Hybrid Images Report

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Experiments

Environment:

- Mac OS X
- python3.5, opencv3, numpy, matplotlib

Approaches (hybrid images):

0. Preprocess images (spatial domain)
- Get the high resolution source images
- Compare the source images and decide which parts to be aligned
- Scale the source images to make the parts to be aligned same size (in pixels)
- Shift the parts to be aligned to the same position (in pixels)
- Cut the source images to same size

1. Read images (spatial domain)
- Using cv2.imread, cv2.cvtColor
- Read the image that is supposed to be the low frequency component in RGB
- Read the image that is supposed to be the high frequency component in grayscale

2. Fourier Transform images (from spatial domain to frequency domain)
- Using numpy.fft.fft2
- For the RGB images, apply Fourier Transform on 3 channels respectively
- For the grayscale images, apply Fourier Transform directly

3. Shift the zero frequency to center (frequency domain)
- Using numpy.fft.fftshift

4. Create Gaussian fliters (frequency domain)

- Compute the Gaussian mask by $e^{-2\pi^2\sigma^2(x^2+y^2)}$ as the same size of the input images
- $\sigma = \dfrac{1}{2\pi\sigma_f}$, where σ_f is the cutoff frequency (where gain is 0.5)
- x, y are the relative coordination with the origin at $(\dfrac{width}{2}, \dfrac{height}{2})$
- low pass filter = Gaussian mask
- high pass filter = 1 - Gaussian mask

5. Filter images (frequency domain)

- Using numpy.multiply
- Element-wise multiply the Fourier-Transformed images and the filters
- For the RGB images, apply the low pass filter on 3 channels respectively
- For the grayscale images, apply the high pass filter directly

6. Make hybrid images (frequency domain)

- Using numpy.add
- Add the high-pass-filtered images to low-pass-filtered images on 3 channels respectively
- For the quality of the hybrid images, I scaled the low-pass-filtered images and high-passed-filtered images with some weights
- The weights are obtained by experiments

7. Shift the zero frequency back (frequency domain)

- Using numpy.fft.ifftshift

8. Inverse Fourier Transform images (from frequency domain to spatial domain)

- Using numpy.fft.ifft2
- Inverse transform the hybrid images on 3 channels respectively

9. Save the hybrid image (spatial domain)

- Using cv2.imwrite

Approaches (Laplacian Pyramid):

1. Read images
- Using cv2.imread
- Read images in grayscale

2. Generate Gaussian pyramid
- Using cv2.pyrDown
- Blur the image and down sampling it with the specified times (8 times in this experiment)

3. Generate Laplacian pyramid
- Using cv2.pyrUp, numpy.subtract
- Laplacian pyramid is obtained by computing the difference of all adjacent levels of Gaussian pyramid
- Since the upper level of the Gaussian pyramid is smaller than the lower level, they have to be resized to the same size to perform the subtraction
- Since the difference may be only 10~40 and the result image may look very dim, I adjust the contrast of the result to make it look more obvious

Experiment Settings:

- Low pass filter cutoff frequencies = [3, 6, 9, 12, 15, 18, 21]
- Frequency gaps between low pass filter and high pass filter = [0, 5, 10, 15, 20, 25]
- High pass filter cutoff frequencies are all combinations of the LPF cutoff frequencies and the frequency gaps (36 different values)

Results

Exp 1: hybrid images of living things and non-living things (shark vs airplane)

low pass cutoff frequency $\sigma_{LPF} = 9$
high pass cutoff frequency $\sigma_{HPF} = 29$
viewing distance for low frequency component = 4 m
viewing distance for high frequency component = 10 cm
low frequency component is scale by a factor 0.8
high frequency component is scale by a factor 0.4

$(\sigma_{LPF} = 3, \sigma_{HPF} = 18)$

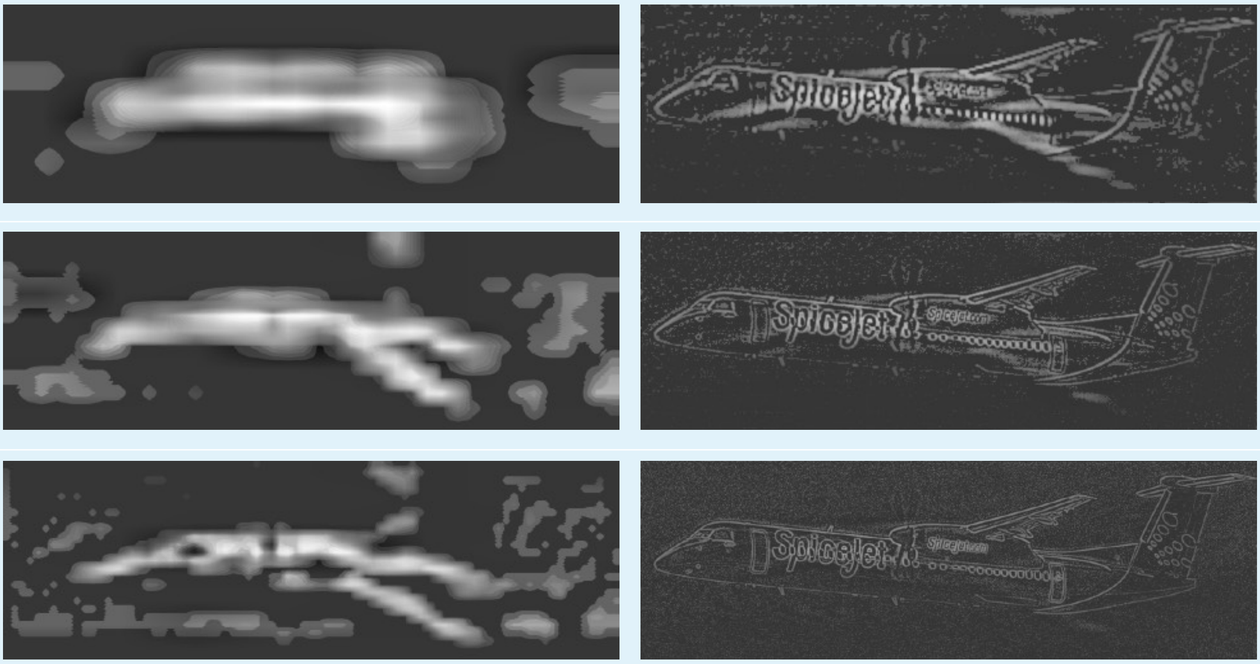
$(\sigma_{LPF} = 6, \sigma_{HPF} = 31)$

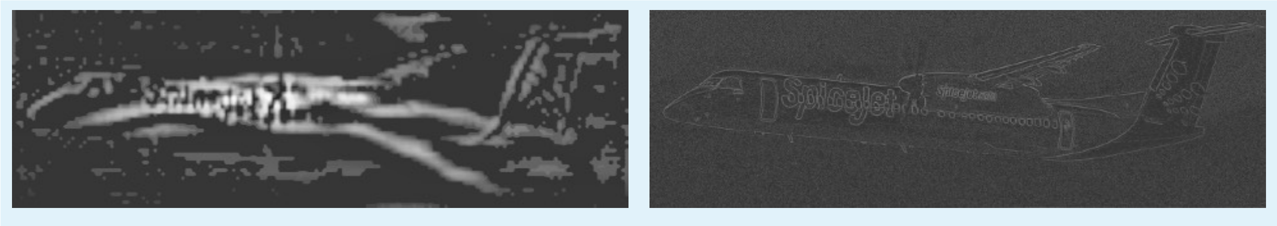
$(\sigma_{LPF} = 9,\ \sigma_{HPF} = 29)$

$(\sigma_{LPF} = 15,\ \sigma_{HPF} = 20)$

$(\sigma_{LPF} = 21,\ \sigma_{HPF} = 21)$

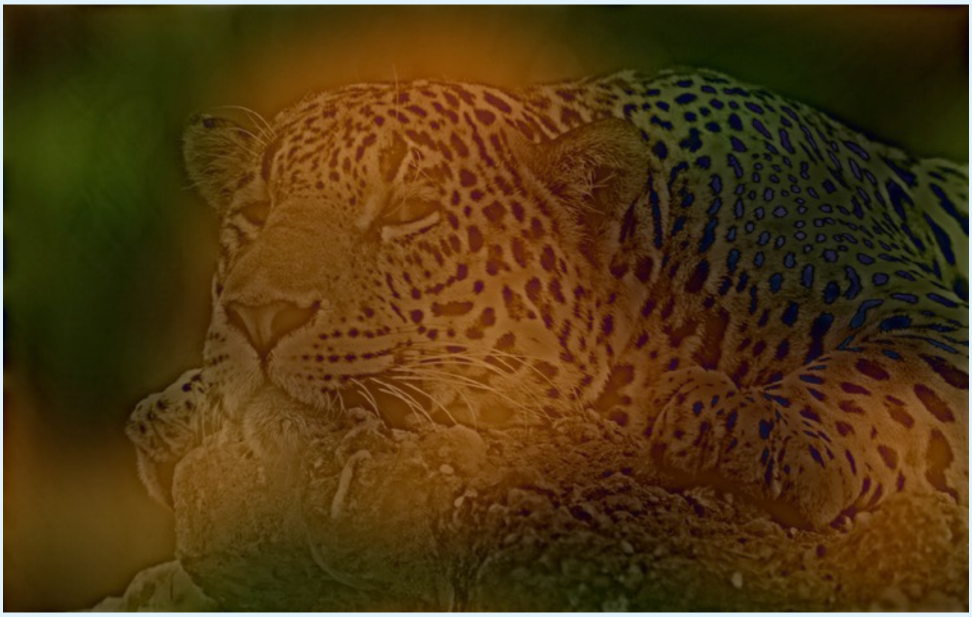
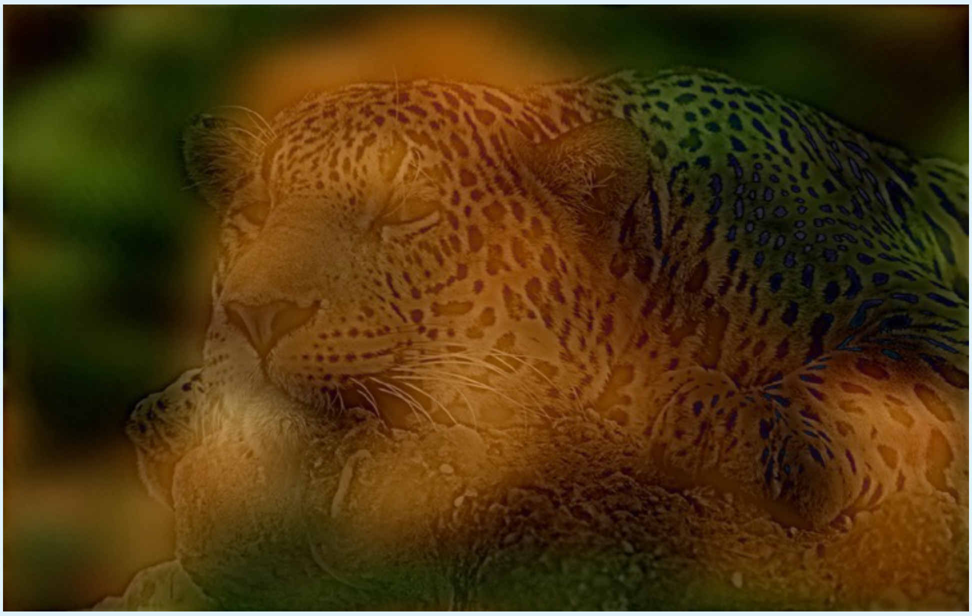
Laplacian Pyramid:





Exp 2: hybrid images of similar things (leopard vs lion)

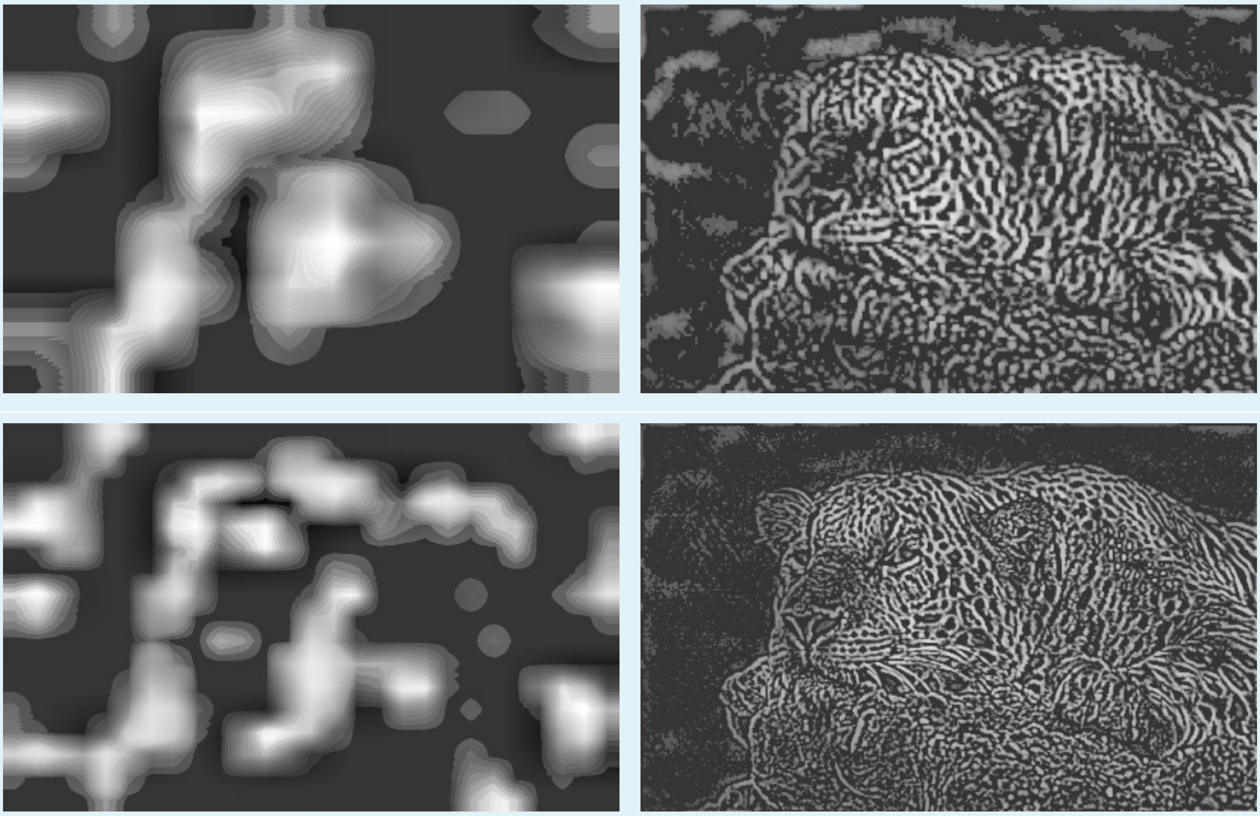
low pass cutoff frequency $\sigma_{LPF} = 9$
high pass cutoff frequency $\sigma_{HPF} = 29$
viewing distance for low frequency component = 4 m
viewing distance for high frequency component = 20 cm
low frequency component is scale by a factor 0.7
high frequency component is scale by a factor 0.3

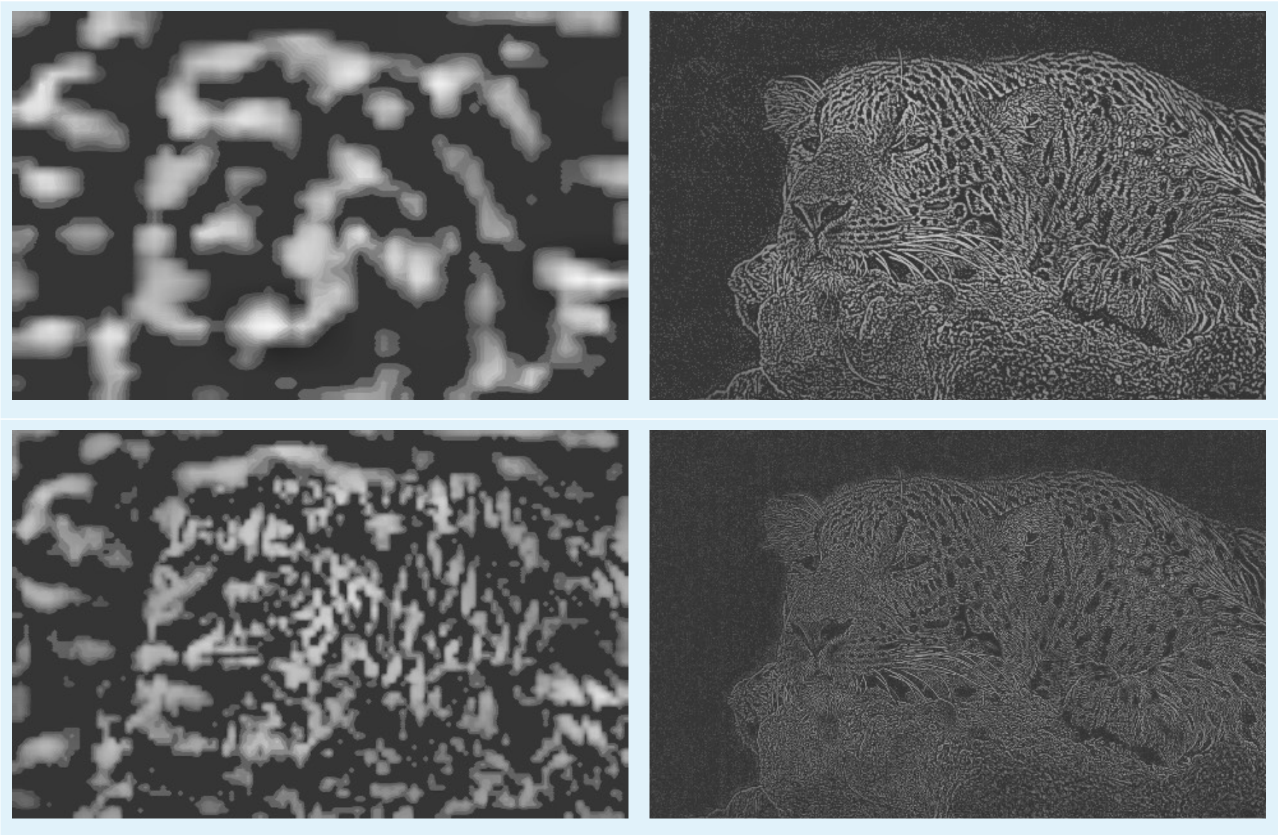
$(\sigma_{LPF} = 3, \sigma_{HPF} = 18)$	
$(\sigma_{LPF} = 6, \sigma_{HPF} = 31)$	

$(\sigma_{LPF} = 9,\ \sigma_{HPF} = 29)$	
$(\sigma_{LPF} = 15,\ \sigma_{HPF} = 20)$	

$(\sigma_{LPF} = 21, \sigma_{HPF} = 21)$

Laplacian Pyramid:

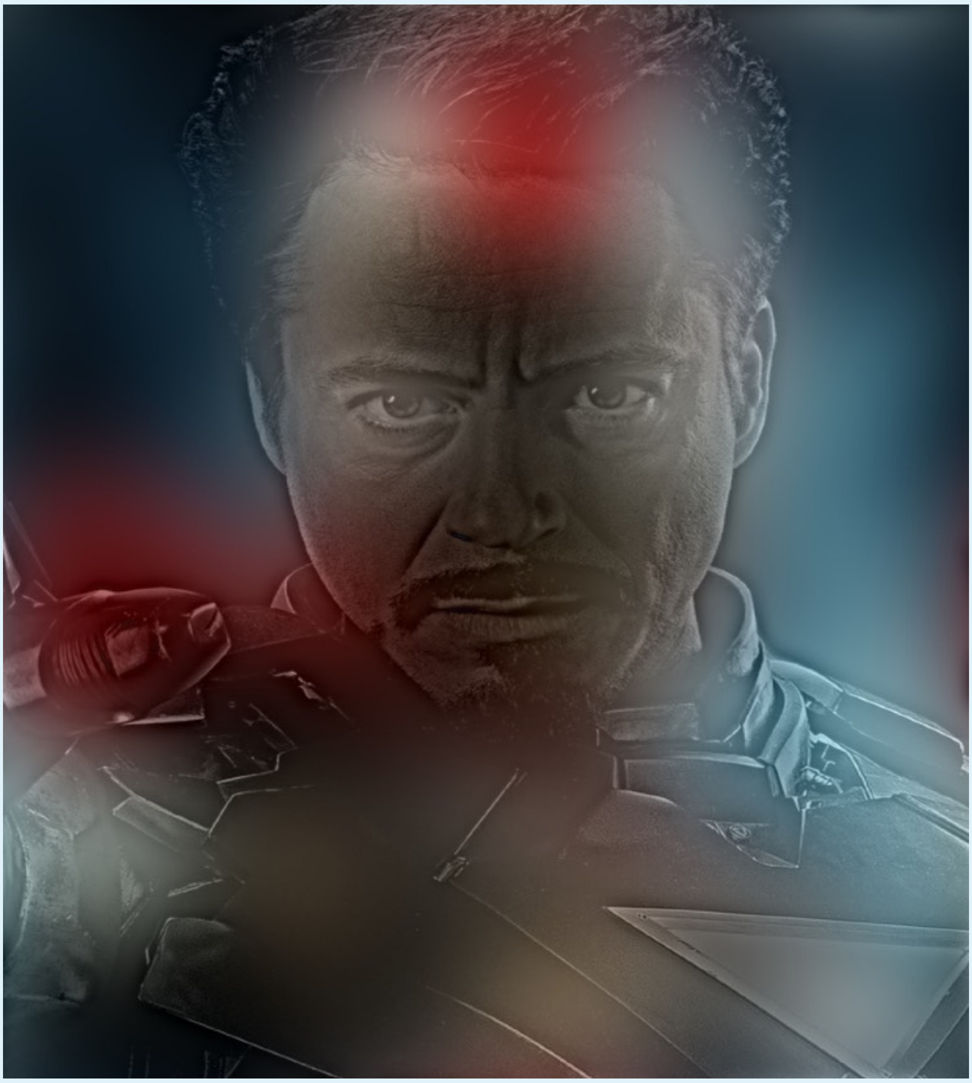




Exp 3: hybrid images of superhero and their costumes (iron man)

low pass cutoff frequency $\sigma_{LPF} = 9$
high pass cutoff frequency $\sigma_{HPF} = 24$
viewing distance for low frequency component = 5 m
viewing distance for high frequency component = 25 cm
low frequency component is scale by a factor 0.85
high frequency component is scale by a factor 0.5

$(\sigma_{LPF} = 3, \sigma_{HPF} = 18)$



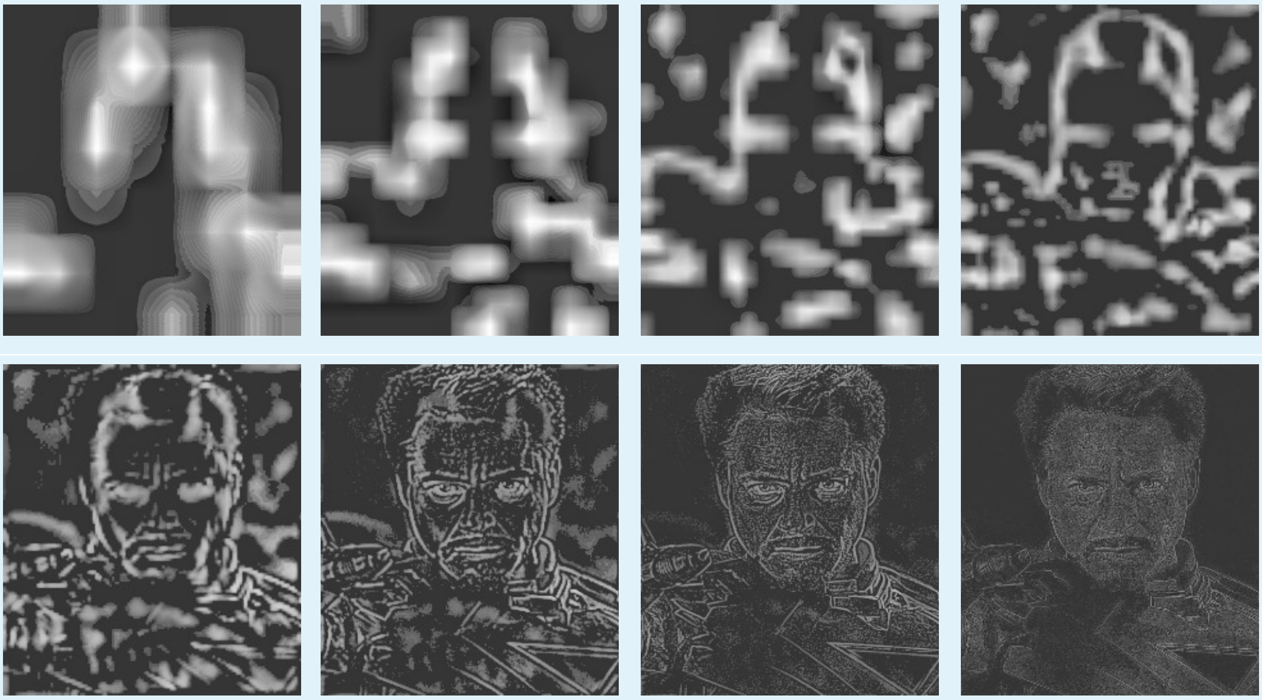
($\sigma_{LPF} = 6$, $\sigma_{HPF} = 31$)

($\sigma_{LPF} = 9$, $\sigma_{HPF} = 29$)

$(\sigma_{LPF} = 15, \sigma_{HPF} = 20)$

$(\sigma_{LPF} = 21, \sigma_{HPF} = 21)$

Laplacian Pyramid:



Exp 4: hybrid images of me and 彭于晏

low pass cutoff frequency $\sigma_{LPF} = 12$
high pass cutoff frequency $\sigma_{HPF} = 32$
viewing distance for low frequency component = 5.5 m
viewing distance for high frequency component = 35 cm
low frequency component is scale by a factor 0.7
high frequency component is scale by a factor 0.4

($\sigma_{LPF} = 3$, $\sigma_{HPF} = 18$)	

($\sigma_{LPF} = 6$, $\sigma_{HPF} = 31$)	

($\sigma_{LPF} = 9$, $\sigma_{HPF} = 29$)	

$(\sigma_{LPF} = 15, \sigma_{HPF} = 20)$

$(\sigma_{LPF} = 21, \sigma_{HPF} = 21)$

Laplacian Pyramid:

Future Work

1. The image preprocessing part can be done better. In this experiment, scaling and shifting are applied. It is possible to apply more complicate transformations on the images like rotation or some other affine transformations, or even use photoshop.
2. Avoid aliasing effect. As you can see in the Exp 4., there are some blue parts at the top of the hybrid image. It may be caused by the aliasing effect. I think there might be some work can be done to avoid this.
3. The ratio of high frequency component and low frequency component is also a problem. To find a good balance is not easy. And sometimes if the weights are too large, the hybrid image could overflow and some strange color would appear in the image as you can see in Exp 3 when both cutoff are set to 21.