.04,  0.04],
       [ 0.04,  0.04,  0.04,  0.04,  0.04],
       [ 0.04,  0.04,  0.04,  0.04,  0.04],
       [ 0.04,  0.04,  0.04,  0.04,  0.04],
       [ 0.04,  0.04,  0.04,  0.04,  0.04]])
```

2)
Code:

```
def gauss1d(sigma):

    # Calulates the length and ensures it is a double
    filter_length = (math.ceil(6 * float(sigma)))

    # Add one if even to ensure it is odd
    if filter_length % 2 == 0:
        filter_length += 1

    # Calculate mid point and edges,sorted into array
    k = math.floor(filter_length/2)
    d = np.arange((-1 * k), k + 1)

    #apply gaussian function
    gauss_fun = np.exp( -(d ** 2)/(2 * sigma ** 2))

    # Normalize values and return results
    return (gauss_fun / np.sum(gauss_fun))
```

Output:

```
In [2]: gauss1d(0.3)
Out[2]: array([ 0.00383626,  0.99232748,  0.00383626])

In [3]: gauss1d(0.5)
Out[3]: array([ 0.10650698,  0.78698604,  0.10650698])

In [4]: gauss1d(1)
Out[4]:
array([ 0.00443305,  0.05400558,  0.24203623,  0.39905028,  0.24203623,
        0.05400558,  0.00443305])

In [5]: gauss1d(2)
Out[5]:
array([ 0.0022182 ,  0.00877313,  0.02702316,  0.06482519,  0.12110939,
        0.17621312,  0.19967563,  0.17621312,  0.12110939,  0.06482519,
        0.02702316,  0.00877313,  0.0022182 ])
```

3)
Code:

```
# Question 3
def gauss2d(sigma):
    two_dim = gauss1d(sigma)[np.newaxis]
    two_dim_transpose = np.transpose(two_dim)
    return signal.convolve2d(two_dim, two_dim_transpose)
```

Output:

```
In [6]: gauss2d(0.5)
Out[6]:
array([[ 0.01134374,  0.08381951,  0.01134374],
       [ 0.08381951,  0.61934703,  0.08381951],
       [ 0.01134374,  0.08381951,  0.01134374]])

In [7]: gauss2d(1)
Out[7]:
array([[  1.96519161e-05,   2.39409349e-04,   1.07295826e-03,
          1.76900911e-03,   1.07295826e-03,   2.39409349e-04,
          1.96519161e-05],
       [  2.39409349e-04,   2.91660295e-03,   1.30713076e-02,
          2.15509428e-02,   1.30713076e-02,   2.91660295e-03,
          2.39409349e-04],
       [  1.07295826e-03,   1.30713076e-02,   5.85815363e-02,
          9.65846250e-02,   5.85815363e-02,   1.30713076e-02,
          1.07295826e-03],
       [  1.76900911e-03,   2.15509428e-02,   9.65846250e-02,
          1.59241126e-01,   9.65846250e-02,   2.15509428e-02,
          1.76900911e-03],
       [  1.07295826e-03,   1.30713076e-02,   5.85815363e-02,
          9.65846250e-02,   5.85815363e-02,   1.30713076e-02,
          1.07295826e-03],
       [  2.39409349e-04,   2.91660295e-03,   1.30713076e-02,
          2.15509428e-02,   1.30713076e-02,   2.91660295e-03,
          2.39409349e-04],
       [  1.96519161e-05,   2.39409349e-04,   1.07295826e-03,
          1.76900911e-03,   1.07295826e-03,   2.39409349e-04,
          1.96519161e-05]])
```

4 a and b)
Though convolution and correlation may seem similar for some certain examples, they ultimately have different applications. Convolution is associative whereas correlation is not. Thus we need two different functions ‘signal.convolve2d’ and ‘signal.correlate2d’ in Scipy.

Code for question 4 (all parts including 4a, 4b and 4c):

```
# Question 4
#Part a
def gaussconvolve2d(array,sigma):
    gc2d_filter = gauss2d(sigma);
    result = signal.convolve2d(array, gc2d_filter, 'same')
    return result

# Though convolution and correlation may seem similar for some certain examples, they ultimately
# have different applications. Convolution is associative whereas correlation is not. Thus we need
# two different functions ‘signal.convolve2d’ and ‘signal.correlate2d’ in Scipy.

#Part b
image_file = "/Users/Terence/Desktop/dog.jpg"

#convert image to grey scale, apply numpy array and calls gaussconvolve2d function
image = Image.open(image_file).convert('L')
array = np.asarray(image)
convolve = gaussconvolve2d(array, 3)

#Part c

# Original image converted to greyscale
image.show()

# Filtered image

# Filters images using the gaussconvolve2d function
filtered_img = Image.fromarray(np.uint8(convolve))
filtered_img.show()
```

4c)
Original greyscale:

Filtered:

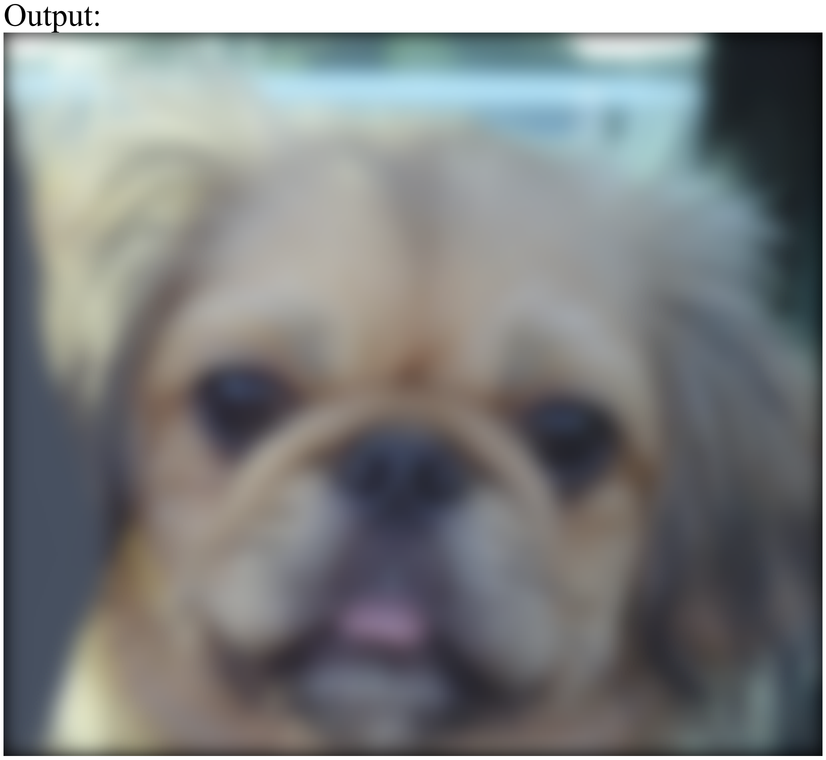
5)
We know that the Gaussian blur is separable thus by taking advantage separability and applying Fourier transforms to the functions we are efficiently simplify the process with multiplication. To further elaborate, by separating Gaussian blur function into two functions, f(x) and f(y). Then by applying Fourier transform to the functions we are able to efficiently reduce the convolution procedure to multiplication. Thus making the whole process more efficient.

Part 2: Hybrid Images

1)
Code:

```
#Question 1
dog_image_file = "/Users/Terence/Desktop/hw1/0b_dog.bmp"
dog = Image.open(dog_image_file)
d_array = np.asarray(dog)
red = gaussconvolve2d(d_array[:,:,0], 5)
green = gaussconvolve2d(d_array[:,:,1], 5)
blue = gaussconvolve2d(d_array[:,:,2], 5)
red=red[:,:,np.newaxis]
green=green[:,:,np.newaxis]
blue=blue[:,:,np.newaxis]
filtered_dog = Image.fromarray(np.uint8(np.concatenate((red, green, blue ), axis=2)))
filtered_dog.show()
```

Output:



2)
Code:

```
#Question 2
cat_image_file = "/Users/Terence/Desktop/hw1/0a_cat.bmp"
cat = Image.open(cat_image_file)
c_array = np.asarray(cat)
c_red =  c_array[:,:,0] - gaussconvolve2d(c_array[:,:,0], 5)+128
c_green = c_array[:,:,1] - gaussconvolve2d(c_array[:,:,1], 5)+128
c_blue =  c_array[:,:,2] - gaussconvolve2d(c_array[:,:,2], 5)+128
c_red = c_red[:,:,np.newaxis]
c_green = c_green[:,:,np.newaxis]
c_blue = c_blue[:,:,np.newaxis]
filtered_cat = Image.fromarray(np.uint8(np.concatenate((c_red, c_green, c_blue ), axis=2)))
filtered_cat.show()
```

Output:

3)

Code:

```
#Question 3
# new arrays without the +128 for high frequency
c_red1 =  c_array[:,:,0] - gaussconvolve2d(c_array[:,:,0], 5)
c_green1 = c_array[:,:,1] - gaussconvolve2d(c_array[:,:,1], 5)
c_blue1 =  c_array[:,:,2] - gaussconvolve2d(c_array[:,:,2], 5)
c_red1 = c_red1[:,:,np.newaxis]
c_green1 = c_green1[:,:,np.newaxis]
c_blue1 = c_blue1[:,:,np.newaxis]

#adding the low and high frequency images and clipping
filtered_combined = Image.fromarray(np.uint8(np.concatenate((np.clip((c_red1 + red),0,255), np.clip(c_green1 + green, 0 ,255), np.clip(c_blue1 + blue,0,255)), axis=2)))
filtered_combined.show()
```

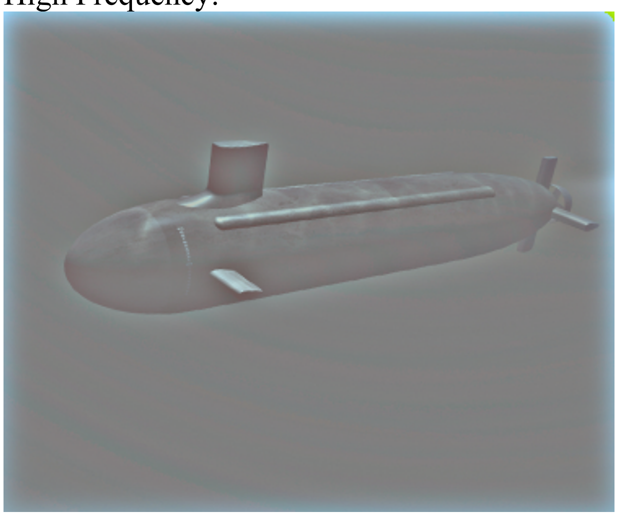
Output:

Note: since we need to do the same process above for 2 more pairs of pictures, for the sake of saving space I will not put the code on the pdf again because of the similarity to the code above (code not required as specified in piazza). The low, high and hybrid picture is included in this pdf below.

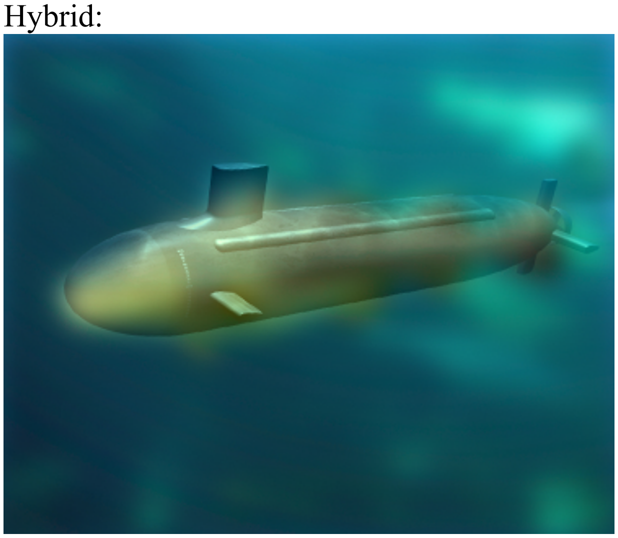
Images used: fish and submarine with sigma = 8

Low frequency:

High Frequency:



Hybrid:



Images used: bird and plane with sigma = 12

Low frequency:

High frequency:

Hybrid: