**Assignment-1**

1. **What are the applications of computer vision?**

* **Computer vision,** a subfield of artificial intelligence and image processing, has a wide range of applications across various industries. It involves teaching computers to interpret and understand visual information from the world, just as humans do. Here are some key applications of computer vision:

1. **Object Detection and Recognition:**

* **Automated Surveillance:** Detect and track objects or people in video feeds for security purposes.
* **Autonomous Vehicles:** Recognize and classify objects on the road, pedestrians, traffic signs, and other vehicles.
* **Retail:** Implement shelf monitoring and stock tracking by recognizing products on shelves.

1. **Image Classification:**

* **Medical Imaging:** Diagnose diseases by analyzing medical images like X-rays, MRIs, and CT scans.
* **Quality Control:** Inspect products on assembly lines for defects and classify them as acceptable or defective.
* **Document Analysis:** Automatically classify and process documents based on their content.

1. **Image Segmentation:**

* **Medical Imaging:** Segment organs or anomalies within medical images for diagnosis and treatment planning.
* **Robotics:** Enable robots to understand their environment by segmenting objects from background.

1. **Facial Recognition:**

* **Security:** Verify individuals for access control or identify suspects in public places.
* **User Authentication:** Unlock devices or access systems using facial recognition.

1. **Gesture Recognition:**

* **Human-Computer Interaction:** Control devices or interact with digital content using hand or body gestures.

1. **3D Reconstruction:**

* **Augmented Reality:** Create immersive AR experiences by reconstructing the 3D environment.
* **Archaeology:** Reconstruct archaeological sites and artifacts in 3D from images.

1. **Video Analysis:**

* **Traffic Management:** Monitor traffic flow and detect accidents or congestion.
* **Retail Analytics:** Analyze customer behavior in stores through video footage.

1. **Emotion Analysis:**

* **Market Research:** Analyze customer emotions and reactions to advertisements or products.
* **Healthcare:** Assess emotional states in patients for diagnostics and treatment.

1. **Brief the Following Terms: Image representation & image processing operations?**
2. **Image representation** is the process of encoding and describing digital images in a way that allows for efficient storage, manipulation, and analysis. It plays a fundamental role in various image processing tasks, such as image enhancement, compression, analysis, and recognition. There are several techniques for representing images, including grayscale representation, color representation, histogram representation, feature extraction, and deep learning-based representation. Here's an explanation of each technique:
3. **Grayscale Representation:** Grayscale representation is used for images where color information is not necessary or relevant. In grayscale images, each pixel is represented by a single intensity value.
   * + - **Techniques:**

* **Single-Channel Image:** A grayscale image is represented as a 2D matrix, where each element represents the intensity of a pixel. Typically, pixel values range from 0 (black) to 255 (white) in 8-bit grayscale images.
* **Vector Form:** The 2D matrix can be flattened into a 1D vector by concatenating rows or columns.

1. **Color Representation:** Color representation is used when color information is essential for image analysis or visualization.

* **Techniques:**
* **RGB:** Representing images in the red, green, and blue (RGB) color space, where each pixel is described by three channels (R, G, and B) representing the intensity of each color.
* **HSV:** Representing images in the hue, saturation, and value (HSV) color space, which separates color and intensity information.
* **CMYK:** Used in printing and represents images using cyan, magenta, yellow, and black channels.

1. **Histogram Representation:** A histogram representation provides insights into the distribution of pixel intensities in an image, which is useful for contrast enhancement and analysis.

* **Techniques:**
* **Intensity Histogram:** A histogram shows the frequency of each intensity level in the image.
* **Color Histogram:** In color images, histograms can be created for each color channel (R, G, B) or color space (HSV, LAB).

The choice of image representation depends on the specific image processing task and the characteristics of the image data. Grayscale representation is suitable when color information is not needed, while color representation is essential for tasks where color plays a role. Histograms provide insights into pixel intensity distribution, and feature extraction helps capture relevant patterns. Deep learning-based representations offer automatic feature learning, enabling high-level image analysis tasks. The choice of representation is a crucial step in designing effective image processing pipelines.

1. **Image Processing Operations** encompass a wide range of techniques and procedures used to manipulate and enhance digital images. These operations are crucial in various applications, including computer vision, medical imaging, remote sensing, and multimedia. Here's a detailed explanation of some common image processing operations:

* **Image Enhancement:**
* **Contrast Adjustment**: This operation involves changing the distribution of pixel intensities to enhance the contrast in an image. It can make details more visible by stretching or compressing the intensity values.
* **Brightness Correction:** Adjusting the overall brightness of an image to make it visually more appealing or to correct exposure issues.
* **Filtering:**
* **Smoothing (Blurring):** Applying a low-pass filter to reduce noise and remove fine details in an image. Commonly used for noise reduction and preprocessing.
* **Sharpening:** Using high-pass filters to enhance edges and fine details, making the image appear crisper. It can increase noise, so it is often combined with smoothing.
* **Geometric Transformations:**
* **Rotation:** Rotating an image by a specified angle to change its orientation.
* **Scaling:** Enlarging or reducing the size of an image.
* **Translation:** Shifting an image's position in the x and y directions.
* **Image Restoration:**
* **Deblurring:** Removing blur or distortion introduced during image capture, such as motion blur or defocus blur.
* **Denoising:** Reducing noise (random variations in pixel values) to improve image quality.
* **Color Manipulation:**
* **Color Balancing:** Adjusting color components to correct color cast or achieve desired color rendition.
* **Colorization:** Assigning colors to grayscale images to create color versions.
* **Image Segmentation:**
* **Object Segmentation:** Dividing an image into regions or objects based on characteristics such as color, intensity, or texture. Used in object recognition and tracking.
* **Edge Detection:** Identifying boundaries between different objects or regions in an image.
* **Histogram Operations:**
* **Histogram Equalization:** Enhancing the contrast of an image by redistributing pixel intensities evenly across the entire range.
* **Histogram Matching:** Adjusting an image's histogram to match that of a reference image.
* **Extraction:**
* **Corner Detection:** Identifying key points or corners in an image that are distinctive and can be used for tracking and registration.
* **Texture Analysis**: Describing and classifying the texture patterns present in an image.
* **Object Detection:** Detecting specific objects or patterns in an image using features such as Haar cascades or deep learning-based approaches.

1. **Write a Short Note on:**
2. **Contrast Stretching:** also known as contrast enhancement or contrast normalization, is an image processing technique used to improve the visual quality of an image by expanding the range of pixel intensities. The primary goal of contrast stretching is to increase the difference between the darkest and lightest regions of the image, making details more discernible and enhancing the overall image quality. **Here's how contrast stretching works:**

* **Histogram Analysis:** The first step in contrast stretching involves analyzing the histogram of the image. The histogram represents the distribution of pixel intensities, with darker values on the left and lighter values on the right. By examining the histogram, you can determine the current dynamic range of the image.
* **Determination of Stretching Parameters:** Based on the analysis of the histogram, you determine two parameters: the minimum intensity value (Min\_in) and the maximum intensity value (Max\_in) in the original image that represent the darkest and lightest pixels, respectively. Additionally, you choose the desired minimum intensity value (Min\_out) and maximum intensity value (Max\_out) for the stretched image. These parameters determine the desired contrast range.
* **Stretching Transformation**: Using the chosen parameters, a linear stretching transformation is applied to the pixel intensities in the image. This transformation maps the original intensity values in the range [Min\_in, Max\_in] to the desired range [Min\_out, Max\_out].
* **The transformation formula is:**

|  |
| --- |
|  |

* **Application of Transformation:** The transformation is applied to each pixel in the image, effectively redistributing the pixel intensities over the new dynamic range.
* **Output Image:** The result is an image with improved contrast, where details that may have been hidden in the original image due to limited contrast are now more visible. The dark and light areas are spread across a broader range of intensities, making the image visually more appealing and informative.

Contrast stretching is a simple yet effective technique for enhancing image quality and making features more discernible. However, it should be applied judiciously, as excessive stretching can lead to the loss of subtle details or introduce artifacts. Additionally, the choice of stretching parameters (Min\_out, Max\_out) should be tailored to the specific image and application.

1. **Adaptive Histogram Equalization (AHE):** Adaptive Histogram Equalization (AHE) is an advanced image enhancement technique used to improve the contrast of images while taking into account local variations in intensity. Unlike traditional histogram equalization, which applies a global transformation to the entire image, AHE operates on small, overlapping regions or tiles within the image. This adaptability allows AHE to address issues such as uneven illumination and enhance local details effectively. **Here's how Adaptive Histogram Equalization works:**

* **Image Division:** The input image is divided into non-overlapping or overlapping tiles or regions. The size of these tiles is a critical parameter, and it affects the degree of local adaptation.
* **Histogram Equalization:** Within each tile, a Standard histogram equalization is applied. This process redistributes the pixel intensities within each tile to achieve a more uniform distribution. As a result, the local contrast is enhanced within each region.
* **Normalization:** After histogram equalization is applied to each tile, the resulting enhanced tiles may have varying intensity scales. To ensure a smooth transition between adjacent tiles and avoid noticeable artifacts, a normalization step is performed. This step scales the pixel intensities within each tile to maintain consistency with its neighboring tiles.
* **Combining Tiles:** The enhanced tiles are reassembled to create the final output image. The combination of locally enhanced tiles produces an image with improved contrast while preserving local details.
* **A few important considerations for Adaptive Histogram Equalization:**
* The choice of tile size and overlap is crucial. Smaller tiles with overlap provide better local adaptation but may introduce artificial seams in the output image.
* AHE is effective at enhancing local details but may also exaggerate noise, especially in regions with low texture.
* Overly aggressive AHE can lead to "over-enhancement" artifacts, where local contrast is boosted excessively, resulting in unnatural-looking images.
* AHE is widely used in medical imaging, particularly for enhancing the visibility of structures in X-rays, CT scans, and MRIs. It is also employed in computer vision tasks, including object detection and image analysis, where improving local contrast can aid in feature extraction.

1. **Explain histogram specification with following example? Suppose that a 3- bit image (L=8) of size 64×64 pixels(MN=4096) has the intensity distribution shown in the following table (on the left) get the histogram transformation function and make the output image with the specified histogram, listed in the table on the right.**

|  |  |  |
| --- | --- | --- |
| **rk** | **nk** | **Pr(rk)=nk/MN** |
| **r0 =0** | 790 | 0.19 |
| **r1 =1** | 1023 | 0.25 |
| **r2 =2** | 850 | 0.21 |
| **r3 =3** | 656 | 0.16 |
| **r4 =4** | 329 | 0.08 |
| **r5 =5** | 245 | 0.06 |
| **r6 =6** | 122 | 0.03 |
| **r7 =7** | 81 | 0.02 |

|  |  |
| --- | --- |
| **Zq** | **SpecifiedPz(zq)** |
| **z0 =0** | 0.00 |
| **z1 =1** | 0.00 |
| **z2 =2** | 0.00 |
| **z3 =3** | 0.15 |
| **z4 =4** | 0.20 |
| **z5 =5** | 0.30 |
| **z6 =6** | 0.20 |
| **z7 =7** | 0.15 |

|  |  |  |
| --- | --- | --- |
| 6 | 0 | 9 |
| 8 | 2 | 7 |
| 1 | 4 | 3 |

1. **Consider the image below and calculate the output of the pixel (2,2) if smoothing is done using neighborhood using (3x3) all the filters below: Box filter, Weighted average filter, Median filter, Min filter, Max filter.**

|  |  |  |
| --- | --- | --- |
| 6 | 0 | 9 |
| 8 | 2 | 7 |
| 1 | 4 | 3 |

* To calculate the output of the pixel (2,2) using different neighborhood filters (3x3) on the given image, we'll apply each filter to the neighborhood of that pixel and calculate the result. Let's go through each filter, Given Image:
* **Box Filter:** A box filter computes the average of the pixel values in the neighborhood.
* **Calculation:** (6 + 0 + 9 + 8 + 2 + 7 + 1 + 4 + 3) / 9 = 40 / 9 ≈ 4.44

|  |  |  |
| --- | --- | --- |
| 1 | 2 | 1 |
| 2 | 4 | 2 |
| 1 | 2 | 1 |

* **Weighted Average Filter:** A weighted average filter assigns different weights to each pixel in the neighborhood and computes the weighted average.
* **Calculation:** (1\*6 + 2\*0 + 1\*9 + 2\*8 + 4\*2 + 2\*7 + 1\*1 + 2\*4 + 1\*3) / (1+2+1+2+4+2+1+2+1) = (6 + 0 + 9 + 16 + 8 + 14 + 1 + 8 + 3) / 21 ≈ 5.19

|  |  |  |
| --- | --- | --- |
| 6 | 0 | 9 |
| 8 | 2 | 7 |
| 1 | 4 | 3 |

|  |  |  |
| --- | --- | --- |
| 0 | 1 | 2 |
| 3 | 4 | 6 |
| 7 | 8 | 9 |

* **Median Filter:** A median filter calculates the median value of the pixel values in the neighborhood. **Neighborhood Sorted**

**Values: Neighborhood**

**Values:**

**The median value is 4.**

* **Min Filter:** A min filter calculates the minimum value of the pixel values in the neighborhood. **Minimum Value = 0**
* **Max Filter:** A max filter calculates the maximum value of the pixel values in the neighborhood. Maximum Value = 9

So, the output of the pixel (2,2) for each filter is as follows:

* Box Filter: ≈ 4.44
* Weighted Average Filter: ≈ 5.19
* Median Filter: 4
* Min Filter: 0
* Max Filter: 9

These values represent the result of applying each filter to the neighborhood of pixel (2,2) in the given image.

1. **Explain smoothing special filter in details?**

* **Smoothing Spatial Filter:** Smoothing filter is used for blurring and noise reduction in the image. Blurring is pre-processing steps for removal of small details and Noise Reduction is accomplished by blurring. Spatial Filtering technique is used directly on pixels of an image. Mask is usually considered to be added in size so that it has specific center pixel. This mask is moved on the image such that the center of the mask traverses all image pixels. Types of Smoothing Spatial Filter: Linear Filter (Mean Filter), Order Statistics (Non-linear) filter.

1. **Linear Filter (Mean Filter:** Linear spatial filter is simply the average of the pixels contained in the neighborhood of the filter mask. The idea is replacing the value of every pixel in an image by the average of the grey levels in the neighborhood define by the filter mask.

* **Types of Mean filter:**

1. **Averaging filter:** It is used in reduction of the detail in image. All coefficients are equal.
2. **Weighted averaging filter:** In this, pixels are multiplied by different coefficients. Center pixel is multiplied by a higher value than average filter.
3. **Order Statistics (Non-linear) filter:**

It is based on the ordering the pixels contained in the image area encompassed by the filter. It replaces the value of the center pixel with the value determined by the ranking result. Edges are better preserved in this filtering. Types of Order statistics filter:

1. **Minimum filter:** 0th percentile filter is the minimum filter. The value of the center is replaced by the smallest value in the window.
2. **Maximum filter**: 100th percentile filter is the maximum filter. The value of the center is replaced by the largest value in the window.
3. **Median filter:** Each pixel in the image is considered. First neighboring pixels are sorted and original values of the pixel is replaced by the median of the list.
4. **Why median filter is better than mean filter?**

* **The choice between a median filter and a mean filter** depends on the specific image processing task and the characteristics of the noise and features in the image. There is no universally "better" filter; rather, each filter has its own advantages and disadvantages. Here's why a median filter is often preferred over a mean filter in certain situations:
* **Advantages of Median Filters:**
* **Noise Reduction:** Median filters are highly effective at reducing noise in images, especially impulse noise such as salt-and-pepper noise. Impulse noise introduces outliers (extremely bright or dark pixels), and the median filter replaces each pixel with the median value of the pixel intensities in the neighborhood. This operation significantly reduces the impact of outlier values.
* **Edge Preservation:** Median filters are good at preserving edges and fine details in images. Unlike mean filters, which perform a linear averaging of pixel values, median filters do not blur edges as much. Edges often have unique pixel values, and the median operation retains these values, resulting in better edge preservation.
* **Robustness to Outliers:** Median filters are robust to outliers because they rely on the median value, which is not sensitive to extreme values. This property makes them suitable for images with irregular noise patterns.
* **Non-linear Operation:** Median filters are non-linear filters, meaning they do not have the superposition property. This non-linearity can be advantageous in situations where linear filters may not be suitable, such as when dealing with non-linear noise or non-uniform backgrounds.
* **When to Choose a Median Filter:**
* Choose a median filter when your image has significant impulse noise, such as salt-and-pepper noise, and preserving edges and fine details is essential.
* Median filters are often used in medical imaging, where preserving fine structures and removing impulse noise are critical.
* In cases where other noise reduction techniques, such as Gaussian or Poisson noise models, may not apply, a median filter can be a robust choice.
* **When to Choose a Mean Filter:**
* Choose a mean filter when you want to perform simple noise reduction and image smoothing without significantly affecting edges or fine details.
* Mean filters are computationally efficient and suitable for applications where real-time processing or low computational cost is important.

While a median filter is often preferred over a mean filter for noise reduction tasks involving impulse noise and edge preservation, the choice of filter should be made based on the specific requirements of the image processing task and the characteristics of the image data.

1. **What is sharpening special filter, describe with the help of Laplacian filter?**

* **A sharpening filter,** also known as an edge enhancement filter, is an image processing filter designed to enhance the edges and fine details in an image. The primary goal of a sharpening filter is to increase the contrast of the edges by emphasizing the high-frequency components, which correspond to rapid changes in pixel values. Sharpening filters work by accentuating the intensity differences between neighboring pixels. They are particularly useful for making images appear crisper and more defined, especially when the original image may appear somewhat blurry or when you want to enhance the visibility of details. **There are several sharpening filters, and some of the common ones include:**
* **Laplacian Filter:** The Laplacian filter highlights regions where the intensity of the image changes rapidly, effectively enhancing edges. It is applied using a convolution operation with a specific kernel, such as the Laplacian kernel.
* **Unsharp Masking (USM):** Unsharp masking is a widely used sharpening technique. It involves creating a high-pass version of the image, subtracting this high-pass image from the original, and then adding it back to the original image with an adjustable weight. This process enhances edges and fine details.
* **High-Boost Filtering:** High-boost filtering is a variant of unsharp masking. It involves combining the original image with a weighted version of the Laplacian image to achieve sharpening. The choice of the weight parameter determines the strength of the sharpening effect.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 5 | 5 | 5 | 5 | 5 |
| 5 | 10 | 10 | 10 | 5 |
| 5 | 10 | 10 | 10 | 5 |
| 5 | 10 | 10 | 10 | 5 |
| 5 | 5 | 5 | 5 | 5 |

* **Gradient Filters**: Gradient filters, such as Sobel and Prewitt filters, are used for edge detection but can also be adapted for sharpening. They emphasize the edges in different directions by calculating the gradient of the image.
* **Frequency Domain Filters:** Some sharpening techniques are applied in the frequency domain, such as Fourier or wavelet-based sharpening. These methods can enhance edges by boosting specific frequency components.

The Laplacian filter enhances edges by amplifying high-frequency components while suppressing low-frequency components (smooth regions). However, it can also amplify noise, so it should be applied judiciously. To reduce noise amplification, it's common to apply a Gaussian smoothing filter before applying the Laplacian filter. This process is known as "Laplacian of Gaussian" or LoG filtering. Here's a simplified example to illustrate the Laplacian filter operation numerically. Suppose we have a 5x5 grayscale image with pixel values:

|  |  |  |
| --- | --- | --- |
| 5 | 5 | 5 |
| 5 | 10 | 10 |
| 5 | 10 | 20 |

|  |  |  |
| --- | --- | --- |
| 0 | -1 | 0 |
| -1 | 4 | -1 |
| 0 | -1 | 0 |

**LaplaciKernel: Neighborhood:**

* **Result** **= (0 \* 5) + (-1\*5)+(0\*5)+(-1 \* 10) + (4 \* 20) + (-1\*10)+(0\*5)+(-1\*10) + (0 \* 5) = 60**
* Sharpened Pixel = 20 (Original Pixel) + k \* 60 (Laplacian Result).
* Depending on the value of `k`, the sharpened pixel value is adjusted, enhancing the edges around the central pixel.

|  |  |  |
| --- | --- | --- |
| 1 | 3 | 7 |
| 8 | 5 | 9 |
| 0 | 2 | 6 |

1. **Apply laplacian filter and enhanced laplacian filter on the given image on the center pixel?**

|  |  |  |
| --- | --- | --- |
| 0 | 1 | 0 |
| 1 | -4 | 1 |
| 0 | 1 | 0 |

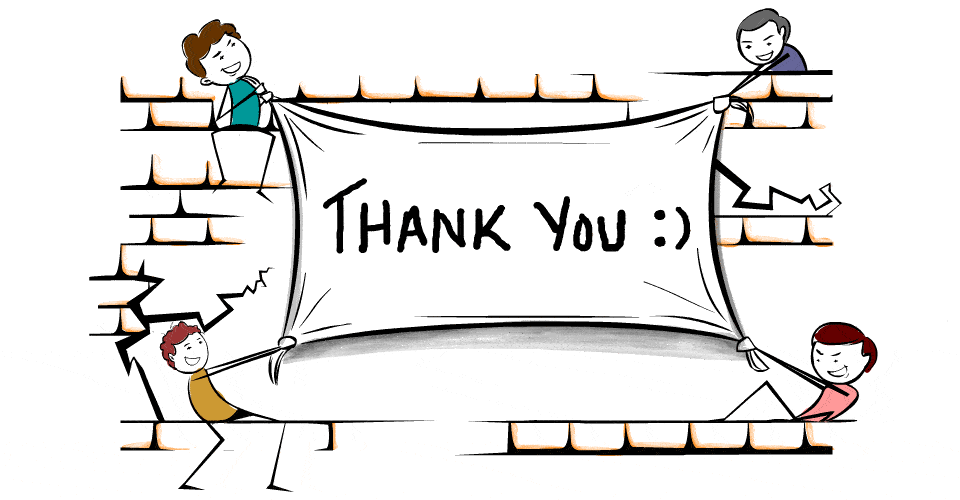
|  |  |  |
| --- | --- | --- |
| 1 | 3 | 7 |
| 8 | 5 | 9 |
| 0 | 2 | 6 |

**\***

**=(1\*0)+(3\*1)+(7\*0)+(8\*1)+(5\*-4)+(4\*1)(0\*0)+(2\*1)+(6\*0)**

**=22-20 = 20**

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