Computational Photography

Assignment #5 HDR [6]

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Result from Example Input

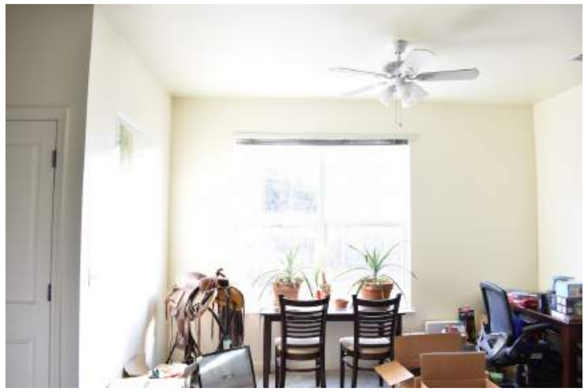
Did you get a good result? If yes/no, what specifically were you happy/unhappy with? Be detailed.

The output of the example image has more details when compared to individual input images and the result looks good. The low exposure images have good amount of detail of the bright features outside the windows but not much of the inside. Whereas the high exposure images have captured significant details of inside of the room but the outdoor features have saturated with white light to some extent. The output image has more or less captured most of the details which are individually present in the images.
One downside of the implementing the algorithm has been that the ‘punch’ in the image is not comparable to the individual image features. Even though the output feature has significantly more features than the input images, the limitations of the display have the image somewhat dull. This could be improved by tonal mapping.

Output of Example Image

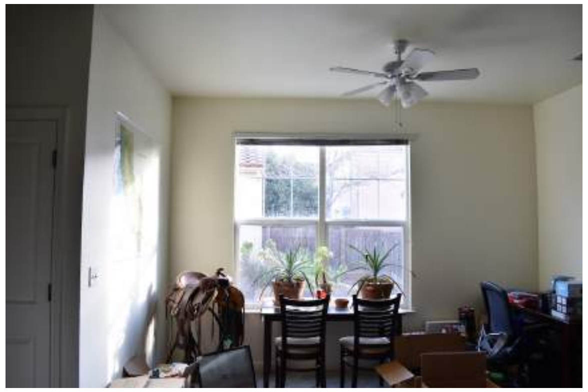
HDR Image Components Thumbnails

11 images were used as components for the HDR image. The images below are 5 of the 11 used the rest are documented in the resource folder under folder: livingroom. These images were clicked from my living room in mountain view.



Input Image 10

Exposure Time (s)	1/4
Aperture	f/5.6
ISO	200

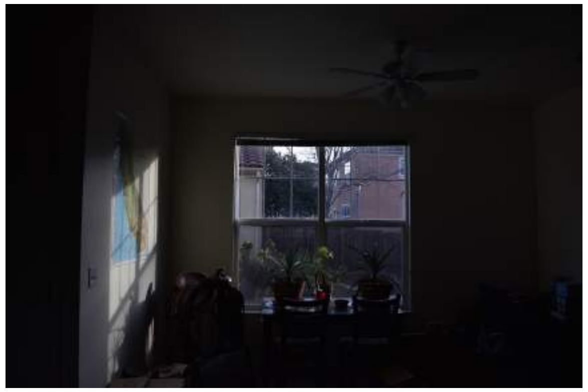


Input Image 8

Exposure Time (s)	1/15
Aperture	f/5.6
ISO	200

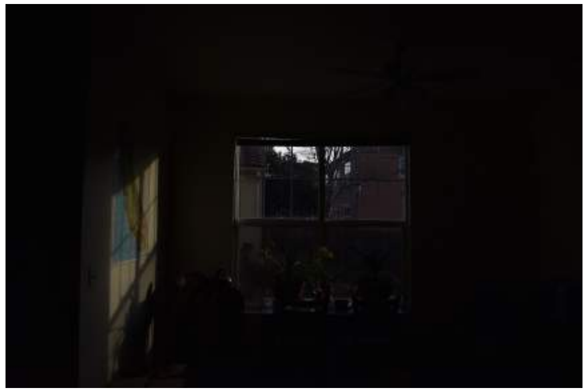
Input Image 6

Exposure Time (s)	1/60
Aperture	f/5.6
ISO	200



Input Image 4

Exposure Time (s)	1/250
Aperture	f/5.6
ISO	200



Input Image 2

Exposure Time (s)	1/500
Aperture	f/5.6
ISO	200

Final HDR Image

A Saddle

HDR Image Requirements

Discuss the camera setting requirements for an HDR image set in general. What settings should be the same for all images? Why?

The HDR image sets need to have varying exposure times to capture images with varying degrees of under and over exposures. The set also requires the settings for aperture and ISO to be fixed. A low ISO setting is preferable to minimize sensor noise. Varying ISO will introduce different noise levels in the images hence the ISO has to be fixed. The aperture needs to be fixed because the depth of field changes with aperture. If image sets have different apertures then some parts on the images will be fuzzy depending on small or large the apertures are. It is also important that the camera is in focus for a good set of images.

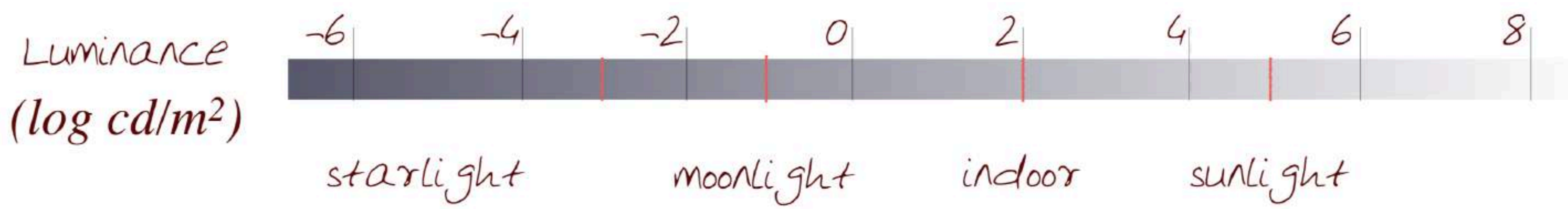
Input Image Sample

Output of Blurred HDR Image

HDR Image Requirements

What is the relevance of the number series (-2, -1, 0, 1, 2) for the exposure times for an HDR image set? Did your images follow this exposure relationship? Explain using your image exposure times.

The numbers are a measure of the luminance represented on a log 10 scale and can be considered as levels of luminance. The unit of each number is log cd/m^2.



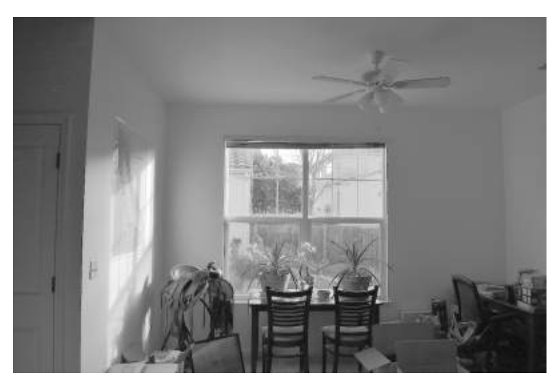
As illustrated in the figure, the numbers represent the intensity of light for different sources of light. Sun being very bright has a luminance of ~10^7 cd/m^2 or luminance level of 7. Moonlight coming from the moon is reflected sunlight. Since the moon reflects around ~10% of sun light the luminance of moonlight is .1 cd/m2 or luminance number of -1.

HDR Image Requirements

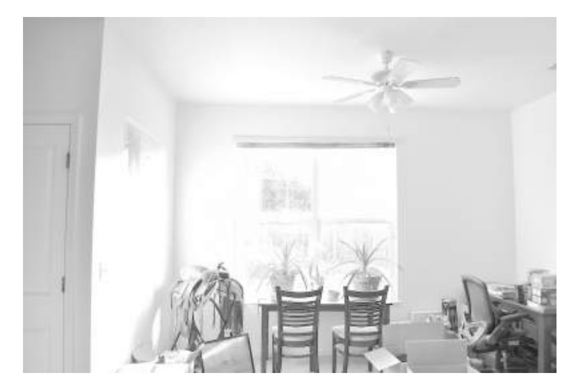
The numbers are relevant for exposure times of the HDR image set because they capture the log luminance intensity of pixels for light originating (reflected, emitted, etc) from a scene as the exposure time changes. For shorter exposure time the luminance number will be small and for longer exposure times the luminance number will be high for the same pixel.

The pictures I clicked did follow the luminance number and exposure relation ship. The images below are that of the intensity values which were scaled for visibility. The images had the same settings for ISO and aperture and it can be seen that the for small exposure time the luminance number was small hence darker images as compared to the large exposure.

Exposure time 1/4000



Exposure time 1/60



Exposure time 1/4

HDR Image Requirements

What else besides camera settings must be controlled for an HDR image set?

Apart from the camera settings it is extremely important that the camera stays still during each shot and also shouldn't move from image to image. If the camera moves as an image is shot the image might be somewhat blurry and it will not be useful for generating a HDR image. If the camera moves between images, the position of features will change in the images and these images cannot be used directly for generating a HDR image. The images will have to be aligned to ensure the features are in the same location in all images (intensity of the features pixels will different due to varying exposure). The HDR image set also have good range of contrast. If the overall contrast is low across the image set then HDR will not come out good. This relates to the lighting conditions of the scene of the image set.

Discussion of Results

How well does your HDR output represent the input image set? Discuss!

The HDR output image captures a lot of the details from the scene which are spread out across different images. Images with low exposure are dark and the features in the room are not well delineated. The low exposure images do capture the features which are brightly lit outside the window because there is sufficient light illuminating those features. On the other hand the high exposure images capture in great detail the features present inside the room even thought room is lit by indirect daylight. The high exposure image have pixels saturated with white light. These pixels are in regions where the features are brightly illuminated.

What worked well? Be specific.

The basic HDR algorithm was able to compose a good image with almost all the features extracted from the image sets. The HDR image has minimal secondary artifacts and no blurring due to the algorithm. The images themselves were well aligned due to camera stability with minimal blurring.

What did not work well? Be specific. Were there any problems you couldn’t solve? What were they? If you had more time, how would you solve these problems?

The image has a little blurring around the chairs but it is only visible when the images are enlarged. This could have been avoided by using auto timer or a remote clicker. Applying an alignment pipeline on the images might have helped resolve the minor misalignment in a couple of the images. I was not able to create an image with good color tone. Using local tone mapping algorithms based on local spatial operators or frequency or gradient domain operators may help adding “life” to the image.

Discussion of Results

Reflect on the project: Knowing what you do now (at the end), if you were to start over, what would you do differently and how would you go about doing it?

To begin with HDR images require image set of images taken with extreme care to avoid/minimize shake which can blur or misalign the images. I would use a clicker and avoid days/time when it is windy. The resultant HDR image looks good but seems a bit dull when compared to features in the individual images. Applying tonal mapping would make the final result much better and make the image look like as human eyes perceive. Tone mapping algorithms based on local spatial operators or frequency or gradient domain operators should help improve the results. Also I would have experimented with lighting of the room to illuminate certain objects to see if interesting feature colors could be extracted. I would also attempt to workout a pipeline and take images to create a panoramic HDR image with increased depth of field. I am interested in exploring if these three concepts could be merged together.

Above & Beyond: Tone Mapping

Tone mapping can be done using local or global operators. Global operators are spatially uniform using global variable of the image. Local operators vary spatially changing for each pixel as operator parameters are extracted from surrounding pixels. The tone mapping was done using different techniques as illustrated on the next few slides. Techniques used are in the snippet below.

```
  gamma = 2.2
  tone_map_image = (np.power(hdr_image/255.0,1.0/gamma)*255).astype(dtype='uint8')
  cv2.imwrite(path.join(output_folder, "outputtoned.png"), tone_map_image)
  tone_map_image = (np.power(hdr_image/255.0,gamma)*255).astype(dtype='uint8')
  cv2.imwrite(path.join(output_folder, "outputtonedlinear.png"), tone_map_image)
  hdr_image = hdr_image.astype(dtype='uint8')
  img_rad_map = cv2.cvtColor(hdr_image, cv2.COLOR_BGR2LAB)
  cv2.imwrite(path.join(output_folder, "outputlab.png"), tone_map_image)
  img_rad_map[:,:,0] = (np.power(img_rad_map[:,:,0]/255.0,1.0/gamma)*255).astype(dtype='uint8')
  tone_map_image = cv2.cvtColor(img_rad_map, cv2.COLOR_LAB2BGR)
  cv2.imwrite(path.join(output_folder, "outputtonedlab.png"), tone_map_image)
  img_rad_map = cv2.cvtColor(hdr_image, cv2.COLOR_BGR2LAB)
  lab_channels = cv2.split(img_rad_map)
  clahe = cv2.createCLAHE(clipLimit=2.0)
  lab_channels[0] = clahe.apply(lab_channels[0])
  img_rad_map = cv2.merge(lab_channels)
  tone_map_image = cv2.cvtColor(img_rad_map, cv2.COLOR_LAB2BGR)
  cv2.imwrite(path.join(output_folder, "outputtonedclahe.png"), tone_map_image)
```

Above & Beyond: Tone Mapping

No Tone Mapping

L*a*b Tone Mapping with gamma correction applied to Luminance after color space conversion

Gamma Tone Mapping

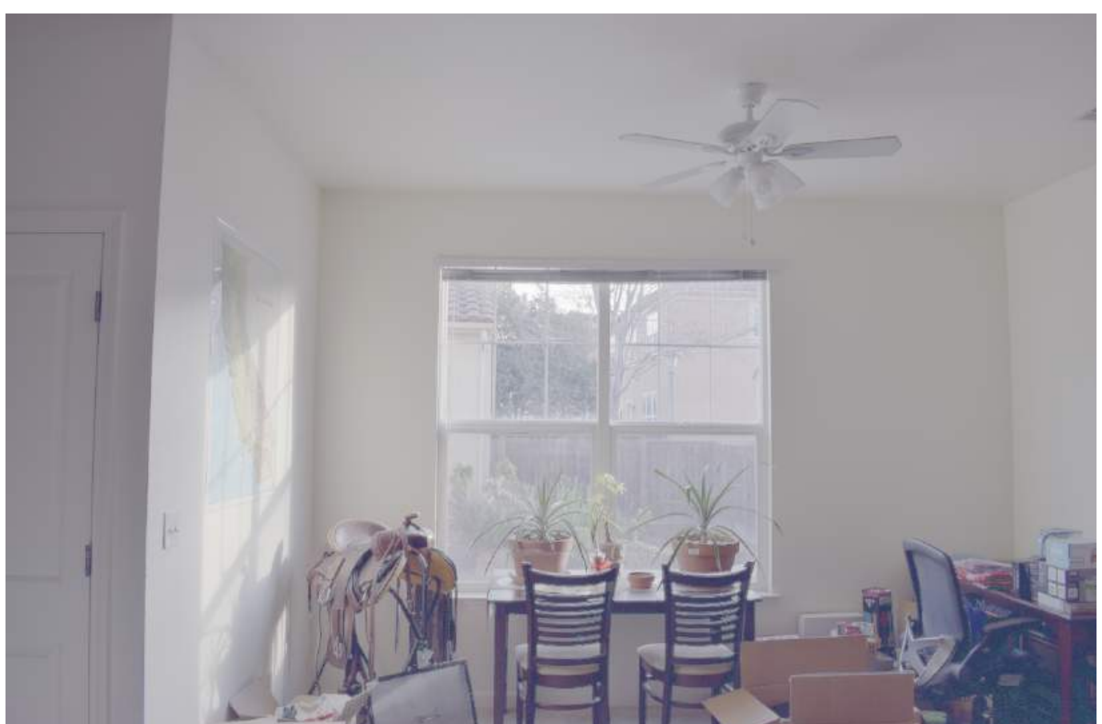
OpenCV CLAHE Tone Mapping

Above & Beyond: Tone Mapping

No Tone Mapping

L*a*b Tone Mapping with gamma correction applied to Luminance after color space conversion

Gamma Tone Mapping



OpenCV CLAHE Tone Mapping

Above & Beyond: Tone Mapping

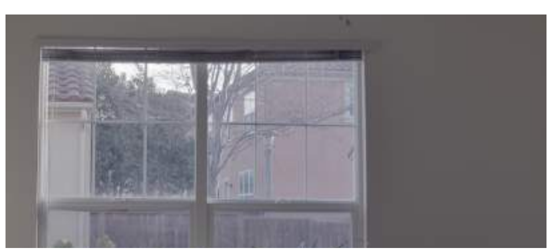
On careful observation it can be seen that the as is output image and the output images using global gamma correction operator are duller when compared to the CLAHE (Constrast Limited Adaptive Histogram Equalization) algorithm. This is due to the fact that local spatial effect of pixels is taken into account for tone mapping.

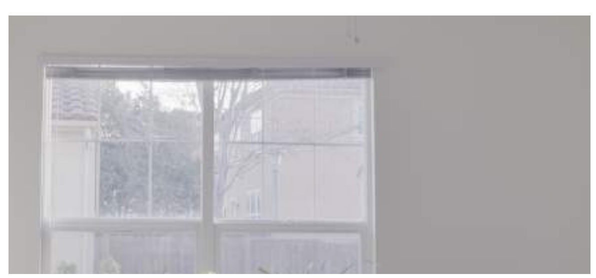
No Tone Mapping

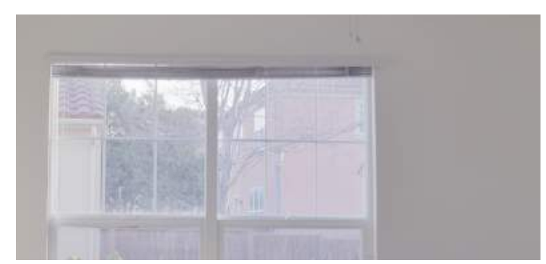
Gamma (1.5) Correction

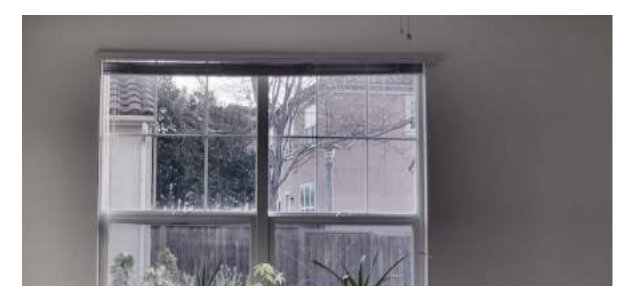
Gamma (1.5) Correction to Luminance

CLAHE









As can be seen the “punch” or dullness goes away in the tone mapping done using CLAHE. CLAHE used a local operator and its power is clearly illustrated.

Resources

[1] Lecture slides

[2] https://www.csie.ntu.edu.tw/~cyy/courses/vfx/13spring/lectures/handouts/lec04_tonemapping_4up.pdf

[3] https://cs.brown.edu/courses/cs129/2012/lectures/18.pdf

[4] https://en.wikipedia.org/wiki/Contrast_ratio

[5] Tone mapping Szelski Chapter 10

[6] This is original work completed for spring 2019 offering of computational photography.