KITES CV course (by Amit Sir)

Lecture 1:

Digital images originate from various digital imaging modalities, each utilizing different parts of the electromagnetic spectrum or other physical phenomena to capture images. Gamma-ray imaging is used for high-energy photon detection, while X-ray imaging, known for its application in medical diagnostics, uses lower energy photons. Computed tomography (CT) imaging combines X-rays with computer processing to create cross-sectional images. Ultraviolet imaging captures wavelengths shorter than visible light, and visible-spectrum imaging is the most common, using the range of light visible to the human eye. Millimeter-wave imaging uses longer wavelengths than infrared, often for security applications, whereas radio-band imaging captures even longer wavelengths used in astronomy. Ultrasound imaging employs sound waves to create images of internal body structures, and electron microscopy uses electron beams for high-resolution imaging at the microscopic level. Information overlays and human-generated imagery add another layer, incorporating additional data or artistic elements into images. Image processing spans various techniques, categorized into low-level (basic operations like noise reduction), mid-level (object recognition), and high-level processing (scene understanding). Major topics in image processing encompass enhancement, restoration, compression, and analysis, each critical for interpreting and utilizing digital images effectively.

Lecture 2:

The human eye's anatomy includes structures such as the cornea, lens, retina, and fovea. The fovea, a small central pit in the retina, is crucial for sharp central vision and is densely packed with cone cells. Brightness perception varies depending on context and light conditions, and optical illusions highlight the complexities of visual perception, demonstrating how our brain interprets visual information. Rods and cones are the photoreceptor cells in the retina, with rods being more sensitive to low light and cones responsible for color vision. Color spaces describe how colors can be represented; additive color spaces like RGB are used in digital displays, while subtractive color spaces like CMYK are used in printing. The HSV (hue, saturation, value) model describes colors in terms of their shade, intensity, and brightness. Tristimulus values are a set of three numbers that describe the color of a light source in terms of human color perception. Color gamuts represent the range of colors that can be displayed or printed by a device. The RPI's Smart Lighting Engineering Research Center focuses on innovative lighting technologies. Lastly, image manipulation in Matlab involves various techniques for processing and analyzing visual data

Lecture 3:

Image Sensors

- Overview of devices that convert light into electronic signals, fundamental for digital imaging.

Perspective Projection

- Explanation of how three-dimensional objects are represented on a two-dimensional image plane, creating the illusion of depth.

CCD Array Sizes and Pixels

- Discussion on Charge-Coupled Device (CCD) arrays, detailing their sizes and the role of individual pixels in capturing image data.

The Bayer Array; Color Sensing

- Introduction to the Bayer filter array used in digital cameras for color sensing, allowing cameras to capture color information with a mosaic of red, green, and blue filters.

Illumination Model

- Description of models that simulate how light interacts with surfaces, crucial for realistic image rendering and computer vision applications.

Sampling and Quantization

- Explanation of the processes of sampling (converting continuous signals to discrete ones) and quantization (assigning discrete values to sampled data) in digital imaging.

Matlab Demo

- Demonstration of image processing techniques using Matlab, a powerful tool for analyzing and visualizing image data.

Image Coordinate Systems

- Discussion on the coordinate systems used to define positions within an image, essential for image manipulation and analysis.

Useful Matlab Commands

- List of useful Matlab commands for image processing, providing practical tools for working with images.

Pixel Neighbors and Distances

- Explanation of how pixels relate to their neighbors and the concept of pixel distances, important for image filtering and edge detection.

Slow Motion Video of a Camera Shutter

- Analysis of slow-motion footage showing the operation of a camera shutter, offering insights into the mechanics of image capture.

Lecture 4:

Image Histograms

- An overview of image histograms, which graphically represent the distribution of pixel intensity values in an image.

Matlab Example

- Demonstration of creating and analyzing image histograms using Matlab, illustrating practical applications.

Point Operations

- Discussion of point operations, which modify pixel values independently, crucial for various image enhancement techniques.

Thresholding

- Explanation of thresholding, a technique used to segment images by converting grayscale images into binary images based on intensity values.

Digital Negative

- Introduction to the digital negative, where image intensities are inverted, producing a photographic negative effect.

Contrast Stretching

- Description of contrast stretching, a method to enhance the contrast of an image by stretching the range of intensity values.

Matlab's imtool

- Overview of Matlab's `imtool`, an interactive tool for displaying and exploring images, useful for visualizing and analyzing image data.

Histogram Equalization

- Explanation of histogram equalization, a technique to improve the contrast of an image by redistributing intensity values, making the histogram more uniform.

Histogram Specification

- Discussion of histogram specification, which modifies an image so that its histogram matches a specified distribution.

Gamma Correction

- Introduction to gamma correction, a nonlinear operation used to adjust the brightness of an image, ensuring proper display on different devices.

Intro to Spatial Filters

- Overview of spatial filters, which process images based on the pixel values in a local neighborhood, used for various effects like blurring and sharpening.

Intro to Edge Detection

- Explanation of edge detection, a fundamental image processing technique used to identify and locate significant transitions in intensity, highlighting object boundaries.

Lecture 5:

Geometric Operations

- Introduction to geometric operations in image processing, which involve altering the spatial arrangement of pixels.

Translation

- Explanation of translation, which shifts an image in the x and y directions without altering its orientation or size.

Scaling

- Discussion of scaling, which changes the size of an image by increasing or decreasing the distance between pixels.

Flipping

- Overview of flipping, which mirrors an image either horizontally or vertically.

Linear Transformations

- Explanation of linear transformations, which include operations like rotation and scaling, described by linear equations.

Rotation

- Description of rotation, which turns an image around a specified point by a certain angle.

Similarity Transformations

- Introduction to similarity transformations, combining rotation, scaling, and translation while preserving the shape of objects.

Shears

- Discussion of shears, which slant the shape of an image along the x or y axis, altering its geometry without changing area.

Affine Transformations

- Explanation of affine transformations, which include linear transformations followed by translation, preserving points, straight lines, and planes.

Matlab Examples

- Demonstration of various geometric operations using Matlab, providing practical examples of implementation.

Projective Transformations

- Overview of projective transformations, which map lines to lines but do not necessarily preserve parallelism, used in perspective corrections.

Example: Estimating a Projective Transformation

- A practical example of estimating a projective transformation, illustrating how to calculate the transformation matrix from corresponding points.

Creating the Output Image

- Explanation of creating the output image after applying geometric transformations, ensuring accurate representation of the transformed image.

Bilinear Interpolation

- Introduction to bilinear interpolation, a resampling method used to interpolate pixel values when transforming images, enhancing smoothness and continuity.

Lecture 6:

Spatial Filters

- Introduction to spatial filters, which operate directly on the pixels of an image to enhance or detect features.

Connection to Convolution

- Explanation of the relationship between spatial filters and convolution, a mathematical operation used to apply filters to images.

The Spatial Domain

- Discussion on the spatial domain, where image processing techniques are applied directly to the image pixels.

Applying Spatial Filters

- Overview of the process of applying spatial filters, including the mechanics of convolving a filter kernel with an image.

Smoothing Filters

- Introduction to smoothing filters, which reduce noise and detail by averaging the pixel values within a neighborhood.

Filtering in Matlab

- Demonstration of various filtering techniques using Matlab, showcasing practical implementations.

Averaging to Remove Gaussian Noise

- Explanation of using averaging filters to reduce Gaussian noise, a common type of statistical noise in images.

Sharpening Filters

- Discussion on sharpening filters, which enhance the edges and fine details in an image.

General Low-Pass Filters

- Overview of low-pass filters, which allow low-frequency components to pass through while attenuating high-frequency noise.

Horizontal and Vertical Edge Detectors

- Explanation of edge detection filters designed to highlight horizontal and vertical edges in an image.

The Laplacian

- Introduction to the Laplacian filter, a second-order derivative filter used for edge detection and enhancement.

Matlab Examples

- Practical examples of applying various spatial filters using Matlab to illustrate their effects on images.

Enhancing Edges

- Techniques for enhancing edges in an image, making them more prominent and defined.

Unsharp Masking

- Explanation of unsharp masking, a technique that enhances the contrast of edges by subtracting a blurred version of the image from the original.

Sobel Edge Detectors

- Introduction to Sobel edge detectors, which use convolution with Sobel kernels to detect edges based on gradients.

The Median Filter (Nonlinear)

- Discussion on the median filter, a nonlinear filter that reduces noise while preserving edges by replacing each pixel with the median value of its neighborhood.

Lecture 7:

The 1-D Fourier Transform

- Introduction to the 1-dimensional Fourier Transform, which transforms a time-domain signal into its frequency components.

The 2-D Fourier Transform

- Explanation of the 2-dimensional Fourier Transform, which is used to analyze spatial frequencies in images.

Interpreting the 2D FT Decomposition

- Discussion on how to interpret the decomposition of an image into its 2D Fourier Transform components.

The 2D FT Basis Functions

- Overview of the basis functions used in the 2D Fourier Transform, which are sinusoidal patterns.

Interpreting the 2D FTs of Natural Images

- Analysis of how natural images can be represented and interpreted using their 2D Fourier Transforms.

Matlab's fftshift

- Explanation of Matlab's `fftshift` function, which shifts the zero-frequency component to the center of the spectrum.

Artifacts Caused by Image Boundaries

- Examination of artifacts that can occur in the Fourier Transform due to image boundaries.

A Lower-Frequency Image

- Analysis of images dominated by low-frequency components, typically resulting in smoother images.

An Image with Strong Edges

- Discussion on the Fourier Transform of images with strong edges, showing higher frequency components.

A High-Frequency Image

- Examination of images with significant high-frequency components, which often appear detailed or noisy.

Fourier Transform Properties

- Overview of key properties of the Fourier Transform, such as linearity, symmetry, and convolution.

Circular Convolution

- Explanation of circular convolution and its implications in the frequency domain.

Zero Padding

- Discussion on zero padding, which involves adding zeros to an image to increase its size, affecting its Fourier Transform.

Edge Orientations in Spatial vs. Frequency Domains

- Analysis of how edge orientations in the spatial domain are represented in the frequency domain.

Sudoku Image Example

- A practical example using a Sudoku image to demonstrate the concepts discussed.