Gradient Domain Fusion

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Introduction

The goal of this project was to explore gradient-domain processing. It is a method for combining multiple images by identifying their gradients and edges to create a high-quality output image. It is a widely used approach in image processing, and this paper aims to explore its principles.

Image Blending

Poisson Blending

The idea behind Poisson blending (Perez et al., 2003) is to seamlessly combine two images by solving a Poisson equation (Equation 1) that enforces continuity and smoothness constraints between the source and target images. It is a widely used technique in image processing that allows for the seamless blending of images without visible artifacts or distortions.

$$\min_{v'} \sum_{i\in M,\ j\in N_i\cap M} ((v'_i - v'_j) - (s_i - s_j))^2 + \sum_{i\in M,\ j\in N_i\cap M^c} ((v'_i - t_j) - (s_i - s_j))^2, \tag{1}$$

Figure 1: Background image (1) combined with object image (2) using copy-paste. Photos references: Waugh.

Figure 2: Comparison of combined image (1) with copy-paste technique and Poisson blended image (2).

The above example (Figure 2) is a quite successful example of the Poisson blending algorithm. There is a nice improvement from the copy-paste to the result of Poisson blending. This works pretty well because the texture around the object image is similar to the background image. Although, you can see some distortion near the waves.

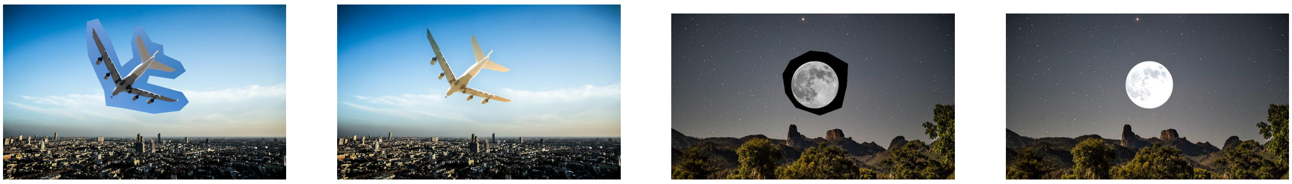

Figure 3: Another good examples of Poisson blending. Photos references: Rohde, 2021, NASA, NationalParks.

Sometimes the Poisson blending does not gives us the good results. For example, we can see a smudge border along the object we wanted to insert (Figure 4). One of the reasons for this failure is that the nature of this blending asks for transparency, something that the simple Poisson blending algorithm cannot do.

Figure 4: Example of failure of Poisson blending algorithm. Photos references: Sartore, Dave.

Mixed Gradients

The main difference between Poisson blending and mixed gradient blending is that mixed gradient blending involves blending the gradients of the source and target images directly (Equation 2), potentially resulting in some visible seams or artifacts. But sometimes these artefacts are exactly what we expect to see, for example bricks lines (Figure 5).

$$\min_{v'} \sum_{i \in M,\ j \in N_i \cap M} ((v'_i - v'_j) - g_{ij})^2 + \sum_{i \in M,\ j \in N_i \cap M^c} ((v'_i - t_j) - g_{ij})^2 \tag{2}$$

Figure 5: Comparison of copy-paste (column 1), Poisson blending (column 2), and mix gradients blending (column 3). Photos references: PJay, Slickspics, Photowall, Phidiaz, Sartore, Dave.

Laplacian pyramid blending

Laplacian pyramid blending is a technique for blending images that uses a multi-scale representation called a Laplacian pyramid. The pyramid levels are blended using a mask that determines the contribution of each level to the final blended image. The blending starts from the top level, and the result is added to the corresponding level of the blended image pyramid. This process is repeated for each level of the pyramid, resulting in a seamless blend of the source and target images.

Figure 6: Example of Laplacian pyramid blending. Photos references: Developer.

Figure 7: Comparison of copy-paste (top-left), Poisson blending (top-right), mix gradients blending (bottom-left), and Laplacian pyramid blending (bottom-right).

Image Enhancement

Poisson Sharpening

The goal of image sharpening is to increase the change in pixel values at the edges. The method is derived from the Poisson equation (Equation 3).

$$\min_{v'} \sum_i (v'_i - s_i)^2 + \sum_{i,\ j \in N_i} ((v'_i - v'_j) - \alpha(s_i - s_j))^2. \tag{3}$$

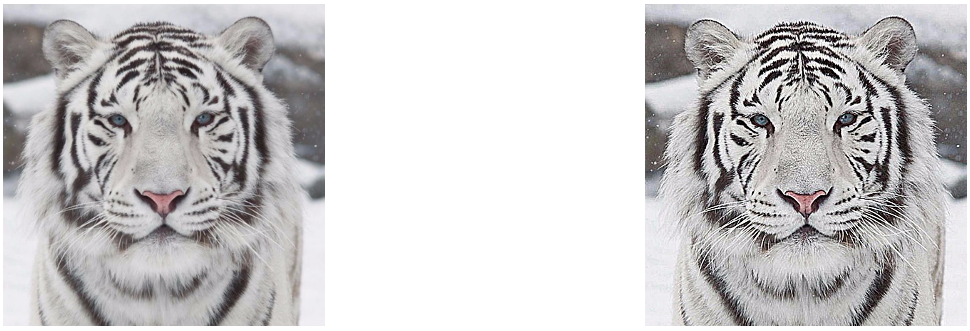

Figure 8: Example of sharpen image using Poisson sharpening algorithm. Photos references: Developer.

Poisson Color Transfer

The goal of the color transfer is to mimic color style on source image into a target image, but still maintain its gradients. This method is also derived from the Poisson equation (Equation 4).

$$\min_{v'} \sum_{i,\ n \in RGB} (v'_i - \alpha(t_i - avg(t_n) * \frac{std(t_n)}{std(s_n)} + avg(s_n)))^2 + \sum_{i,\ j \in N_i} ((v'_i - v'_j) - (s_i - s_j))^2. \tag{4}$$

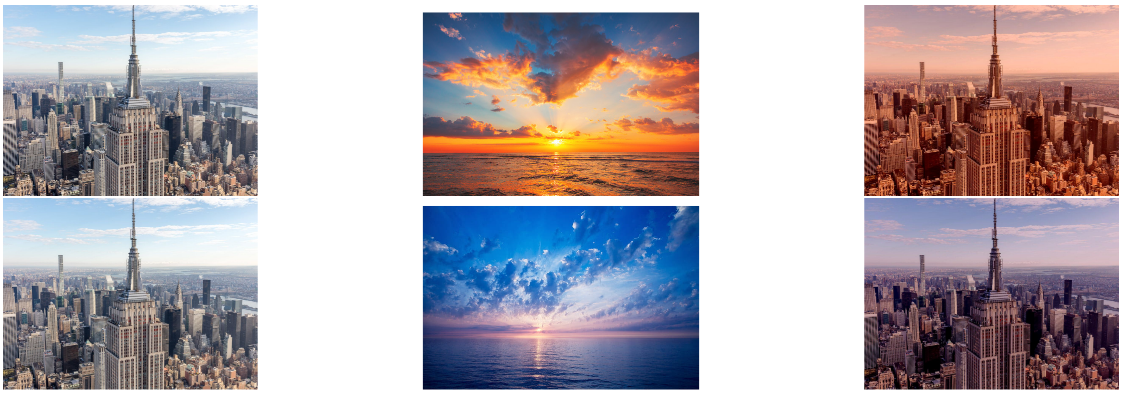

Figure 9: Example of transfer color algorithm. Column 1 - target image, column 2 - source image, column 3 - color transfer output. Photos references: Plitt, Wallpaperflare, Va.

Poisson Color2Gray

The color2gray gradient-based algorithm converts a color image into a grayscale image by computing the gradient magnitude of the color image and using it to modify the initial grayscale image.

The process starts by converting the color image into a grayscale image using a standard luminance conversion formula. Next, the gradient magnitude of the color image is computed using an average of RGB channels values. The resulting gradient magnitude image is then used to modify the initial grayscale image by adjusting the intensity of the pixels in a way that preserves the edges and details of the original color image. Finally, the modified gradient image is added to the initial grayscale image to obtain the final color2gray gradient-based conversion.

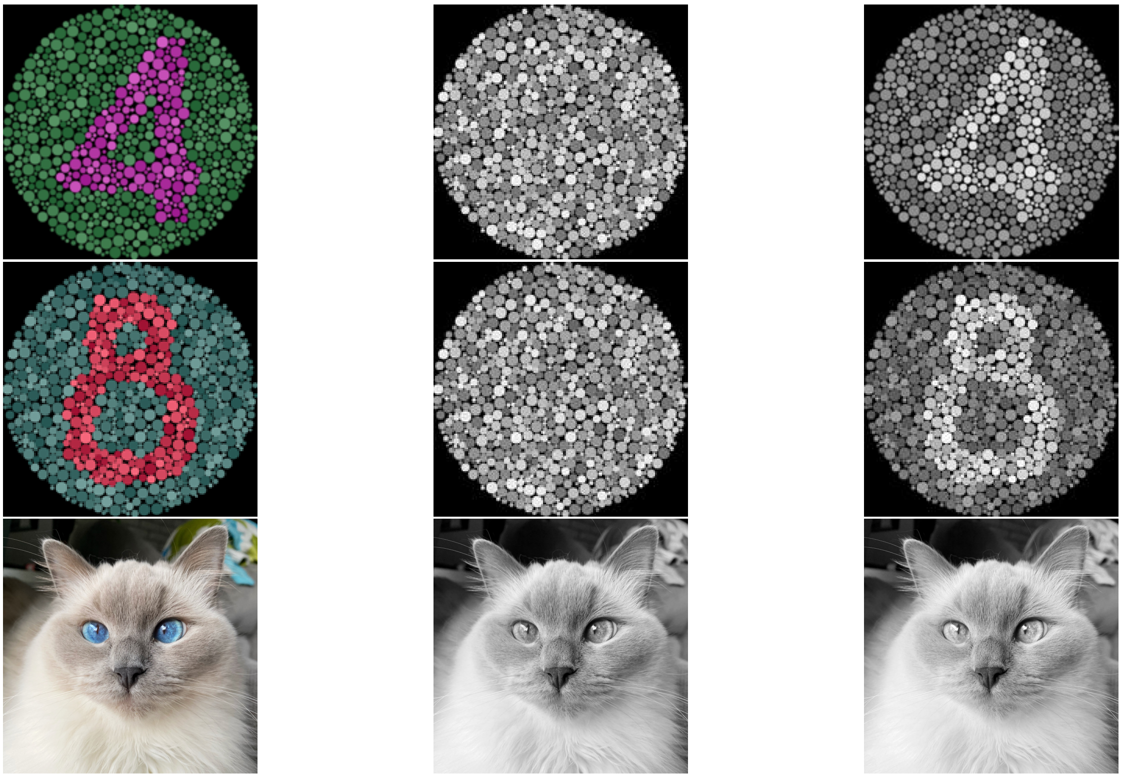

Figure 10: Comparison between original images (column 1), standard gray images (column 2), and images after color2gray algorithm (column 3).

References

NEOSiAM 2021. Beach image.

K. Dave. Tree image.

Prisma Developer. White tiger image.

NASA. Moon image.

NationalParks. Night view image.

Patrick Perez, Michel Gangnet, and Andrew Blake. 2003. Poisson image editing. page 313–318.

Phidiaz. Graffiti word image.

Photowall. Brick wall image.

PJay. Graffiti color image.

Amy Plitt. Ny city image.

Russ Rohde. Plane image.

Joel Sartore. Rainbow image.

Slickspics. Old wall image.

News Va. Sunset image.

Wallpaperflare. Sea image.

Janice Waugh. Beach image.