# Project 4- Final Project

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**Poisson Image Editing**

## Background

Poisson Image Editing is a technique for "seamlessly blending" two images together fully automatically. It was originally conceived in this paper by Patrick Perez, Michel Gangnet, and Andrew Blake from Microsoft Research UK.

This technique is an image processing operator that allows the user to insert one image into another, without introducing any visually unappealing seams. Furthermore, this technique also makes sure that the color of the inserted image is also shifted, so that the inserted object feels as if it is part of the environment of the target image. So, a bright object copy-and-pasted into a rather dark image, will have its color shifted to a darker color. In the below image, an image of a kitten has been copy-and-pasted into an image of a library using poisson blending, and as can be observed, there are no visible seams.

## Data Description:

## Data Characteristics:

- We have two RGB images as an input and one RGB image as an output. Output is made by adding the first RGB image to the second one.

## Sample of input and output:

source images

target images

Result images

## Project description:

In this project we want to investigate image processing with gradient amplitude. We use a simple technique used for non-photorealistic composition, body mapping and rendering. We actually want to use the amplitude gradient combination to integrate the image, which is called the pwa-sohn combination (pwa-sohn; meaning "fish" in French), because in the combination process we will solve a second-order partial differential equation that is usually It is known as the Poisson equation (after Simeon Dennis Poisson).

The simplest way to combine is to replace the pixels in a target image with the pixels in a source image. Unfortunately, this can lead to significant seams, even if the backgrounds are similar. In this approach, we want to get rid of these differences in intensity.

The insight is that humans are perceptually sensitive to slopes rather than the intensity of the absolute image. Therefore, we set the problem as one of the values for the output pixels, which maintains the maximum gradient in the source region without changing any of the target pixels. Note that we are making a deliberate decision here to ignore the overall intensity of the source area - we are merging the (modified) source gradients and forgetting the absolute source intensity.

**Explain some terms:**
1- According to mathematical definitions, a **gradient** is an image derivative of an image, so the purpose of processing the **gradient** amplitude is to create a new image by merging the gradients which requires solving the **Poisson** equation.

2- An **image gradient** is a directional change in the intensity or color in an image. The gradient of the image is one of the fundamental building blocks in image processing. For example, the **Canny edge detector** uses an image gradient for edge detection.

3- The **Sobel operator**, sometimes called the **Sobel–Feldman** operator or **Sobel filter**, is used in image processing and computer vision, particularly within edge detection algorithms where it creates an image emphasizing edges.

4- Compositing is the process of combining multiple images to form a single, cohesive image. It's a common visual technique in photography and film.
Homographies are a transformation that we can use to transform one image into another when both images are pictures of the same plane, but from a different perspective

## Method
Gradient-domain image processing, also known as Poisson image editing, is a type of digital image processing. In this method, instead of applying the manipulations directly to the pixel values, it acts on the basis of differences between neighboring pixels.

It is a two-step process in image processing. In the first step, the image gradient must be selected (Seamless cloning). The second step is to solve the Poisson equation to arrive at a new image that can produce the desired gradient in the first step (Mixing gradients).

In image editing, the gradient is obtained from an existing image and modified. Various operators such as Sobel are used to find the gradient of an image. Then, by directly manipulating this gradient while creating the resulting image, several different effects are created.

This principle and method are used in other cases such as seamless stitching of the image, removal of undesirable details from an image, non-photographic rendering filters, removal of image obstruction, and the ability to seamlessly simulate one part of an image on another.

**Seamless cloning**

Digital compositing is a common task in image editing in which some or all of one photo is pasted into another photo. Traditionally this is done by pasting the pixel values from one image to the other. The pasting can be performed in the gradient domain: if the differences between pixels are pasted rather than the actual pixel values, there is sometimes much less user input needed to achieve a clean result.

## Data pre-processing and Feature Engineering:

## Code description:

The code is in **MATLAB**.
In this code, the composition of two images is done in such a way that it takes two images as input. Introduces the first image with the title “source” which is the image that is to be added to the second image and the second image with the title “target”. In the first step, the source image is displayed, and the user can select the desired range with the mouse. By pressing any key on the keyboard, the second image is displayed, and the user can see the path drawn in the previous image and can locate it with the mouse, and select the place to paste. Now, by pressing a key on the keyboard screen, the user will see the selected range of the first image, the edges of which have also disappeared on the second image.

**PIE function:**

after Initialization set m=0 to use the default method (seamless cloning) and then set c=0 to use the default image type (true color). We use the default image type (true color). In this step, if the mask is not grayscale, we convert it. Then we create the laplacian mask for the second derivative of the source image and normalize the mask image to assure that unknown pixels = 1 and then convert it to logical to ignore any fractions (soft masks).

We do the below step for each color channel:
- loop through the mask image again to:
1- initialize the coefficient matrix
2- initialize the B vector
if the method is seamless cloning; so, initially put B= (-) laplacian of im_source, otherwise (mixing gradients), B= (-) max(laplacian of im_source, laplacian of im_target)
- create the coefficient matrix A
In next step we create the gradient mask for the first derivative and for this step we should get the first derivative of the target image and also the first derivative of the source image. Then we nitialize the final gradient with the source gradient. If the gradient of the target image is larger than the gradient of

the source image, use the target's gradient instead. All of this steps are in the 1-D invironment. Now we map to 2-D. Then we get the final laplacian of the combination between the source and target images (lap=second deriv of x + second deriv of y) which is done by create the laplacian of the source image.

**Blend function:**

This function blends the source image with the target one based on the boundary given as a BW mask using Poisson Image Editing (PIE).

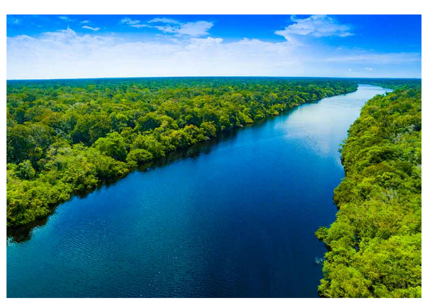
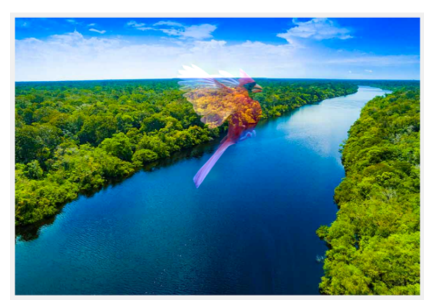
## Input and output:

**Inputs**:
im_target: target image
im_source: source image
im_mask: mask image
m: 0 for seamless cloning (default), and 1 for mixing gradients.
c: 0 for true color source and target images (default), and 1 for grayscale source and target images.

**Take a look at the below table:**

| |
|---|
| im_out = PIE(targetImage,sourceImage,mask,0,0); for seamless cloning (true color) |
| im_out = PIE(targetImage,sourceImage,mask,1,0); for mixing gradients (true color) |
| im_out = PIE(targetImage,sourceImage,mask,0,1); for seamless cloning (grayscale) |
| im_out = PIE(targetImage,sourceImage,mask,1,1); for mixing gradients (grayscale) |

**Outputs**:
im_out: output image after blending the source image with the source image based on the given mask (uint8).

| source images | target image | output image |
|---|---|---|
|  |  |  |

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**output image after blending the source image with the source image based on the given mask (uint8).**

**Bells & Whistles (Extra Points):**

### 1- Changing the mask shape

It is clear and simple to deal with a rectangular mask. However, we should find a way to represent an arbitrary mask.
In this approach It reshapes the unknown region of the composited image to be represented as a 1D vector. Consequently, $f_l$ is used instead of f(i, j) using a map function that is responsible for mapping $f_l$ to the corresponding f(i,j) in the original space in both directions, such that $\Phi( f(i, j)) \rightarrow f_l$ and $\Phi^{-1}( f(l)) \rightarrow f(i, j)$. So, each unknown pixel is indexed sequentially using a single scalar number. Thus, after solving this linear system of equations, you can get the intensity of the unknown pixels. Eventually, the final composited image is constructed after remapping the 1D vector $\vec{x}$ into the 2D space using the map function.

### 2- Problems:

Image simulation has many useful applications, such as removing unwanted objects, repairing damaged parts of images, and sewing panoramas. Instead of using pixel intensity, gradient domain is used in Poisson image editing. But this has two main problems: color bleeding and bleeding artifacts. Bleeding problems cause smudges in the generated image (bleeding artifacts) and also lead to the colors of the target image dominating the colors of the source image (color bleeding).

Several image blending techniques have been invented for this application. **The Adobe Photoshop healing brush tool** allows blending of two images instead of use of straightforward blending using alpha compositing. Other techniques use a multi-scale representation for cloning regions of an image into another one. Interior boundary pixels are interpolated using weighted values by mean value coordinate techniques. Patchbased synthesis is another approach to image cloning based on searching for similar patches in the image to generate a natural composited image. On the other hand, the gradient domain is used in many techniques for cloning the selected pixels of the source image into the target image.

**Alpha blending** was introduced by Ray and Catmull, who used the alpha channel in image formats to express transparency in images. The alpha channel is used in a direct cloning operation that preserves the original color of the source and the target images. Many approaches have been presented to extract the source object from a given image; both Grabcut for interactive foreground extraction method and the paint selection method in Ref., extract foreground objects using hard cutting mattes. The optimized color sampling method in Ref. generates accurate soft-cutting mattes. However, alpha blending gives undesirable results if the source and target images have different illumination.

The **healing brush** was introduced in Photoshop 7.0 to provide seamless cloning of image regions with different textures and illumination. Georgiev noted that the healing brush tool is based on ensuring continuity of derivatives by use of a fourth-order partial differential equation (PDE). The healing brush tool is the most popular tool used by designers for seamless image cloning.

**Multi-scale representation** was used by Burt and Adelson to compose multiple images to generate a large mosaic image. The pyramid-based texture analysis method in Ref. matches the textures of images using multi-scale pyramids. The multi-scale image harmonization approach in Ref. uses multi-scale histogram matching to transfer appearance between images with different textures and noise patterns, but it gives unsatisfactory results if the source and target images have no stochastic textures.

**Mean value coordinates** provide another basis for image cloning, in which the interior boundary pixels are interpolated by weighted values. Coordinates for the instant image cloning method in Ref. achieve good results which preserve the colors of the image from changes at real time in the case of approximate similarity textures of the pixels that close to the boundaries of both target and source images. However, this method has a problem with concave regions. The improved coordinate-based image cloning method in Ref. uses an alternative sampling approach which can handle concave regions. The environment-sensitive cloning in images method in Ref. uses global features of the target image to improve the blending process. In this method, it is combined alpha matting and mean value techniques by using a gradient vector field as a weighted gradient of target and source images. It is used mean value coordinates to solve Laplace equations without needing a large linear system.

**Patch-based** methods have been widely used for image cloning and image inpainting in recent years. It is used patch matching for image and video completion. The variational framework for image inpainting in Ref. combines gradientbased techniques with patch-based techniques to provide robust patch matching. The image melding method in Ref. clones two images with completely different structures without losing small details or artifacts in the composited image. However, image melding emphasises quality of results rather than high performance. In this method, it is used neighborhood search to give accurate patch matching and increased performance with a limited patch search space.

The **gradient domain** was used instead of pixel intensities in image cloning by P´erez et al., solving Poisson equations with a predefined boundary condition; however, the composited image suffers from color bleeding and bleeding artifact problems. The photomontage method in Ref. and drag-and-drop pasting method in Ref. attempt to find an optimized boundary condition for avoiding boundary artifacts in the composited image. Content aware copying and pasting preserve the colors of the source image using a combination of the alpha matte and gradient domain approaches. The improved method for color image editing in Ref. uses the gradient norm together with color information in the cloning process to avoid the color bleeding problem. Sketch2Photo presents a hybrid image blending method that optimizes the boundary by specifying texture and color consistency of boundary pixels. Then, hybrid image blending acts on the source and target images on two stages: improved Poisson blending, followed by alpha blending.

**Future Work:**

Additional work that can be done in the future for this project should be mentioned as follows:

1- Ability to change the size of the cutting part of the first image to create a fit (being compatible) with the second image.

2- Ability to control the amount of blurring of the edges of the cut part of the first image and modify it based on the second image's background color.

3- Ability to change the color of the cut part of the first image (merging the grayscale part of the first image with the RGB image)

4- Cut a moving object from a video and add it to the target video.