**Assignment-2**

1. **What is image transform?**

* **Image transform =** Operation to change the default representation space of a digital image (spatial domain -> another domain), so that all the information present in the image is preserved in the transformed domain, but represented differently.
* Image transformation, also known as image processing or image manipulation, refers to the process of altering or enhancing the visual characteristics of a digital image. Image transformation techniques are commonly used in various fields, including computer vision, photography, and graphics, to achieve different objectives such as improving image quality, extracting useful information, or preparing images for analysis or presentation.
* **Some common image transformations include:**
* **Resizing:** Changing the dimensions (width and height) of an image. This can involve making an image smaller (downsampling) or larger (upsampling).
* **Rotation:** Rotating an image by a specified angle, which can be used to correct the orientation of an image or create artistic effects.
* **Cropping:** Removing unwanted portions of an image to focus on a specific region of interest.
* **Color adjustments:** Altering the color characteristics of an image, such as adjusting brightness, contrast, saturation, or applying color filters.

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1. **What is meant by Image Restoration?**

* **Image restoration** in computer vision refers to the process of improving the quality or fidelity of a degraded or corrupted image to recover its original or cleaner version. Images may get degraded due to various factors such as noise, blurring, compression artifacts, or other forms of distortion during acquisition, transmission, or storage. The goal of image restoration techniques is to remove or reduce these distortions and restore the image to a more visually pleasing and informative state. There are two main categories of image restoration methods: deterministic methods and stochastic methods.

1. **Deterministic Methods:** Deterministic methods are based on predefined mathematical models or algorithms that aim to remove specific types of degradation from an image. Some common deterministic image restoration techniques include:

* **Linear Filtering:** Linear filters, such as the Wiener filter and the mean filter, are used to remove additive noise and blur from images. These filters operate in the spatial domain or frequency domain to enhance image quality.
* **Non-Linear Filtering:** Non-linear filters like the median filter and bilateral filter are effective at removing various types of noise, including salt-and-pepper noise. They are often used for impulse noise removal.

1. **Stochastic Methods:** Stochastic methods, also known as statistical or probabilistic methods, treat image restoration as a statistical estimation problem. They model the degradation process and use statistical methods to estimate the most likely clean image given the observed degraded image.
2. **Explain Fourier transformation and its properties?**

* **Fourier transformation:** is a mathematical technique used in signal processing, image processing, and various other fields to analyze and represent signals and images in terms of their frequency components. It decomposes a signal or an image into a sum of sinusoidal functions, allowing us to understand its frequency content and perform operations in the frequency domain. There are two main types of Fourier Transformations: the 1D Fourier Transform (1DFT) and the 2D Fourier Transform (2DFT).

1. **1D Fourier Transform (1DFT):** The 1D Fourier Transform is used for analyzing one-dimensional signals, such as audio waveforms or time-domain signals. It decomposes a 1D signal into its constituent sinusoidal frequencies.

* **Mathematical Formulation:** **X(f) = ∫[x(t) \* e^(-j2πft)] dt**
* **Where:**
* X(f) is the complex frequency-domain representation.
* x(t) is the time-domain signal.
* f is the frequency variable.
* j is the imaginary unit (√(-1)).

1. **2D Fourier Transform (2DFT):** The 2D Fourier Transform is used for analyzing two-dimensional data, such as grayscale or color images. It extends the concept of the 1D Fourier Transform to two dimensions and decomposes an image into its constituent spatial frequencies.

* **Mathematical Formulation: F(u, v) = ∬[f(x, y) \* e^(-j2π(ux + vy))] dx dy**
* **Where:**
* F(u, v) is the complex frequency-domain representation.
* f(x, y) is the 2D spatial-domain image.
* u and v are the spatial frequency variables.
* j is the imaginary unit (√(-1)).
* **Applications:** 1D and 2D Fourier Transforms are used in a wide range of applications, including signal processing, image analysis, image compression, pattern recognition, and filtering.
* **Fourier transformation Properties:**

1. **Separable Property:**The Fourier Transform of a separable function is also separable. This means that if a signal or image can be represented as a product of one-dimensional functions (e.g., f(x, y) = g(x) \* h(y)), the Fourier Transform of the entire function can be expressed as the product of the Fourier Transforms of the individual one-dimensional functions.
2. **Spatial Shift Property:** Shifting a signal or image in the spatial domain (e.g., translating an image) corresponds to a phase shift in the frequency domain. Specifically, if f(x, y) is the original function, and f(x - a, y - b) is the shifted version, the Fourier Transform of the shifted function is F(u, v) = e^(-j2π(au + bv)) \* F(u, v), where (a, b) are the shift parameters.
3. **Periodicity Property:** Periodic signals have discrete frequency spectra in the Fourier domain. If a signal is periodic with period T, its Fourier Transform will consist of delta functions located at integer multiples of 1/T.
4. **Convolution Property:** The Fourier Transform of the convolution of two functions (e.g., f \* g) is equal to the product of their individual Fourier Transforms (F \* G). This property simplifies the computation of convolution operations in the frequency domain, making them equivalent to multiplication.
5. **Correlation Property:** The Fourier Transform of the cross-correlation between two functions (e.g., f ⨀ g) is equal to the product of the complex conjugate of the Fourier Transform of one function and the Fourier Transform of the other (F \* G\*). This property is useful for template matching and pattern recognition.
6. **Scaling Property:** Scaling a function in the spatial domain (e.g., resizing an image) leads to scaling in the frequency domain. Specifically, if f(ax, by) is the scaled version of f(x, y), the Fourier Transform of the scaled function is F(u/a, v/b), where (a, b) are the scaling factors.
7. **Conjugate Symmetry Property:** For real-valued functions, the Fourier Transform exhibits conjugate symmetry. This means that if f(x, y) is real, then F(u, v) = F\*(-u, -v), where F\* denotes the complex conjugate of F. This property simplifies the analysis of real-valued signals.
8. **Orthogonality Property:** The complex exponentials used in the Fourier Transform are orthogonal in the frequency domain. This property underlies concepts like the Parseval's theorem, which relates energy in the time domain to energy in the frequency domain.
9. **Multiplication Property:** The multiplication of a function by a complex exponential in the spatial domain corresponds to convolution with a shifted delta function in the frequency domain.
10. **Rotation Property:** Rotating a function in the spatial domain (e.g., rotating an image) results in a rotation in the frequency domain. The relationship between the spatial and frequency domain rotations involves complex exponential factors.
11. **Explain:**

* In advanced computer vision and image processing, various filters are used to enhance or modify images for different purposes. Here, I'll explain four types of filters: Min Filter, Max Filter, Midpoint Filter, and Alpha-Trimmed Mean Filter:

1. **Min Filter:** The Min Filter, also known as the minimum filter or erosion filter, is a neighborhood-based filter used to reduce the brightness of an image. For each pixel, it replaces the pixel value with the minimum value in its local neighborhood.

* **Effect:** The Min Filter is effective at removing bright spots and small objects in an image while preserving dark features and boundaries. It is used in applications such as noise reduction and object segmentation.

1. **Max Filter:** The Max Filter, also known as the maximum filter or dilation filter, is the counterpart of the Min Filter. It increases the brightness of an image by replacing each pixel value with the maximum value in its local neighborhood.

* **Effect:** The Max Filter is useful for enhancing bright regions and making objects or features larger in an image. It is commonly used in morphological operations and for feature extraction in computer vision tasks.

1. **Midpoint Filter:** The Midpoint Filter calculates the midpoint or median value of pixel intensities in a local neighborhood and replaces the central pixel with this value. It is a variation of the median filter.

* **Effect:** The Midpoint Filter reduces the impact of extreme values or outliers in the neighborhood, resulting in a smoothing effect that retains image details better than simple mean or median filters. It can be used for noise reduction and contrast enhancement.

1. **Alpha-Trimmed Mean Filter:** The Alpha-Trimmed Mean Filter is a robust filter that combines aspects of the mean and median filters. Instead of calculating the mean or median of all pixel values in the neighborhood, it calculates the mean of the central (2k + 1) pixel values after removing the k smallest and k largest values.

* **Effect:** The Alpha-Trimmed Mean Filter is effective at reducing the impact of outliers and noise while preserving image features. By adjusting the value of k, the filter can be tailored to different noise levels and image characteristics. It is used in applications requiring noise reduction without excessive smoothing.

In advanced computer vision, the choice of filter depends on the specific image processing task and the characteristics of the image and noise. Min and Max Filters are useful for morphological operations and feature enhancement, while Midpoint and Alpha-Trimmed Mean Filters are effective for noise reduction and image smoothing while preserving important image features. These filters are part of a toolbox of techniques used to improve image quality and extract relevant information for various computer vision applications.

| **Index** | **Walsh Function Values** |
| --- | --- |
| 0 | 1 1 1 1 1 1 1 1 |
| 1 | 1 1 1 1 -1 -1 -1 -1 |
| 2 | 1 1 -1 -1 -1 -1 1 1 |
| 3 | 1 1 -1 -1 1 1 -1 -1 |
| 4 | 1 -1 -1 1 1 -1 -1 1 |
| 5 | 1 -1 -1 1 -1 1 1 -1 |
| 6 | 1 -1 1 -1 -1 1 -1 1 |
| 7 | 1. -1 1 -1 1 -1 1 -1 |

1. **Write a short note on:**
2. **Walsh-Hadamard Transform:** The Walsh-Hadamard transform is a non-sinusoidal, orthogonal transformation technique that decomposes a signal into a set of basis functions. These basis functions are Walsh functions, which are rectangular or square waves with values of +1 or –1. Walsh-Hadamard transforms are also known as Hadamard, Walsh, or Walsh-Fourier transforms. **The first eight Walsh functions have these values:**

* The Walsh-Hadamard transform returns sequency values. Sequency is a more generalized notion of frequency and is defined as one half of the average number of zero-crossings per unit time interval. Each Walsh function has a unique sequency value. We can use the returned sequency values to estimate the signal frequencies in the original signal.
* Three different ordering schemes are used to store Walsh functions: sequency, Hadamard, and dyadic. Sequency ordering, which is used in signal processing applications, has the Walsh functions in the order shown in the table above. Hadamard ordering, which is used in controls applications, arranges them as 0, 4, 6, 2, 3, 7, 5, 1. Dyadic or gray code ordering, which is used in mathematics, arranges them as 0, 1, 3, 2, 6, 7, 5, 4.

1. **Slant Transform:** The Slant Transform, or Slant-Hadamard Transform, is a variation of the Walsh-Hadamard Transform that introduces a slant parameter. This parameter allows the Slant Transform to capture directional information in images, making it particularly useful for edge detection and texture analysis.

* **Properties:** The Slant Transform's directional sensitivity makes it adept at capturing features that are aligned in a particular direction. It emphasizes patterns and structures oriented at the slant angle while attenuating others.

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1. **Haar Transform:** The **Haar transform** is the simplest of the [wavelet transforms](https://en.wikipedia.org/wiki/Wavelet_transform). This transform cross-multiplies a function against the Haar wavelet with various shifts and stretches, like the Fourier transform cross-multiplies a function against a sine wave with two phases and many stretches. The Haar transform is one of the oldest transform functions, proposed in 1910 by the Hungarian mathematician [Alfréd Haar](https://en.wikipedia.org/wiki/Alfr%C3%A9d_Haar" \o "Alfréd Haar). It is found effective in applications such as signal and image compression in electrical and computer engineering as it provides a simple and computationally efficient approach for analysing the local aspects of a signal. The Haar transform is derived from the Haar matrix. An example of a 4×4 Haar transformation matrix is shown below.

* The Haar transform can be thought of as a sampling process in which rows of the transformation matrix act as samples of finer and finer resolution. Compare with the [Walsh transform](https://en.wikipedia.org/wiki/Walsh_transform), which is also 1/–1, but is non-localized.

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1. **Discrete cosine transform: (DCT)**is a transform that is mainly used in compression algorithms. As DCT was mainly introduced for image compression algorithms, we can try to understand it in terms of images. DCT on an image acts the same way the discrete fourier transform (DFT) works on a bunch of discrete values. It tries to approximate the pixels using cosine waves. This allows us to store it efficiently in a compressed form. Several formulas define DCT, but the most common one is given below: Here, the sequence of data is **x(n), with n=0,1,2,...,N. X(k)** represents the **kth** transform.

* **Applications:**
* Image compression algorithms like JPEG and HEIF.
* Audio file formats like MP3, AAC, and more.
* Video file formats like MPEG.
* Scientists and Engineers also use them for digital signal processing, telecommunications, and more.

1. **Describe in detail about various types of mean filters?**

* Mean filters are a category of image processing filters that are used to smooth or blur an image by averaging the pixel values in a local neighborhood around each pixel. These filters are simple and effective at reducing noise and removing fine details from an image. There are various types of mean filters, each with its own characteristics. Here some common types of mean filters in detail:

1. **Geometric Mean Filter:** The geometric mean filter replaces each pixel value with the geometric mean of pixel values within a neighborhood. This filter is particularly useful for images with multiplicative noise, such as speckle noise.

* **Mathematical Formulation:** The geometric mean is calculated by taking the product of pixel values within the neighborhood and then taking the nth root, where n is the number of pixels in the neighborhood: **P\_new(x, y) = (Π P(x', y'))^(1/(w \* h))**
* **Effect:** The geometric mean filter is effective at reducing multiplicative noise while preserving edges and structural details better than the arithmetic mean filter.

1. **Harmonic Mean Filter:** The harmonic mean filter replaces each pixel value with the harmonic mean of pixel values within a neighborhood. It is particularly effective at reducing the impact of extreme values or outliers in the neighborhood.

* **Mathematical Formulation:** The harmonic mean is calculated as the reciprocal of the average of the reciprocals of pixel values within the neighborhood**: P\_new(x, y) = (w \* h) / (Σ (1 / P(x', y')))**
* **Effect:** The harmonic mean filter can effectively reduce the impact of outliers and spikes in pixel values, making it suitable for certain noise reduction tasks.

1. **Contraharmonic Mean Filter:** The contraharmonic mean filter is designed to handle both positive and negative outliers in the pixel values within a neighborhood. It has two parameters: Q (order) and p (power).

* **Mathematical Formulation:** The contraharmonic mean is calculated as the ratio of the sum of the pth power of pixel values to the sum of the (p-1)th power of pixel values within the neighborhood: **P\_new(x, y) = (Σ(P(x', y')^(p+1))) / (Σ(P(x', y')^p))**
* **Effect:** The contraharmonic mean filter can be adjusted to emphasize positive or negative outliers. When Q is positive, it emphasizes positive outliers, and when Q is negative, it emphasizes negative outliers. This filter can be useful in image restoration and denoising tasks.

Each type of mean filter has its own advantages and limitations, and the choice of filter depends on the specific requirements of the image processing task. Generally, mean filters are simple and effective for noise reduction and image smoothing but may result in some loss of image details.

1. **What are the types of noise models? Explain in detail?**

* In advanced computer vision, understanding and modeling noise is crucial for accurate image analysis and enhancement. Various types of noise can corrupt digital images, and different noise models are used to describe and simulate these disturbances. Here, I'll explain some common types of noise models in detail, focusing on their relevance in advanced computer vision:

1. **Additive White Gaussian Noise (AWGN):**

* **Description:** AWGN is a common type of noise characterized by its statistical properties. It's an additive noise, meaning it's added to each pixel value independently and follows a Gaussian (normal) distribution.
* **Properties: Mean (μ):** Usually zero, but it can be adjusted.
* **Variance (σ^2):** Determines the spread or strength of noise.
* **Application in Advanced Computer Vision:** AWGN is relevant in computer vision tasks when modeling sensor noise, noise introduced during image transmission, or noise during data augmentation for training deep learning models.

1. **Salt-and-Pepper Noise:**

* **Description:** Salt-and-pepper noise is a type of noise that randomly replaces some pixel values with either the minimum or maximum possible value (e.g., 0 or 255 in an 8-bit grayscale image).
* **Properties: Noise fraction:** Determines the percentage of pixels affected by this noise.
* **Application in Advanced Computer Vision:** Salt-and-pepper noise modeling is important for simulating noisy conditions in computer vision tasks, such as object detection and image segmentation, where robustness to noise is essential.

1. **Speckle Noise:**

* **Description:** Speckle noise is a multiplicative noise that affects pixel values by multiplying them with random values drawn from a multiplicative distribution. Speckle noise is commonly modeled as a multiplicative Gaussian noise.
* **Properties: Multiplicative factor:** Determines the strength of noise.
* Application in Advanced Computer Vision: Speckle noise is relevant in remote sensing, medical imaging, and satellite imagery analysis. Accurate modeling is necessary for denoising and feature extraction in these domains.

1. **Poisson Noise:**

* **Description:** Poisson noise is associated with the inherent randomness in photon arrivals during image acquisition. It's particularly relevant in low-light imaging conditions.
* **Properties: Intensity parameter (λ):** Represents the average photon count.
* **Application in Advanced Computer Vision:** Poisson noise modeling is crucial in fields like fluorescence microscopy, where photon counting is used. It impacts image segmentation, object tracking, and quantitative analysis.

1. **Quantization Noise:** Description: Quantization noise occurs due to the limited number of discrete levels in the digitization process, such as when converting analog data to digital values.

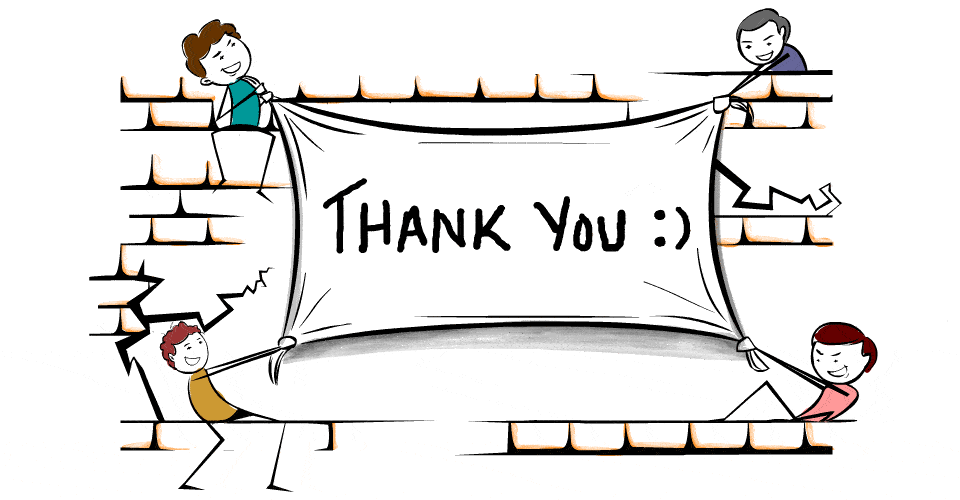
* **Properties: Depends on the bit depth:** Higher bit depths result in less quantization noise.
* **Application in Advanced Computer Vision:** Understanding quantization noise is vital in high-precision imaging systems, where accurate intensity measurements and feature extraction are required.

1. **Color Noise:**

* **Description:** Color noise refers to noise that affects color channels in color images. It can be modeled similarly to grayscale noise but independently for each color channel (e.g., Red, Green, and Blue).
* **Properties:** Similar to the properties of the grayscale noise models.
* Application in Advanced Computer Vision: Color noise modeling is essential in computer vision tasks that involve color image analysis, including object recognition and scene understanding.

Understanding and modeling these noise types is essential for designing robust computer vision algorithms, image enhancement techniques, and deep learning models that can perform well under various noise conditions commonly encountered in advanced computer vision applications.

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