hw2-my-hdr-stack-Copy1

October 4, 2022

[1]:
```
import numpy as np
import cv2
# import skimage
import matplotlib.pyplot as plt
import src.cp_hw2
# import src.cp_exr
```

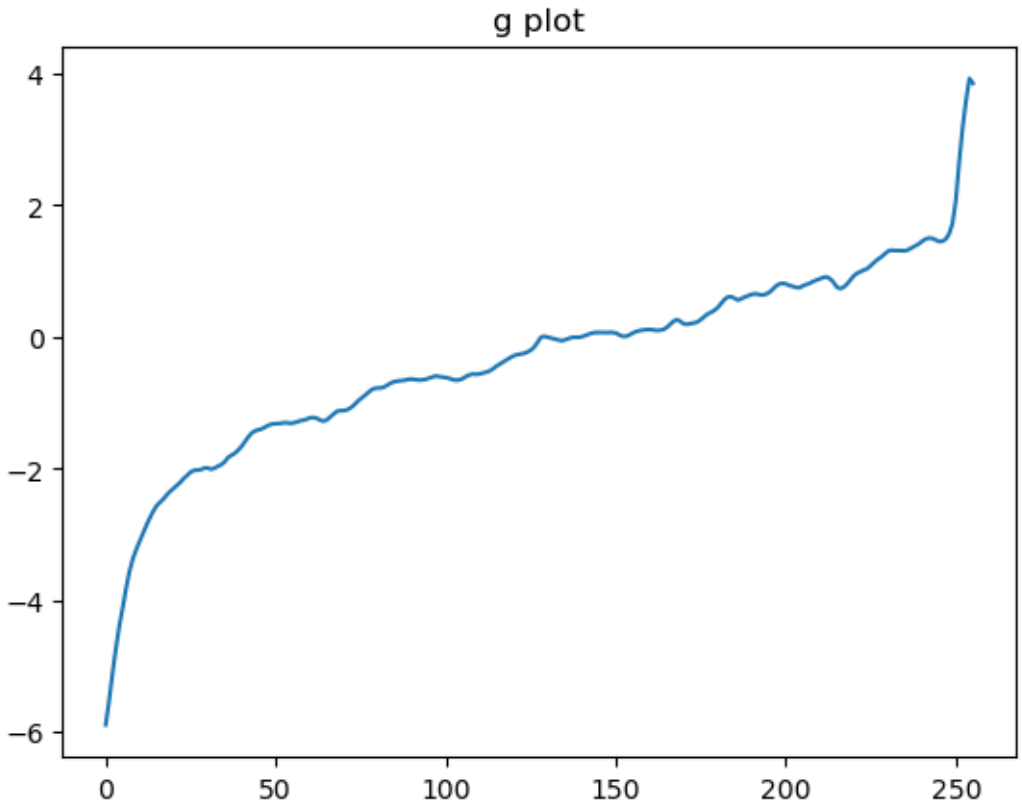
[2]:
```
# Q1.2) Linearize Rendered Images

# Read images
image_files = ['data/gphoto-exposure-stack-no-noise-reduction-myroom/
 ↪exposure'+str(i)+'.jpg' for i in range(1,17)]
images_stack_for_lin = []
for imf in image_files :
    img = plt.imread(imf)
    img = img[::200, ::200]
    images_stack_for_lin.append(img)
images_stack_for_lin = np.array(images_stack_for_lin)
images_stack_for_lin_reshaped = images_stack_for_lin.
 ↪reshape(images_stack_for_lin.shape[0],-1).swapaxes(0,1)
```

[3]:
```
# t_filler = lambda x : 2.0 ** (x-1-12)
# t = [t_filler(i) for i in range(1,19)]
t = [1/4000,1/2000,1/1000,1/500,1/250,1/125,1/60,1/30,1/15,1/8,1/4,1/
 ↪2,1,2,4,8,15,30]
# variable t used in general scope later on in the program
def get_g(images_stack_reshaped, images_stack, w, t, r_l=1, is_w_photon=False) :

    n = 256;
    A = np.zeros((images_stack_reshaped.shape[0]*images_stack_reshaped.
 ↪shape[1]+n+1,
                  n+images_stack_reshaped.shape[0]))
    b = np.zeros((A.shape[0],1))
    cur_row_A = 0
    for i in range(images_stack_reshaped.shape[0]) : # Corresponds to pixel in␣
 ↪image
```

```
        for j in range(images_stack_reshaped.shape[1]) : # Corresponds to image␣
 ↪in sequence
    #         wt_ij = 1 # placeholder
            if is_w_photon :
                wt_ij = w(images_stack_reshaped[i,j], t[j])
            else :
                wt_ij = w(images_stack_reshaped[i,j])
#             print(wt_ij)
            A[cur_row_A, images_stack_reshaped[i,j]] = wt_ij
            A[cur_row_A, n+i-1] = -wt_ij
            b[cur_row_A, 0] = wt_ij * np.log(t[j])
            cur_row_A = cur_row_A + 1

    # Adding the terms corresponding to the smoothing regularization
    for i in range(n) :
        if is_w_photon :
            wt_i = 1
        else :
            wt_i = w(i)
        A[cur_row_A,i-1] = r_l * wt_i
        A[cur_row_A,i] = -2*r_l*wt_i
        A[cur_row_A,i+1] = r_l*wt_i
        cur_row_A += 1

    # Normalize the curve by setting its middle value to 0
    A[cur_row_A,128] = 1 # Corresponds to g128 in g0-g255

    v = np.linalg.lstsq(A, b, rcond=None)
#     print(v)
    v_sol = v[0]
    g = v_sol[:n]
#     L = v_sol[n:]
#     L = L.reshape(images_stack.shape[1], images_stack.shape[2], images_stack.
 ↪shape[3])

    return g

w = lambda x, zmin=0.05, zmax=0.95 : 0.01
g = get_g(images_stack_for_lin_reshaped, images_stack_for_lin, w, t, 10)
```

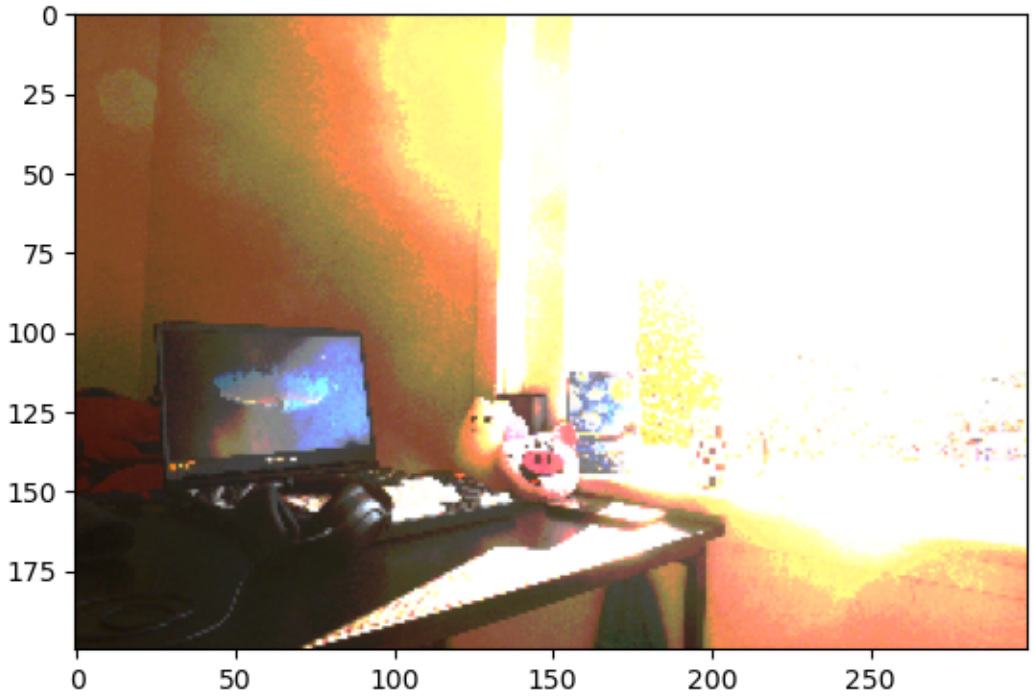
[6]:
```
# Plotting g
plt.plot(np.arange(0,256),g)
plt.title('g plot')
plt.show()
# Linearizing the image
# The other image is too small to make sense of, so looking at a larger image
images_stack = []
```

```
for imf in image_files :
    img = plt.imread(imf)
    img = img[::20, ::20]
    images_stack.append(img)
images_stack = np.array(images_stack)

def linearize_image(images_stack, g) :
    lin_images_stack = np.exp(g[images_stack])
    lin_images_stack = lin_images_stack.squeeze(-1)
    return lin_images_stack

lin_images_stack = linearize_image(images_stack, g)
plt.imshow(lin_images_stack[8])
# display_hdr_image(lin_images_stack[8],0.05)
```




```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

[6]: <matplotlib.image.AxesImage at 0x7f9e07a95de0>



[7]:
```
# Q1.3) Merge exposure stack into HDR image (30 points)
# We've already loaded .jpg images. Lets load .tiff images as well.
image_files_tiff = ['data/gphoto-exposure-stack-no-noise-reduction-myroom/
 ↪exposure'+str(i)+'.tiff' for i in range(1,17)]
images_stack_tiff = []
for imf in image_files_tiff :
#     img = plt.imread(imf)
    # TO CHANGE TODOOOOO
    img = cv2.imread(imf, -1)
    img = img[...,::-1]
    img = img[::5, ::5]
    images_stack_tiff.append(img)
images_stack_tiff = np.array(images_stack_tiff)
```

[8]:
```
images_stack_normalized = images_stack / 255.0
images_stack_tiff_normalized = images_stack_tiff / (2**16 - 1)
#
# Over-exposure vs under-exposed pixel selection is still off. Fix later!
def linear_merging(im_s, lin_im_s, t, w_v, is_w_photon=False) :

    I_hdr_num = np.zeros(im_s[0].shape)
    I_hdr_den = np.zeros(im_s[0].shape)
    for k in range(len(im_s)) :
        if is_w_photon :
```

```
            if np.max(lin_im_s) > 256 :
                w_v_imk = w_v(im_s[k],t[k],0.0001, 0.995)
            else :
                w_v_imk = w_v(im_s[k],t[k],0.00001, 0.92)
        else :
            if np.max(lin_im_s) > 256 :
                w_v_imk = w_v(im_s[k], 0.02, 0.98)
            else :
                w_v_imk = w_v(im_s[k])
        I_hdr_num += (w_v_imk * lin_im_s[k] / t[k] )
        I_hdr_den += (w_v_imk)

    I_hdr = I_hdr_num / I_hdr_den

    # where num is zero, hdr final should also be zero
    I_hdr_num_zero = np.where(I_hdr_num == 0)
    if len(I_hdr_num_zero) == 3 :
        I_hdr_num_zero = np.vstack((np.
↪vstack((I_hdr_num_zero[0],I_hdr_num_zero[1])), I_hdr_num_zero[2])).T
    else :
        I_hdr_num_zero = np.vstack((I_hdr_num_zero[0],I_hdr_num_zero[1])).T


    # where num is not zero, but den is zero, all hdr final values should be␣
↪max val
    I_hdr_den_zero = np.where(I_hdr_den == 0)
    if len(I_hdr_den_zero) == 3 :
        I_hdr_den_zero = np.vstack((np.
↪vstack((I_hdr_den_zero[0],I_hdr_den_zero[1])), I_hdr_den_zero[2])).T
    else :
        I_hdr_den_zero = np.vstack((I_hdr_den_zero[0],I_hdr_den_zero[1])).T

    I_hdr_max_val = []

    if I_hdr_num_zero.size > 0 :
        if len(I_hdr.shape) == 3 :
            I_hdr[I_hdr_num_zero[:,0],I_hdr_num_zero[:,1],I_hdr_num_zero[:,2]]␣
↪= 0
        else :
            I_hdr[I_hdr_num_zero[:,0],I_hdr_num_zero[:,1]] = 0

    if I_hdr_den_zero.size > 0 :
        for index in I_hdr_den_zero :
            if len(I_hdr.shape) == 3 :
                if I_hdr_num[index[0],index[1],index[2]] != 0 :
                    I_hdr_max_val.append(index)
            else :
```

```
                if I_hdr_num[index[0],index[1]] != 0 :
                    I_hdr_max_val.append(index)
        I_hdr_max_val = np.array(I_hdr_max_val)
        if I_hdr_max_val.size > 0 :
            I_hdr_max_val = np.stack(I_hdr_max_val)
            if len(I_hdr.shape) == 3 :
                I_hdr[I_hdr_max_val[:,0],I_hdr_max_val[:,1],I_hdr_max_val[:,2]]␣
 ↪= np.nanmax(I_hdr)
            else :
                I_hdr[I_hdr_max_val[:,0],I_hdr_max_val[:,1]] = np.nanmax(I_hdr)

    return I_hdr

def linear_merging_channelwise(im_s, lin_im_s, t, w_v, is_w_photon=False) :

    I_hdr = np.zeros(im_s[0].shape)
    I_hdr[...,0] = linear_merging(im_s[...,0], lin_im_s[...,0], t, w_v,␣
 ↪is_w_photon)
    I_hdr[...,1] = linear_merging(im_s[...,1], lin_im_s[...,1], t, w_v,␣
 ↪is_w_photon)
    I_hdr[...,2] = linear_merging(im_s[...,2], lin_im_s[...,2], t, w_v,␣
 ↪is_w_photon)

    return I_hdr

def log_merging(im_s, lin_im_s, t, w_v, is_w_photon=False) :

    eps = 1e-8
    I_hdr_num = np.zeros(im_s[0].shape)
    I_hdr_den = np.zeros(im_s[0].shape)
    for k in range(len(im_s)) :

        if is_w_photon :
            if np.max(lin_im_s) > 256 :
                w_v_imk = w_v(im_s[k],t[k],0.0001, 0.995)
            else :
                w_v_imk = w_v(im_s[k],t[k],0.00001, 0.92)
        else :
            if np.max(lin_im_s) > 256 :
                w_v_imk = w_v(im_s[k], 0.02, 0.98)
            else :
                w_v_imk = w_v(im_s[k])
        I_hdr_num += ( w_v_imk * ( np.log(lin_im_s[k] + eps) - np.log(t[k])))
        I_hdr_den += w_v_imk

    I_hdr = I_hdr_num / I_hdr_den
    # where num is zero, hdr final should also be zero (regardless of den)
```

```
    I_hdr_num_zero = np.where(I_hdr_num == 0)
    I_hdr_num_zero = np.vstack((np.
 ↪vstack((I_hdr_num_zero[0],I_hdr_num_zero[1])), I_hdr_num_zero[2])).T

    # where num is not zero, but den is zero, all hdr final values should be␣
 ↪max val
    I_hdr_den_zero = np.where(I_hdr_den == 0)
    I_hdr_den_zero = np.vstack((np.
 ↪vstack((I_hdr_den_zero[0],I_hdr_den_zero[1])), I_hdr_den_zero[2])).T
    I_hdr_max_val = []

    if I_hdr_num_zero.size > 0 :
        I_hdr[I_hdr_num_zero[:,0],I_hdr_num_zero[:,1],I_hdr_num_zero[:,2]] = 0

    if I_hdr_den_zero.size > 0 :
        for index in I_hdr_den_zero :
            if I_hdr_num[index[0],index[1],index[2]] != 0 :
                I_hdr_max_val.append(index)
        I_hdr_max_val = np.array(I_hdr_max_val).T
        if I_hdr_max_val.size > 0 :
            I_hdr_max_val = np.stack(I_hdr_max_val)
            I_hdr[I_hdr_max_val[:,0],I_hdr_max_val[:,1],I_hdr_max_val[:,2]] =␣
 ↪np.nanmax(I_hdr)

    return np.exp(I_hdr)

# setting w for merging testing
# w_v = np.vectorize(w)

# I_hdr_lin_merged = linear_merging(images_stack_normalized, lin_images_stack,␣
 ↪t, w_v)
# I_hdr_tiff_lin_merged = linear_merging(images_stack_tiff_normalized,␣
 ↪images_stack_tiff, t, w_v)

# I_hdr_log_merged = log_merging(images_stack_normalized, lin_images_stack, t,␣
 ↪w_v)
# I_hdr_tiff_log_merged = log_merging(images_stack_tiff_normalized,␣
 ↪images_stack_tiff, t, w_v)

# src.cp_hw2.writeHDR('I_jpg_lin_merged.HDR', I_hdr_lin_merged)
# src.cp_hw2.writeHDR('I_tiff_lin_merged.HDR', I_hdr_tiff_lin_merged)

# src.cp_hw2.writeHDR('I_jpg_log_merged.HDR', I_hdr_log_merged)
# src.cp_hw2.writeHDR('I_tiff_log_merged.HDR', I_hdr_tiff_log_merged)
```

[31]:
```
# Weighting Schemes
def w_uniform(z, Z_min = 0.05, Z_max=0.95) :
    if isinstance(z,np.uint8) or isinstance(z,int):
        z = z / 255.0
    if Z_min <= z <= Z_max :
        return 1
    return 0

def w_tent(z, Z_min = 0.001, Z_max=0.999) :
    if isinstance(z,np.uint8) or isinstance(z,int) :
        z = z / 255.0
    Z_min = 0.001
    Z_max = 0.995
    if Z_min <= z <= Z_max :
        return np.min([z, 1.0-z])
    return 0

def w_gaussian(z, Z_min = 0.001, Z_max=0.999) :
    if isinstance(z,np.uint8) or isinstance(z,int):
        z = z / 255.0
    Z_min = 0.001
    Z_max = 0.999
    if Z_min <= z <= Z_max :
        return np.exp(-4 * (((z-0.5)**2) / ((0.5)**2)))
    return 0

def w_photon(z, tk, Z_min = 0.05, Z_max=0.95) :
# for tiff
#         Z_min = 0.0001
#         Z_max = 0.995
# # for jpeg
#         Z_min = 0.00001
#         Z_max = 0.92

    if isinstance(z,np.uint8) or isinstance(z,int):
        z = z / 255.0
    if Z_min <= z <= Z_max :
        return tk
    return 0
```

[32]:
```
# HDR display util functions
def linear_scaling(img_cc, scale, should_plot=False):
#     img_scaled = np.clip(skimage.color.rgb2gray(img_cc) * scale, 0, 1)
    img_scaled = np.clip(img_cc * scale, 0, 1)
    if should_plot :
        plt.imshow(img_scaled)
```

```
        plt.title('linear scaling')
        plt.show()
    return img_scaled

# Gamma Encoding
def gamma_encoding(val) :
    if val <= 0.0031308 :
        return 12.92 * val
    else :
        return (1+0.055) * np.power(val, 1/2.4) - 0.055

def display_hdr_image(img, scale, title='', should_plot=True) :
    img_scaled = linear_scaling(img, scale)
    ge_f = np.vectorize(gamma_encoding)
    image_ge = ge_f(img_scaled)
    if should_plot :
        plt.imshow(image_ge)
        plt.title(title)
        plt.show()
    return image_ge
```

[28]:
```
w_uniform_vectorized = np.vectorize(w_uniform)
w_tent_vectorized = np.vectorize(w_tent)
w_gaussian_vectorized = np.vectorize(w_gaussian)
w_photon_vectorized = np.vectorize(w_photon)

# Creating all merged raw images
I_hdr_tiff_lin_merged_w_uniform = linear_merging(images_stack_tiff_normalized,␣
 ↪images_stack_tiff, t, w_uniform_vectorized)
I_hdr_tiff_lin_merged_w_uniform_channelwise =␣
 ↪linear_merging_channelwise(images_stack_tiff_normalized, images_stack_tiff,␣
 ↪t, w_uniform_vectorized)
I_hdr_tiff_log_merged_w_uniform = log_merging(images_stack_tiff_normalized,␣
 ↪images_stack_tiff, t, w_uniform_vectorized)

I_hdr_tiff_lin_merged_w_tent = linear_merging(images_stack_tiff_normalized,␣
 ↪images_stack_tiff, t, w_tent_vectorized)
I_hdr_tiff_log_merged_w_tent = log_merging(images_stack_tiff_normalized,␣
 ↪images_stack_tiff, t, w_tent_vectorized)

I_hdr_tiff_lin_merged_w_gaussian = linear_merging(images_stack_tiff_normalized,␣
 ↪images_stack_tiff, t, w_gaussian_vectorized)
I_hdr_tiff_log_merged_w_gaussian = log_merging(images_stack_tiff_normalized,␣
 ↪images_stack_tiff, t, w_gaussian_vectorized)
```

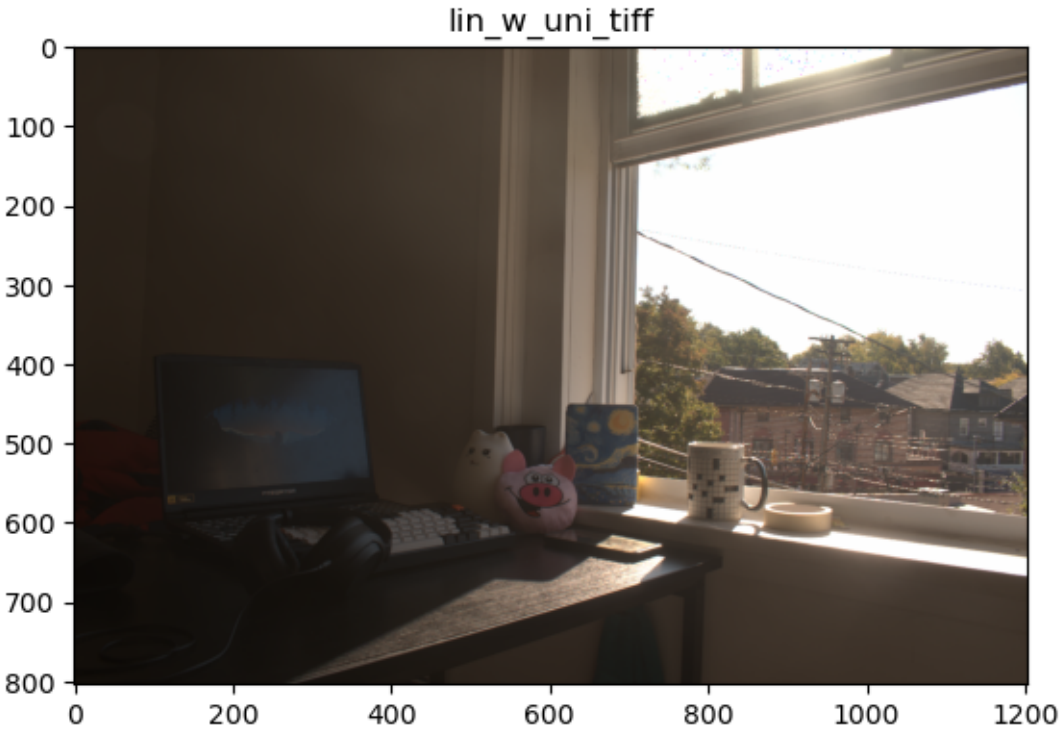
```
I_hdr_tiff_lin_merged_w_photon = linear_merging(images_stack_tiff_normalized,␣
 ↪images_stack_tiff, t, w_photon_vectorized, is_w_photon=True)
I_hdr_tiff_log_merged_w_photon = log_merging(images_stack_tiff_normalized,␣
 ↪images_stack_tiff, t, w_photon_vectorized, is_w_photon=True)
```

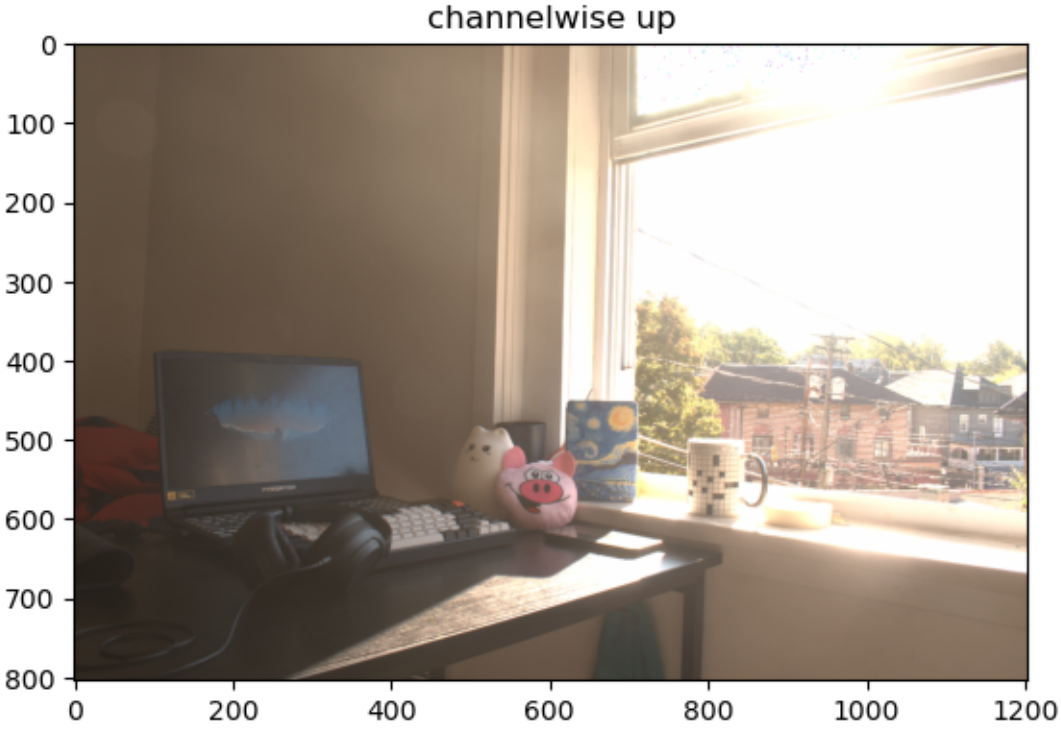
[29]:
```
# # Creating all merged jpeg images

g_uniform = get_g(images_stack_for_lin_reshaped, images_stack_for_lin,␣
 ↪w_uniform_vectorized,t, 10)
g_tent = get_g(images_stack_for_lin_reshaped, images_stack_for_lin,␣
 ↪w_tent_vectorized,t, 10)
g_gaussian = get_g(images_stack_for_lin_reshaped, images_stack_for_lin,␣
 ↪w_gaussian_vectorized,t, 10)
g_photon = get_g(images_stack_for_lin_reshaped, images_stack_for_lin,␣
 ↪w_photon_vectorized,t, 10, is_w_photon=True)

lin_images_stack_uniform = linearize_image(images_stack, g_uniform)
lin_images_stack_tent = linearize_image(images_stack, g_tent)
lin_images_stack_gaussian = linearize_image(images_stack, g_gaussian)
lin_images_stack_photon = linearize_image(images_stack, g_photon)

I_hdr_jpeg_lin_merged_w_uniform = linear_merging(images_stack_normalized,␣
 ↪lin_images_stack_uniform, t, w_uniform_vectorized)
I_hdr_jpeg_log_merged_w_uniform = log_merging(images_stack_normalized,␣
 ↪lin_images_stack_uniform, t, w_uniform_vectorized)

I_hdr_jpeg_lin_merged_w_tent = linear_merging(images_stack_normalized,␣
 ↪lin_images_stack_tent, t, w_tent_vectorized)
I_hdr_jpeg_log_merged_w_tent = log_merging(images_stack_normalized,␣
 ↪lin_images_stack_tent, t, w_tent_vectorized)

I_hdr_jpeg_lin_merged_w_gaussian = linear_merging(images_stack_normalized,␣
 ↪lin_images_stack_gaussian, t, w_gaussian_vectorized)
I_hdr_jpeg_log_merged_w_gaussian = log_merging(images_stack_normalized,␣
 ↪lin_images_stack_gaussian, t, w_gaussian_vectorized)

I_hdr_jpeg_lin_merged_w_photon = linear_merging(images_stack_normalized,␣
 ↪lin_images_stack_photon, t, w_photon_vectorized, is_w_photon=True)
I_hdr_jpeg_log_merged_w_photon = log_merging(images_stack_normalized,␣
 ↪lin_images_stack_photon, t, w_photon_vectorized, is_w_photon=True)
```

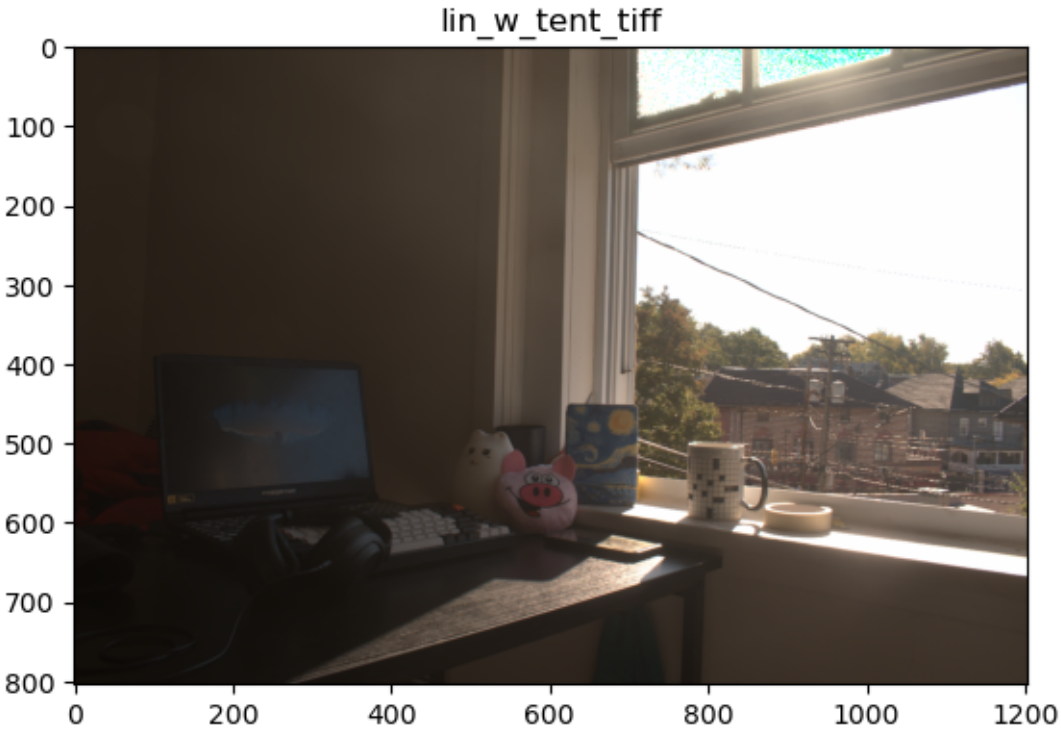
```
/tmp/ipykernel_5075/2109691339.py:23: RuntimeWarning: invalid value encountered
in divide
  I_hdr = I_hdr_num / I_hdr_den
/tmp/ipykernel_5075/2109691339.py:95: RuntimeWarning: invalid value encountered
in divide
```

```
    I_hdr = I_hdr_num / I_hdr_den
```

[33]:
```
# Displaying images
# Displaying RAW source generated images
_ = display_hdr_image(I_hdr_tiff_lin_merged_w_uniform,0.
↪0000004,'lin_w_uni_tiff')
_ = display_hdr_image(I_hdr_tiff_lin_merged_w_uniform_channelwise, 0.000002,␣
↪'channelwise up')
_ = display_hdr_image(I_hdr_tiff_lin_merged_w_tent,0.0000004,'lin_w_tent_tiff')
_ = display_hdr_image(I_hdr_tiff_lin_merged_w_gaussian,0.
↪0000004,'lin_w_gaussian_tiff')
_ = display_hdr_image(I_hdr_tiff_lin_merged_w_photon,0.
↪0000004,'lin_w_photon_tiff')

_ = display_hdr_image(I_hdr_tiff_log_merged_w_uniform,0.
↪0000006,'log_w_uni_tiff')
_ = display_hdr_image(I_hdr_tiff_log_merged_w_tent,0.0000006,'log_w_tent_tiff')
_ = display_hdr_image(I_hdr_tiff_log_merged_w_gaussian,0.
↪0000006,'log_w_gaussian_tiff')
_ = display_hdr_image(I_hdr_tiff_log_merged_w_photon,0.
↪0000006,'log_w_photon_tiff')

# Displaying JPEG source generated images

_ = display_hdr_image(I_hdr_jpeg_lin_merged_w_uniform,0.002,'lin_w_uni_jpeg')
_ = display_hdr_image(I_hdr_jpeg_lin_merged_w_tent,0.002,'lin_w_tent_jpeg')
_ = display_hdr_image(I_hdr_jpeg_lin_merged_w_gaussian,0.
↪002,'lin_w_gaussian_jpeg')
_ = display_hdr_image(I_hdr_jpeg_lin_merged_w_photon,0.002,'lin_w_photon_jpeg')

_ = display_hdr_image(I_hdr_jpeg_log_merged_w_uniform,0.002,'log_w_uni_jpeg')
_ = display_hdr_image(I_hdr_jpeg_log_merged_w_tent,0.002,'log_w_tent_jpeg')
_ = display_hdr_image(I_hdr_jpeg_log_merged_w_gaussian,0.
↪002,'log_w_gaussian_jpeg')
_ = display_hdr_image(I_hdr_jpeg_log_merged_w_photon,0.002,'log_w_photon_jpeg')

print('log with gaussian and tent hyper params, zmin and zmax need to be tuned,␣
↪but we are happy with some of the other images so we arent going down this␣
↪route.' )
print('lin_w_uni_tiff and lin_w_photon_tiff are the two best images, out of␣
↪which the uniform weighing scheme image is picked.')
print('lin_w_uni_jpeg and lin_w_photon_jpeg come right after these only because␣
↪the colors seem too highlighty near the lights.')
```


lin_w_uni_tiff
0
100
200
300
400
500
600
700
800
0
200
400
600
800
1000
1200


channelwise up
0
100
200
300
400
500
600
700
800
0
200
400
600
800
1000
1200


lin_w_tent_tiff
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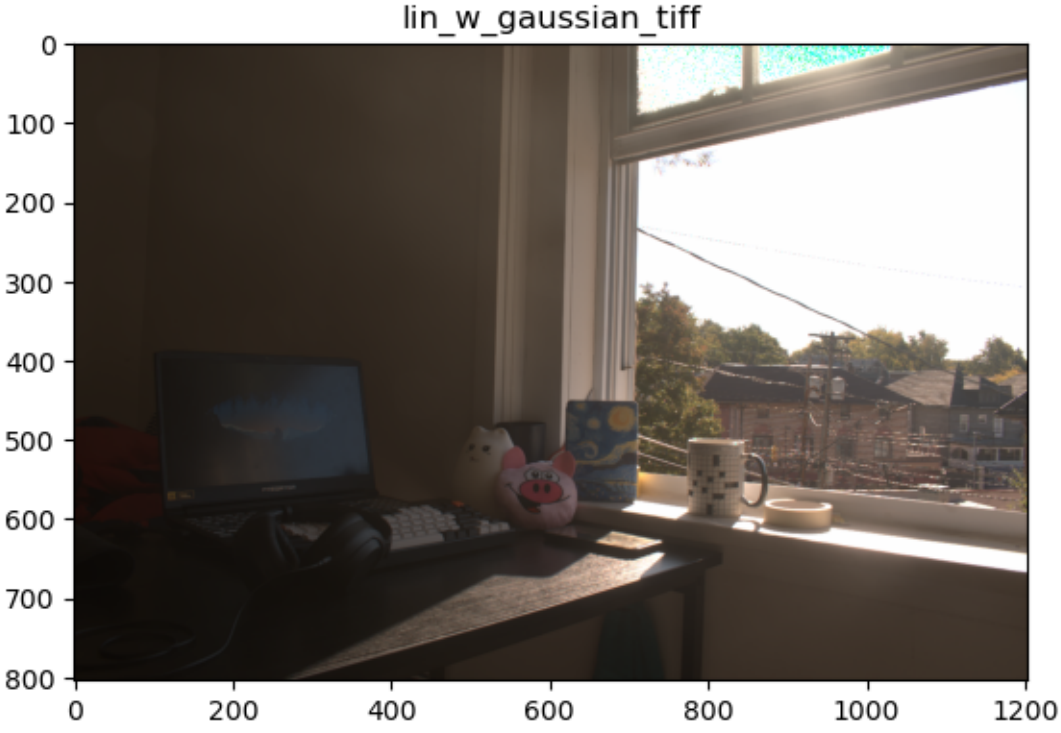
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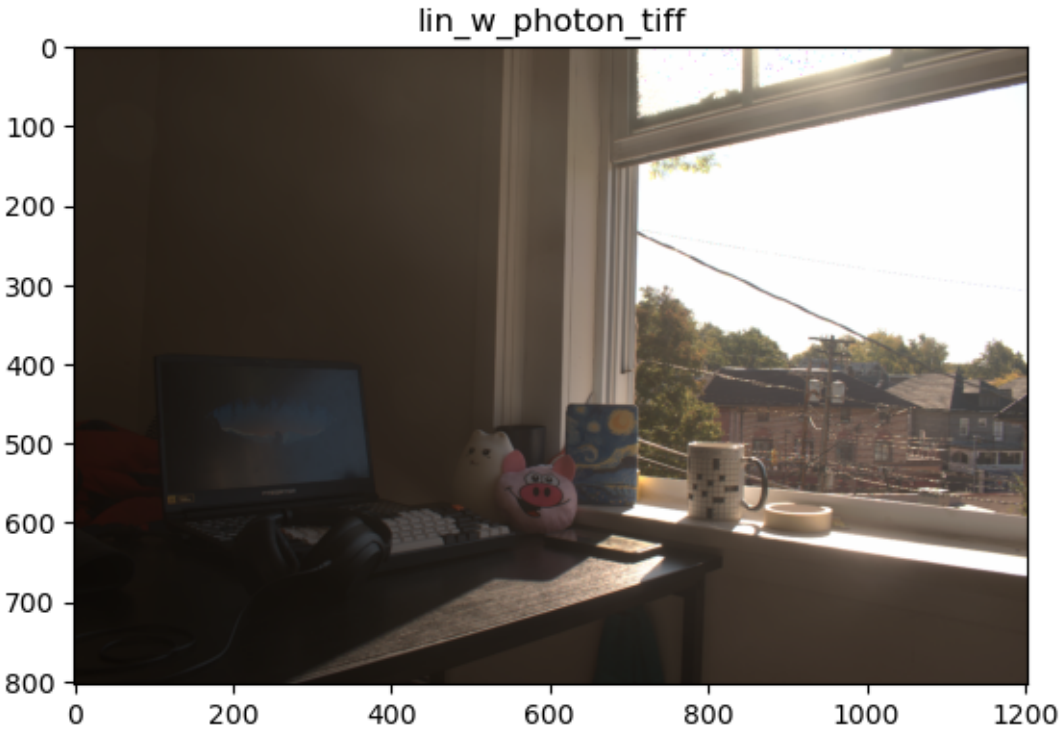
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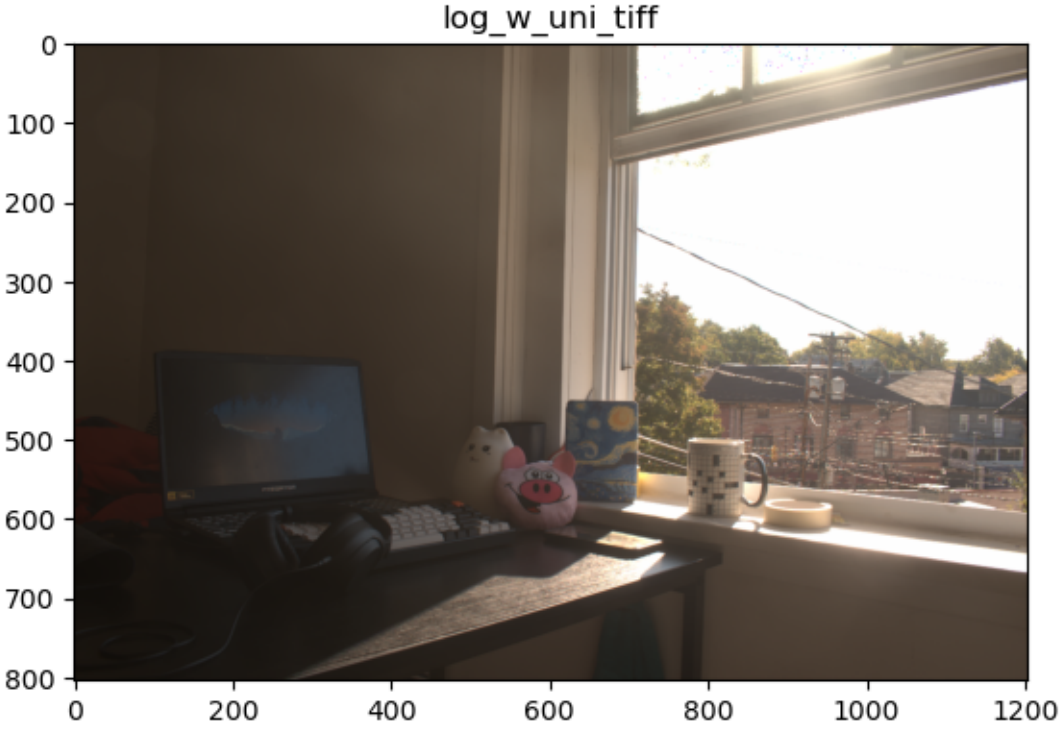
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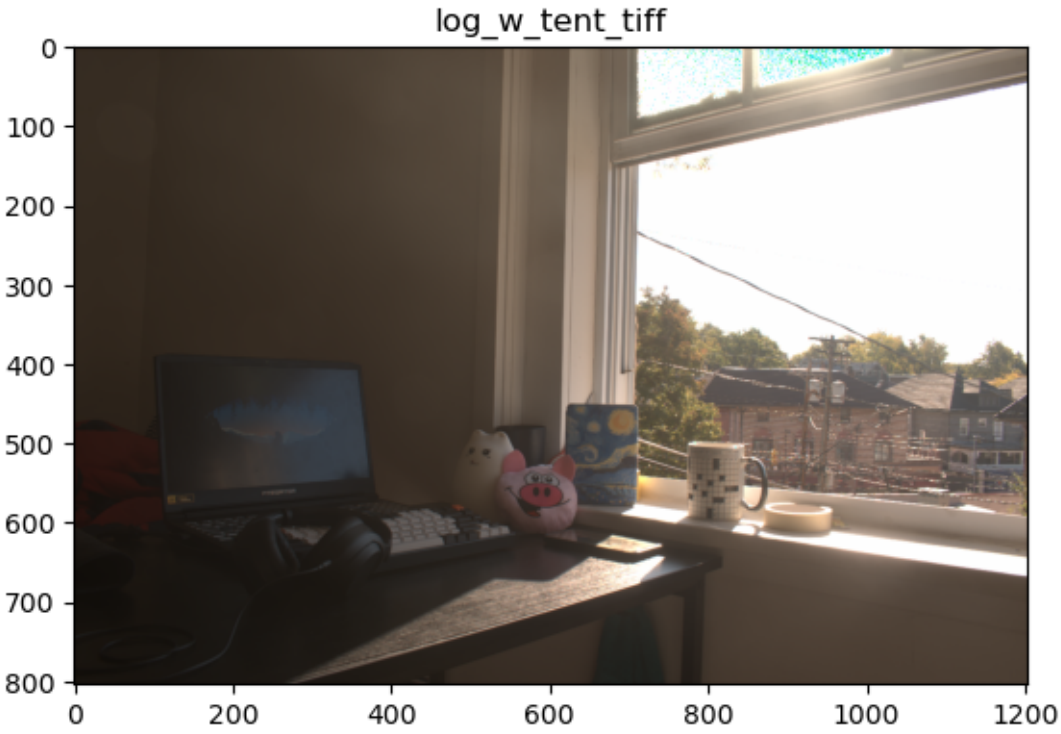
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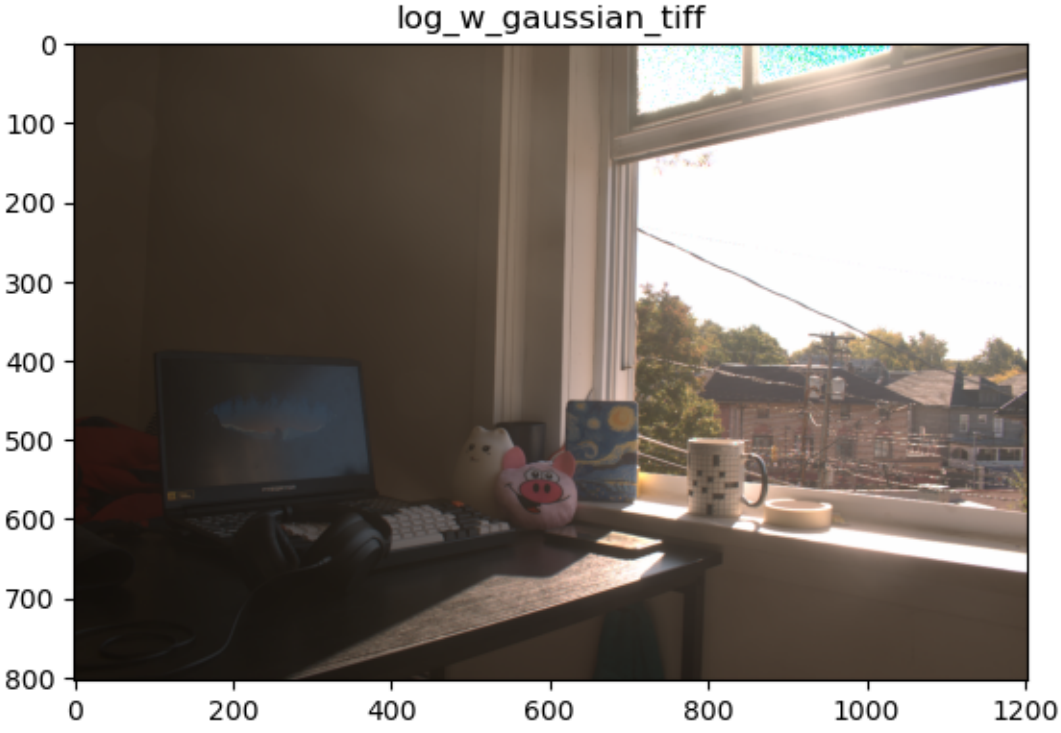
log_w_gaussian_tiff
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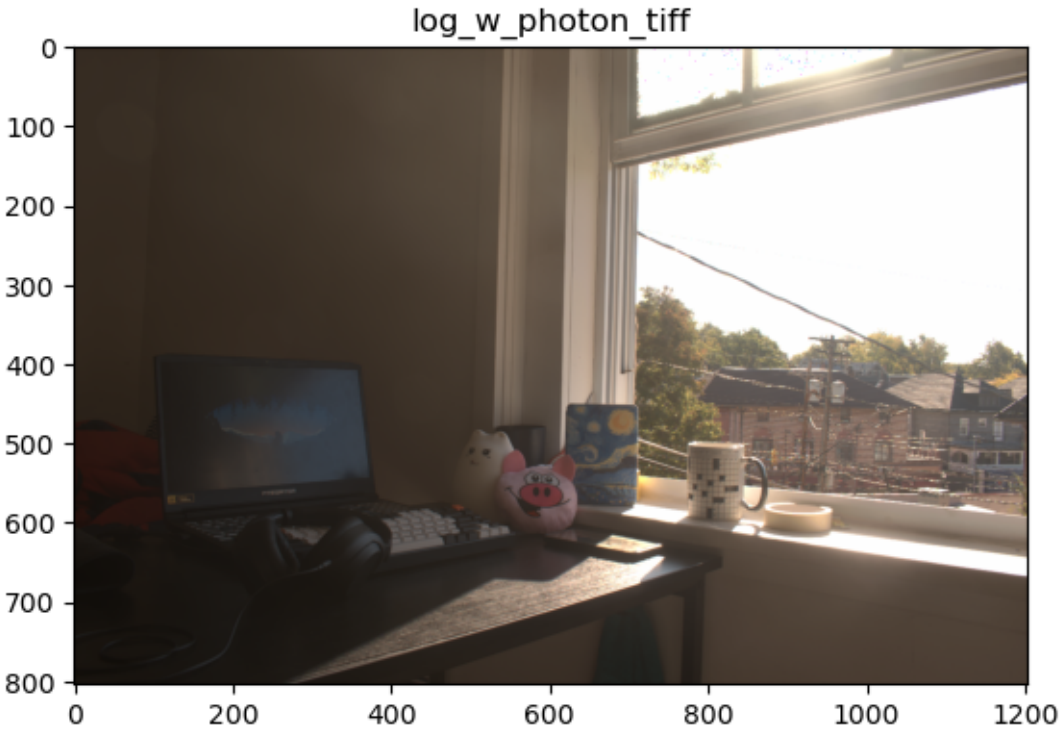
log_w_photon_tiff
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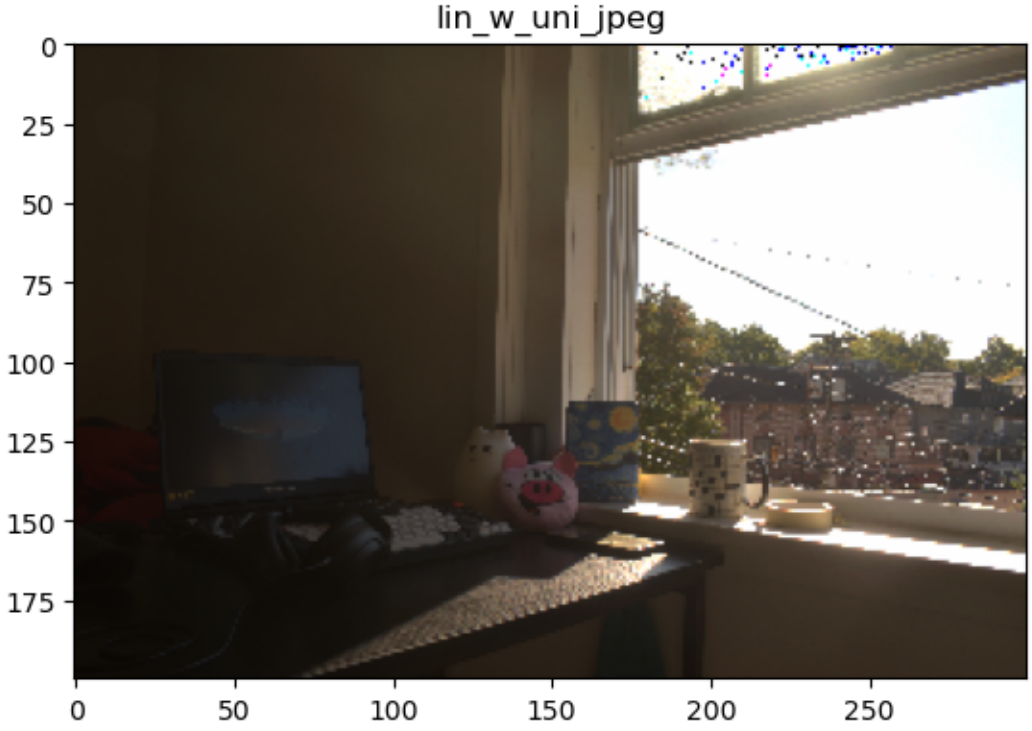
lin_w_uni_jpeg
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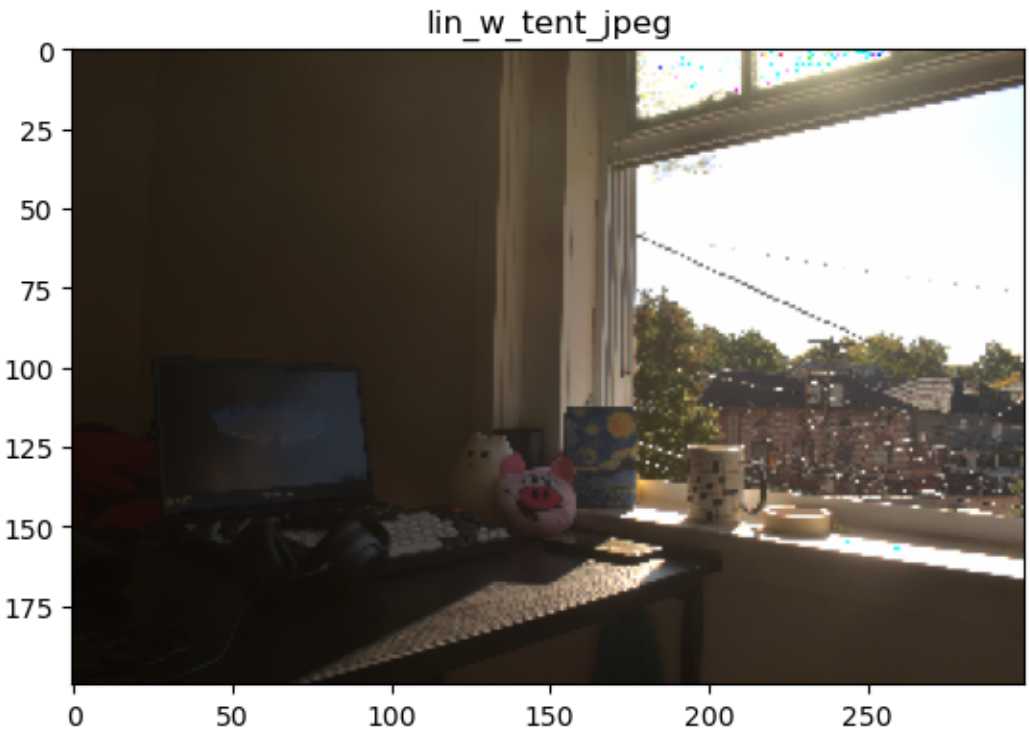
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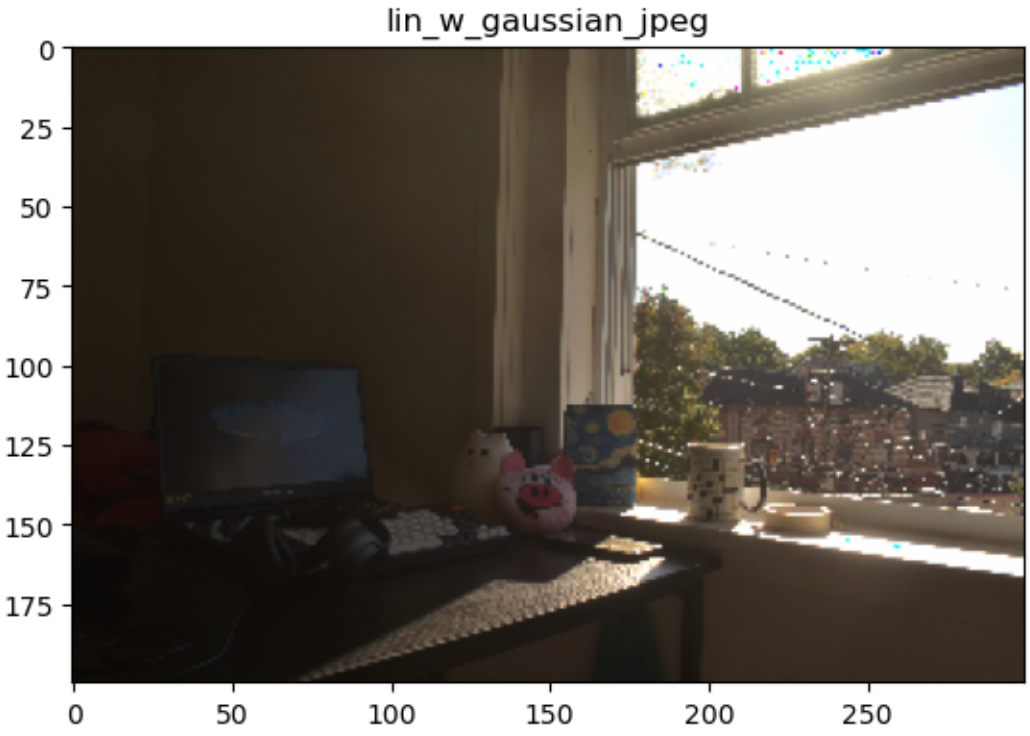
lin_w_gaussian_jpeg
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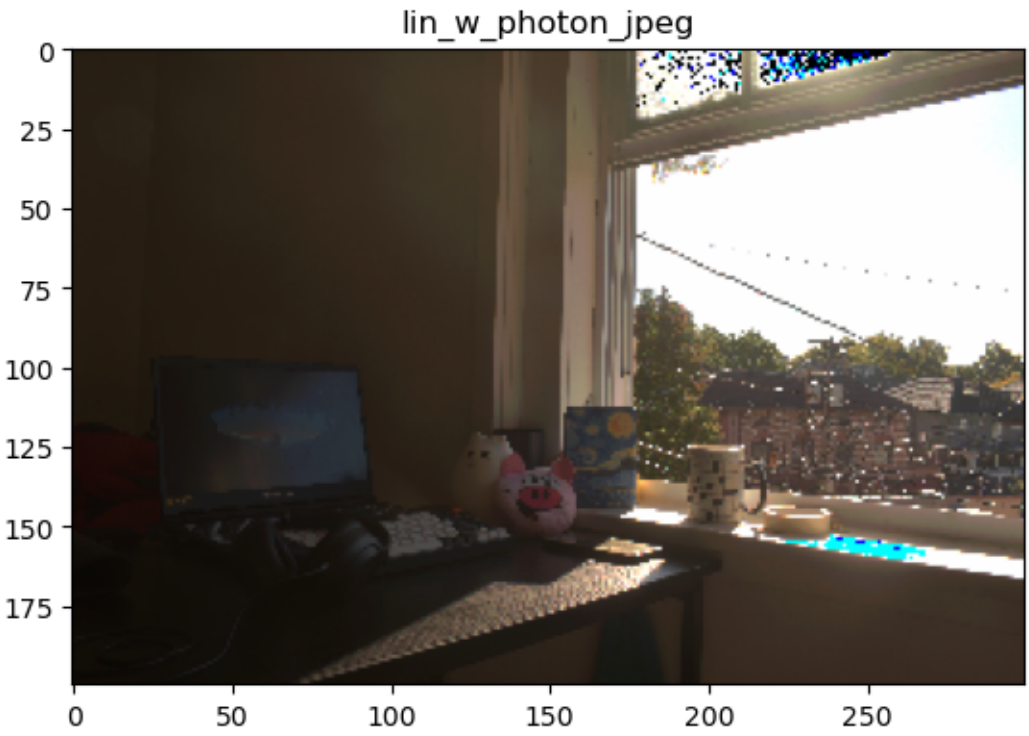
lin_w_photon_jpeg
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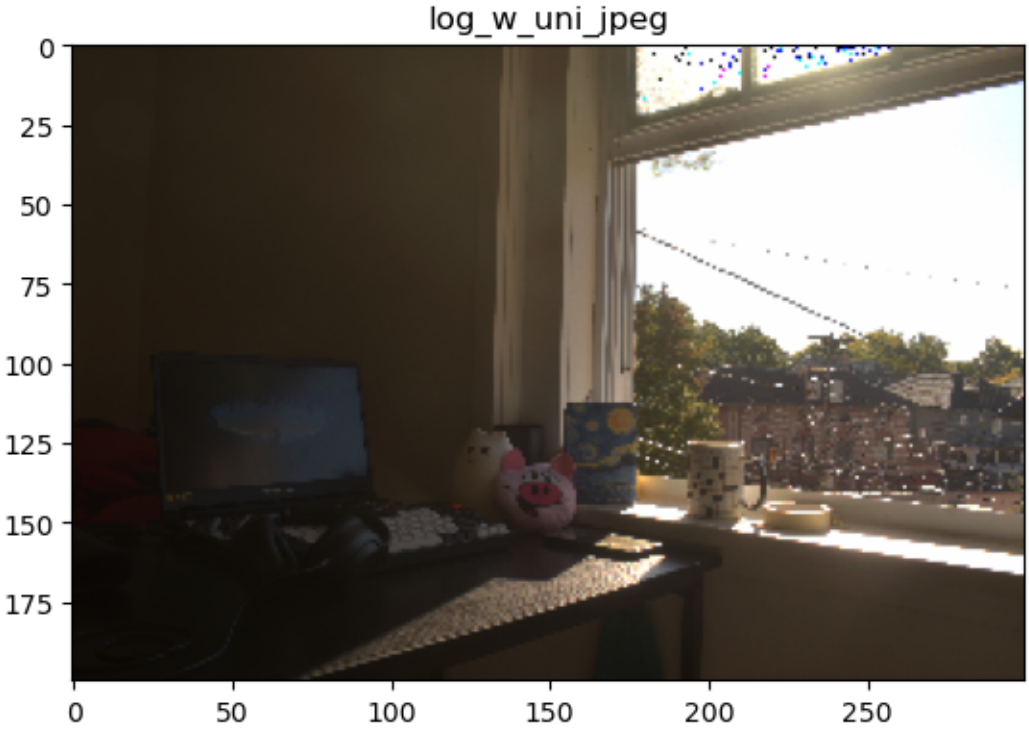
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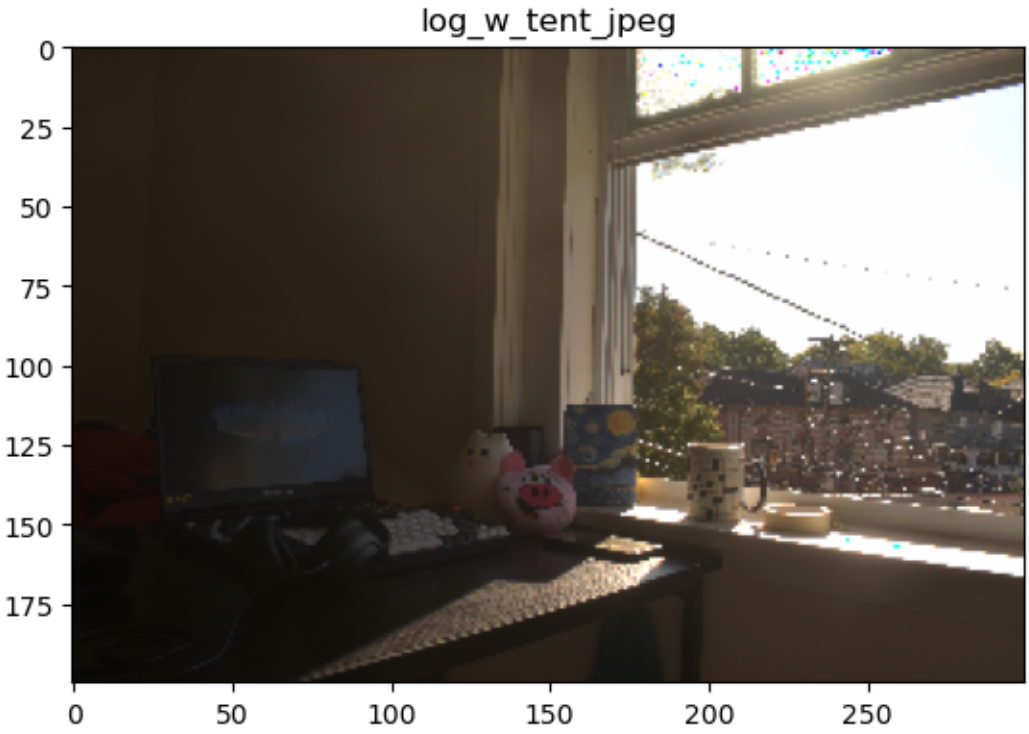
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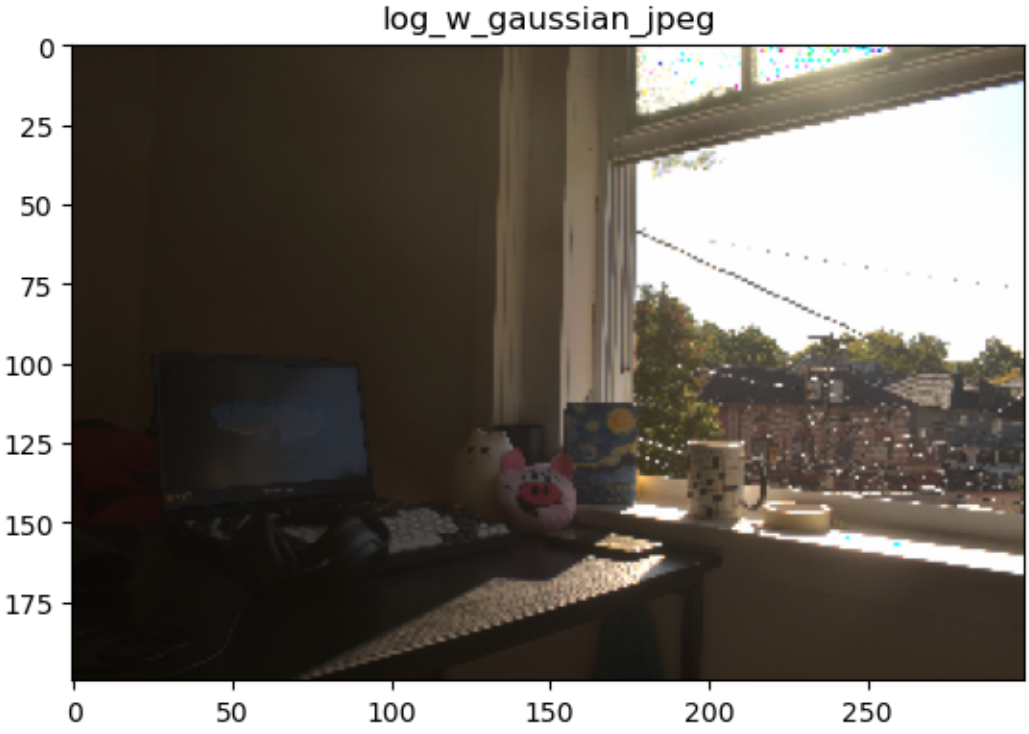
log_w_gaussian_jpeg
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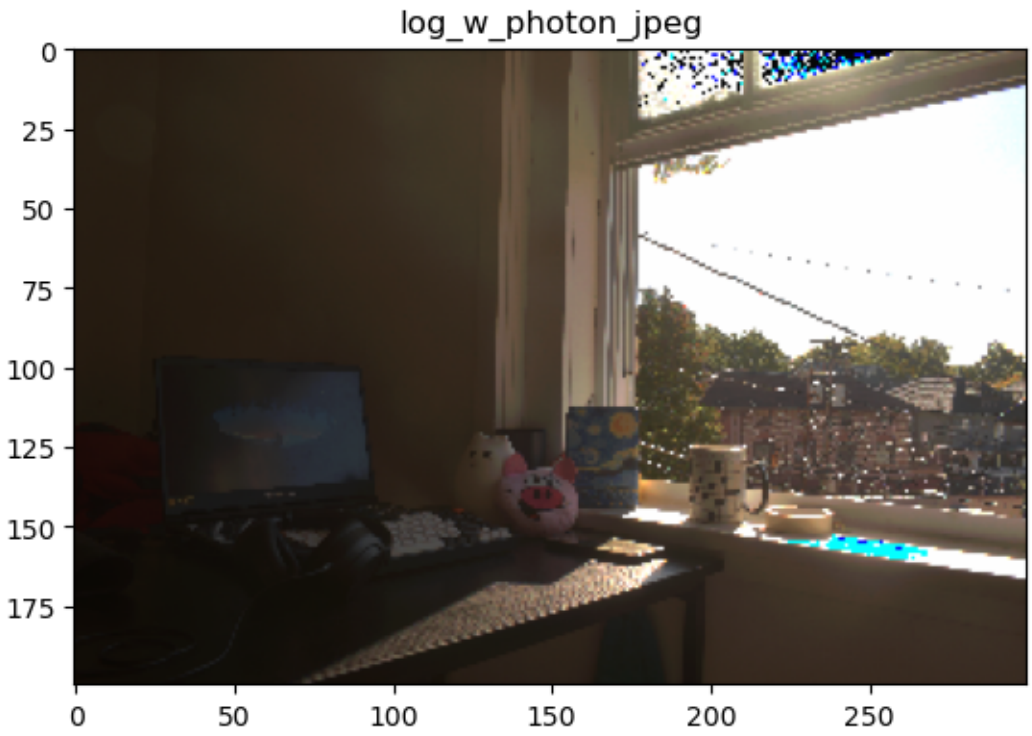


log with gaussian and tent hyper params, zmin and zmax need to be tuned, but we are happy with some of the other images so we arent going down this route.
lin_w_uni_tiff and lin_w_photon_tiff are the two best images, out of which the uniform weighing scheme image is picked.
lin_w_uni_jpeg and lin_w_photon_jpeg come right after these only because the colors seem too highlighty near the lights.

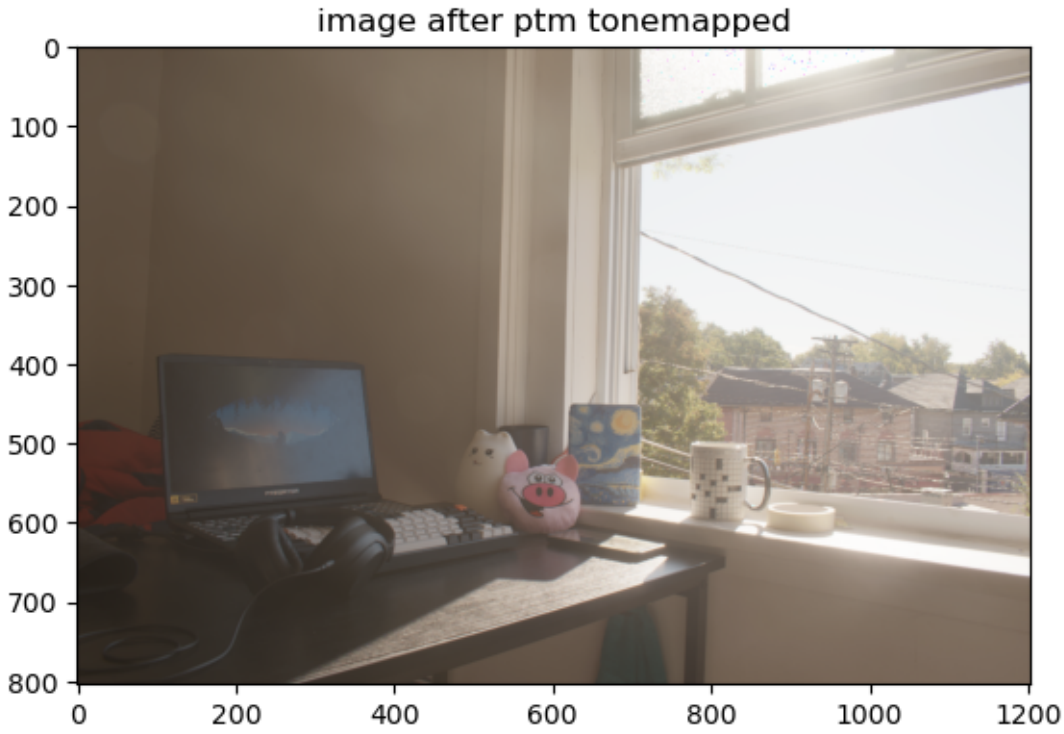
[49]:
```
# Selecting an image
# lin_w_photon_tiff and lin_w_photon_jpeg
src.cp_hw2.writeHDR('I_hdr_tiff_lin_merged_w_photon-part4a.HDR',␣
 ↪I_hdr_tiff_lin_merged_w_photon)
src.cp_hw2.writeHDR('I_hdr_jpeg_lin_merged_w_tent-part4a.HDR',␣
 ↪I_hdr_jpeg_lin_merged_w_tent)
im_hdr_selected = I_hdr_tiff_lin_merged_w_photon.copy()
```

[ ]:
```
```

[48]:
```
# Photographic ToneMapping

# kinda sus, make sure its right
def calc_geometric_mean_log(im) :

    if im.min() < 0 :
```

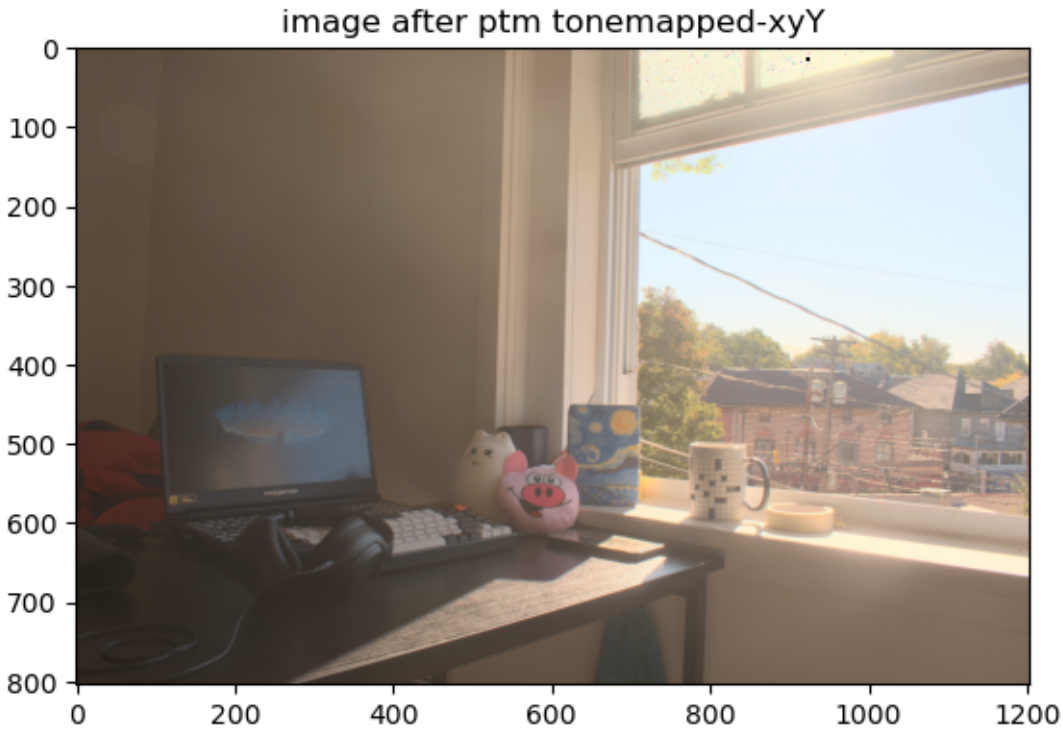
```
        # clipping out negative values and raising them to be over 0
        g_mean = np.exp(np.log(im - (1.00000001) * im.min()).mean())
    else :
        # else
        g_mean = np.exp(np.log(im + 1e5).mean())

    return g_mean

def calc_geometric_mean(im) :
    pass

def place_key(g_mean, im, K) :
    im_keyed= K * (im) / g_mean
    return im_keyed

def set_white(im_keyed, B) :
    im_white = B * np.max(im_keyed)
    return im_white

# Note : don't really understand what the difference
# would be upon applying tonemapping for the 3 channels separately
# in the case mentioned in the hints. That would be same as this right?
def complete_photographic_tonemap(im, K, B) :

    g_mean = calc_geometric_mean_log(im)
    im_keyed = place_key(g_mean, im, K)
    im_white = set_white(im_keyed, B)

    im_tonemapped_num = im_keyed * (1 + im_keyed / (im_white**2))
    im_tonemapped_den = 1 + im_keyed

    im_tonemapped = im_tonemapped_num / im_tonemapped_den

    return im_tonemapped

def complete_photographic_tonemap_throughxyY(im, K, B) :

    im_XYZ = src.cp_hw2.lRGB2XYZ(im)
    x = im_XYZ[...,0].copy() / im_XYZ.sum(2)
    y = im_XYZ[...,1].copy() / im_XYZ.sum(2)
    Y = im_XYZ[...,1].copy()

    Y_tonemapped = complete_photographic_tonemap(Y, K, B)

    X = (x * Y_tonemapped) / y
    Y = Y_tonemapped
    Z = (1 - x - y) * Y_tonemapped / y
```

```
    im_XYZ_tonemapped = np.concatenate((np.stack((X,Y),-1),np.
 ↪expand_dims(Z,-1)),-1)
    im_RGB_tonemapped = src.cp_hw2.XYZ2lRGB(im_XYZ_tonemapped)

    return im_RGB_tonemapped

im_hdr_selected_cc_wb_ptm = complete_photographic_tonemap(im_hdr_selected, K=0.
 ↪72, B=0.95)
im_hdr_selected_cc_wb_ptm_tonemapped =␣
 ↪display_hdr_image(im_hdr_selected_cc_wb_ptm, 1, 'image after ptm tonemapped')

im_hdr_selected_cc_wb_ptm_xyY =␣
 ↪complete_photographic_tonemap_throughxyY(im_hdr_selected, K=0.72, B=0.95)
im_hdr_selected_cc_wb_ptm_tonemapped =␣
 ↪display_hdr_image(im_hdr_selected_cc_wb_ptm_xyY, 1, 'image after ptm␣
 ↪tonemapped-xyY')
src.cp_hw2.writeHDR('im_hdr_selected_cc_wb_ptm_xyY-part4a.HDR',␣
 ↪im_hdr_selected_cc_wb_ptm_xyY)
```




```
/tmp/ipykernel_5075/2361107979.py:45: RuntimeWarning: invalid value encountered
in divide
  x = im_XYZ[…,0].copy() / im_XYZ.sum(2)
```

```
/tmp/ipykernel_5075/2361107979.py:46: RuntimeWarning: invalid value encountered
in divide
  y = im_XYZ[…,1].copy() / im_XYZ.sum(2)
```



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