HIGH DYNAMIC RANGE IMAGING

A presentation by **Alipio, Basabe, Gamido, Tan, Tolledo**

OBJECTIVES

In this activity, the group aimed to do the following:

- Take multiple photos of scenes in NIP using different shutter speeds
- Conduct High Dynamic Range image processing on the photos taken
- Recover the Response Curve of the photographs
- Showcase how the smoothness constant λ affects the resulting HDR image

01 METHODOLOGY

EXPERIMENTAL SETUP

Scenes with **intense brightness and dark shadows** were selected and images were taken of each scene with **fixed f-number** and **varying shutter speeds**: 1/12000, 1/8000, 1/4000, 1/2000, 1/750, 1/500, 1/12000 sec. Shown in Fig. 1 are the 6 scenes selected.

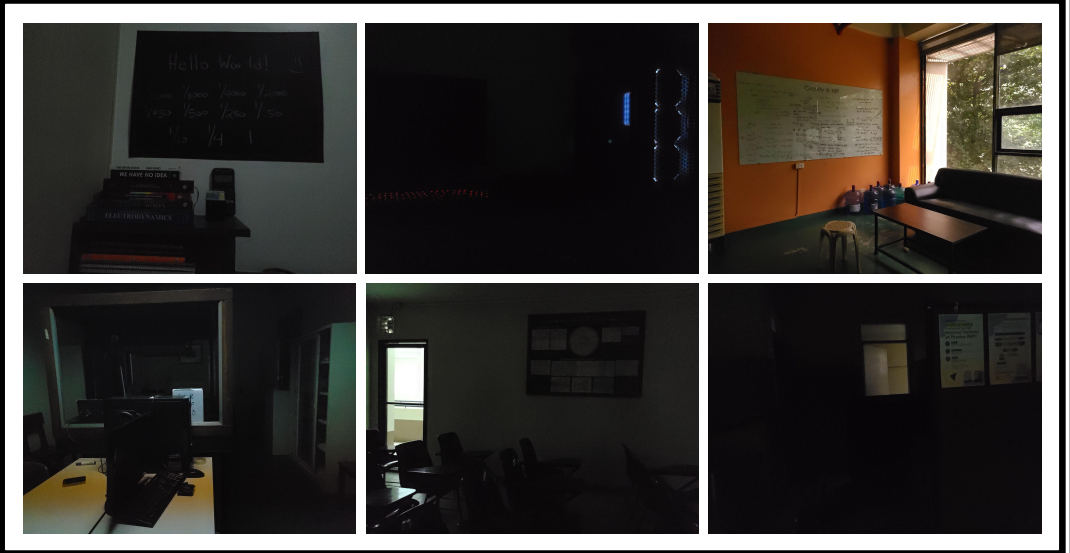

Figure 1. Scenes with intense brightness and dark shadows.

DEBEVEC-MALIK ALGORITHM

500 sample points were selected per image and their ln(shutter speed) vs gray level value (Z's) were plotted. The response curve of the images were then calculated to map the pixel values in the images to its corresponding radiance levels. A radiance map that estimates the radiance at each pixel was calculated. The radiance map give us a highly accurate representation of the actual light levels in the images at every pixel, allowing us to preserve fine details in the bright and dark parts of the image. HDR images were reconstructed and the smoothness constant λ was varied to investigate how it affects the resulting HDR image.

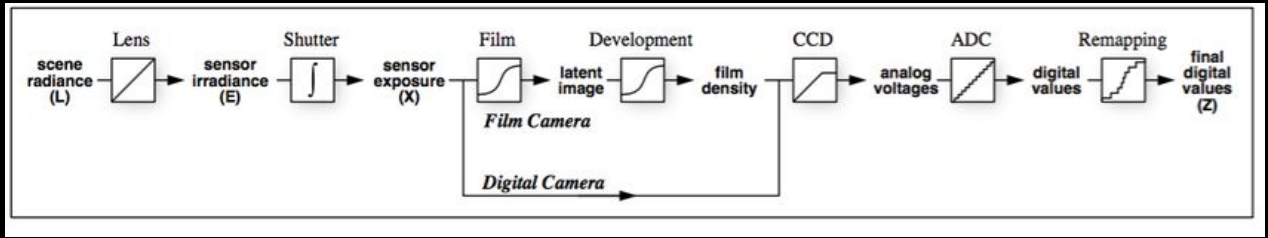

Figure 2. HDR imaging process by Debevec-Malik.

02 RESULTS & ANALYSIS

RESPONSE FUNCTION RECOVERY

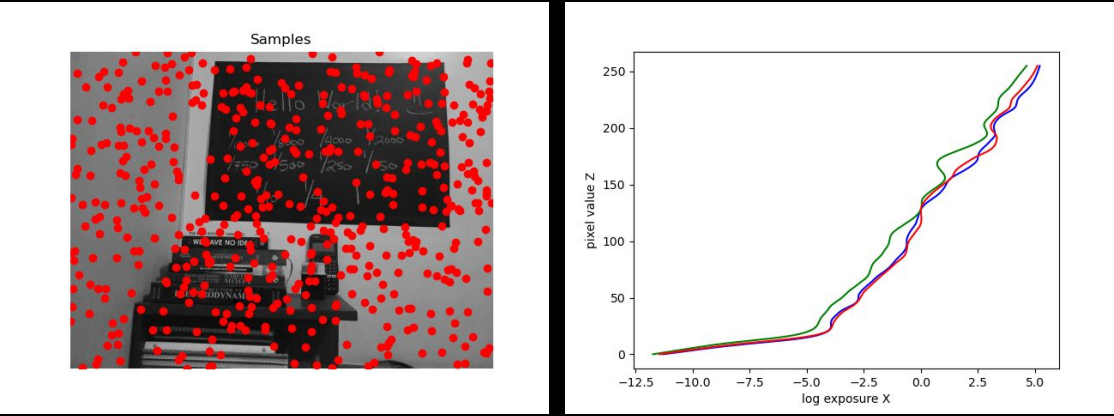

Figure 3. Response curve arising from randomly sampled points in the scene.

The resulting **response curve (g)**, arising from **500 sample points** in Fig. 3, represents the relationship between the **incident light** striking the camera sensor and the **resulting pixel values** in the image. This **nonlinear response** is directly responsible for the **dynamic range** of the imaging system. As a result, this dynamic range tells us the system's ability to **capture and preserve details** in scenes that contain well-lit and poorly-lit areas. Moving forward, we utilize the response curve to **interpolate for radiance values** within the image.

SCENE VISUALIZATION

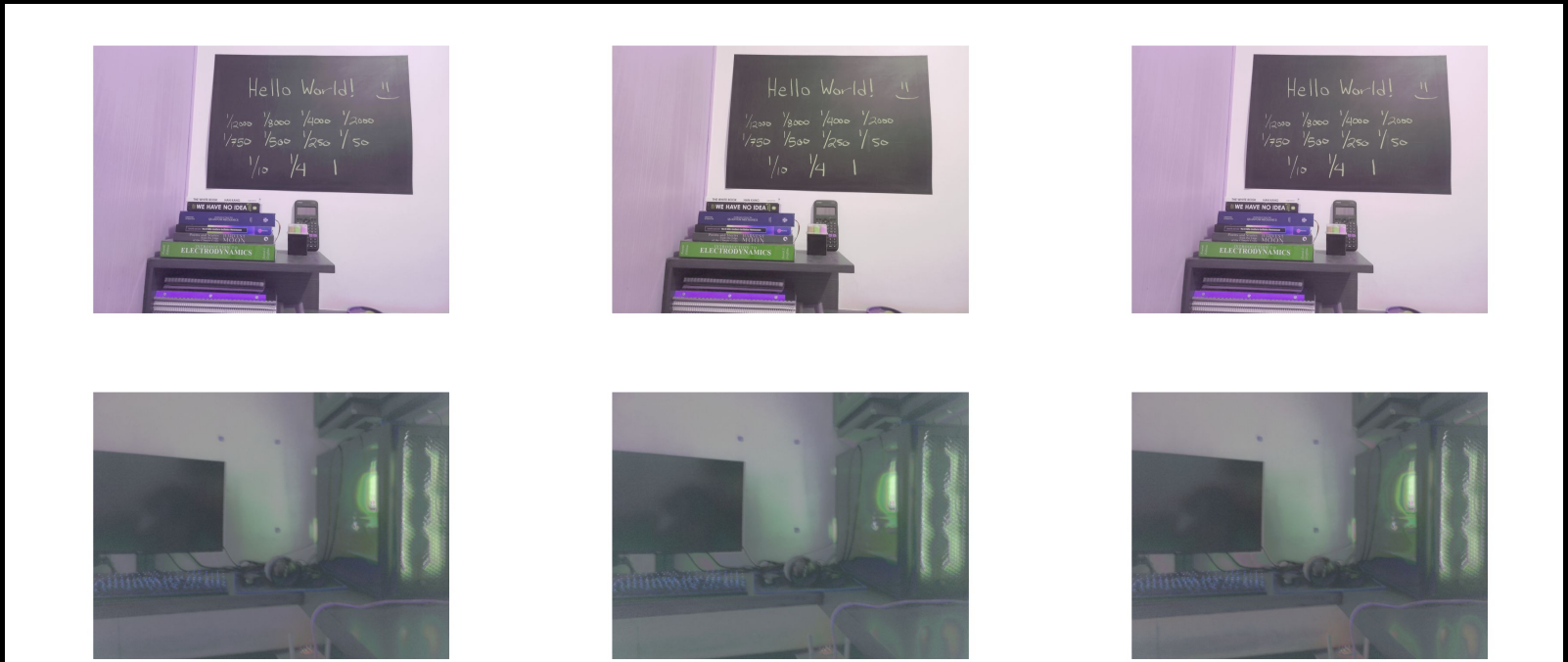

Figure 4. Recovered HDR images using the Debevec-Malik algorithm. From left to right: λ = 5, 25, 50.

ANALYSIS

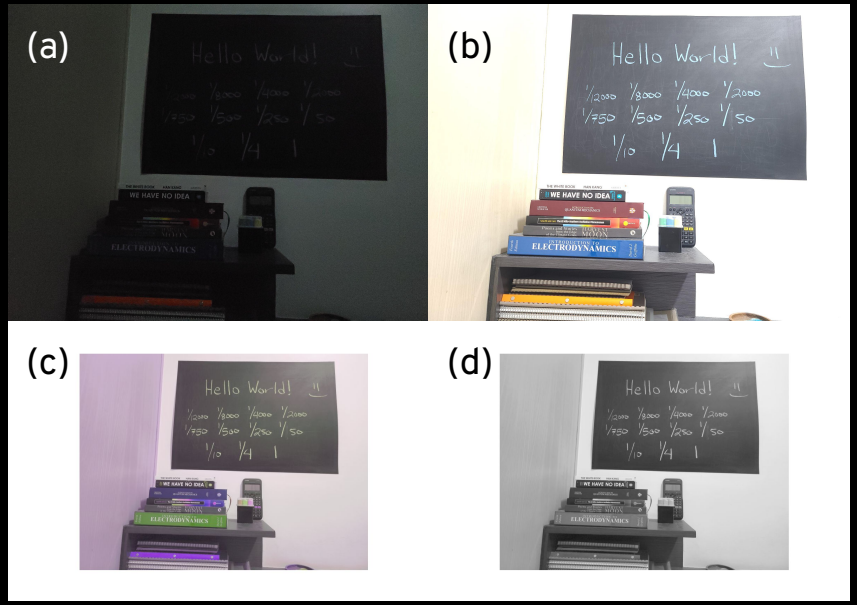

Figure 5. Comparison between a) scene at low exposure, b) scene high exposure, c) scene recovered HDR image, d) grayscale recovered HDR image.

The recovered high dynamic range radiance map in Fig. 5.d show **less saturation of pixel values on both the dark and bright pixel areas**. As expected, details present only on low exposure and only on high exposure values **combine in the recovered image**.

Note that the recovered HDR image **may not be color correct** when comparing the scenes in Fig. 5. The process was applied to each channel such that when combining the channels again, the image produced may not be color correct. Similar to Debevec, **the grayscale image is enough as it displays the intensities of each pixel**.

ANALYSIS

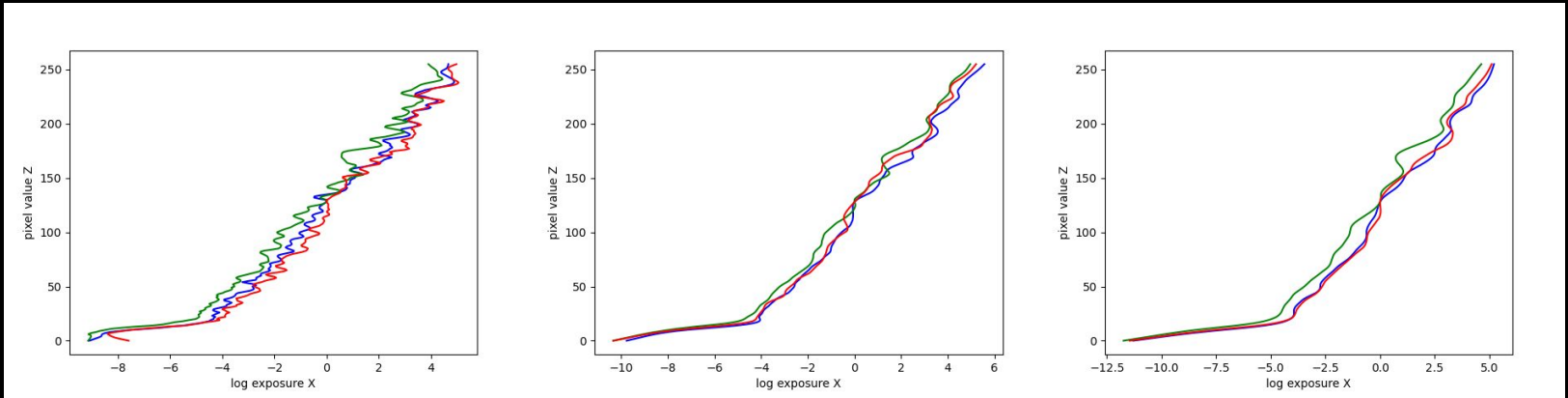

Figure 6. Recovered response curves with varying smoothing factor. From left to right: λ = 5, 25, 50.

The recovered response curve shown in Fig. 6 shows an overall good consistency between the channels with the green channel dominating for the middle to high exposure values. When comparing smoothness factor, the channels are most consistent at λ = 25 thus making its corresponding recovered HDR image the best out of all the smoothing factors.

OTHER TRIALS

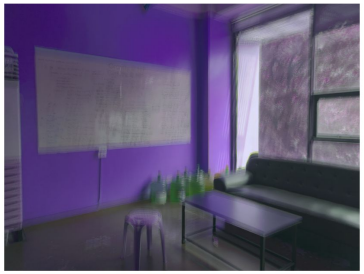
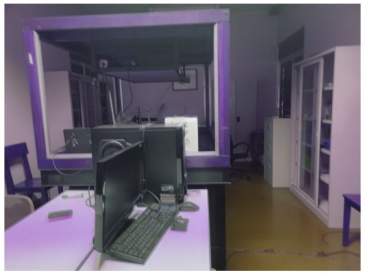
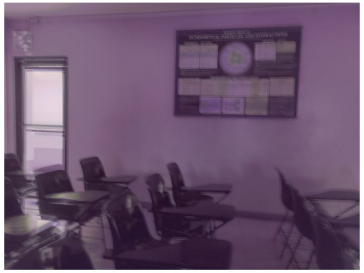
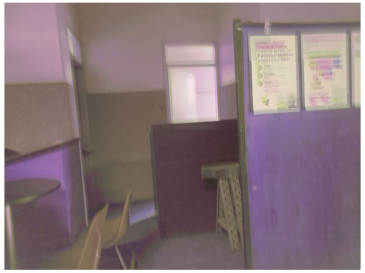

Figure 7. Recovered HDR images using the Debevec-Malik algorithm.

Once again, we perform the **Debevec-Malik algorithm on a new set of scenes** and obtain their reconstructed HDR images as seen in Fig. 7. Due to the **instability during the capturing process**, the recovered HDR images show visible signs of blurriness. However, it can be noted that the well-lit and poorly-lit areas both exhibit a **great level of detail** as opposed to their original counterparts. Additionally, their r**ecovered response curves now faithfully mirror the camera's response to light** regardless of the variations of exposure levels.

CONCLUSIONS AND LIMITATIONS

The Debevec-Malik algorithm was successfully implemented. By taking multiple images at **different exposures**, we have managed to put them back together to form a single, **composite image** which is essentially the **resolved HDR image**. However, the colors of the resulting images are **not consistent with the original**. This can be resolved by **color correcting the images**, but that is already outside the scope of the activity. There were also scenes with very **noticeable shifts in the images** and this affected the results when they were put through the HDR algorithm. These could be salvaged with **image-aligning algorithms**, but that is again no longer in the scope of this activity.

03 REFLECTION

REFLECTION

It was a success on our part to get the HDR algorithm to work on these images. It was a bit challenging for the group because the code provided in the paper was in Matlab, and most of us are unfamiliar with it. So we had to look for different sources that helped us do the Debevec-Malik Algorithm in Python. We referred to a code posted on github by user Luka Basek when we struggled with the coding. Of course, our code could still definitely be improved. It took approximately 13 minutes for each image to run, so there's definitely room for optimization in the code. Our first set of images taken were also unaligned, and so the results were blurry images. Thankfully, we still had time and were able to take new sets of photos that no longer had shifting. Using color correction and image-aligning, if needed, is also something we recommend to improve the results.

SELF-GRADE

Technical Correctness: 30/30

Quality of Presentation: 30/30

Reflection: 30/30

Ownership: 10/10

TOTAL: 100

Looking at the objectives, we successfully took photos of scenes in NIP under varying shutter speed, we successfully applied HDR imaging on these photos and retrieved their response curve using the Debevec-Malik algorithm, and showcase the effect of the smoothness constant on the resulting HDR images. Our presentation clearly discusses our objectives, methods, and results. And so, we have given ourselves a perfect score of 100.

REFERENCES

[1] Debevec, P., & Malik, J. (1997). Recovering high dynamic range radiance maps from photographs. *Association for Computing Machinery*. https://doi.org/10.1145/258734.258884

[2] Khanna, M. (2021, December 12). HDR Imaging: What is an HDR image anyway? - Towards Data Science. *Medium*. https://towardsdatascience.com/hdr-imaging-what-is-an-hdr-image-anyway-bdf05985492c

[3] *OpenCV: High Dynamic Range (HDR)*. (n.d.). https://docs.opencv.org/3.4/d2/df0/tutorial_py_hdr.html