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| **Scheme of Valuation/Answer Key**<br>(Scheme of evaluation (marks in brackets) and answers of problems/key) | | | |
| **APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**<br>Eighth Semester B.Tech Degree (R,S) Examination May 2024 (2019 Scheme) | | | |
| **Course Code: CST438** | | | |
| **Course Name: IMAGE PROCESSING TECHNIQUE** | | | |
| Max. Marks: 100 | | | Duration: 3 Hours |
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| **PART A** | | | |
| | | ***Answer all questions, each carries 3 marks.*** | Marks |
| 1 | | The basic elements of visual perception are the structure of the eye, image formation in the eye, brightness adaptation, and discrimination. The eyes act as a sensor or camera, neurons act as the connecting cable, and the brain acts as the processor. In addition to these basic elements, there are seven components of visual perception that are important for learning: visual discrimination, visual memory, spatial relationships, form constancy, sequential memory, visual figure-ground, and visual closure. | (3) |
| 2 | | Spatial resolution refers to the number of pixels used in making an image, while intensity resolution refers to the number of intensity levels used to represent the image. Spatial resolution determines the clarity or sharpness of an image. Higher spatial resolution means higher image quality and higher amount of pixels required to represent the image. On the other hand, higher intensity level resolution means finer level of detail discernible in an image. | (3) |
| 3 | | The 2D Fourier Transform has several properties that make it useful in image processing and analysis. Some of these properties include:<br>Translation Distributivity and Scaling<br>Rotation Periodicity and Conjugate Symmetry<br>Separability<br>Convolution and Correlation | (3) |
| 4 | | Solve the problem using Hadamard Transform | (3) |
| 5 | | Unsharp masking is a technique used in digital image processing to sharpen an image by increasing its apparent resolution. It works by creating a blurred copy of the original image and then subtracting this blurred copy from the original image. The result is an image that appears sharper because it has a higher | (3) |

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| | | contrast between adjacent pixels.<br>Crispening is a term used in the photographic and printing industries to describe the process of sharpening edges in an image. Unsharp masking is commonly used for crispening edges. | |
| 6 | | Median filtering is a non-linear digital filtering technique that is often used to remove noise from an image or signal. It works by replacing the gray level of each pixel by the median of the gray levels in a neighborhood of the pixels, instead of using the average operation. Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise.<br>Some features of median filtering include:<br>- It is very effective at removing impulse noise, such as "pepper and salt" noise, in an image.<br>- It progresses across different regions of the image in terms of pixel by pixel.<br>- It can be used for edge detection.<br>- It can improve the contrast of an image.<br>- It can highlight contour regions. | (3) |
| 7 | | The Sobel and Prewitt operators are two commonly used edge detection filters in image processing. Both filters are used to detect edges in an image by approximating the gradient magnitude of the image.<br>The Sobel operator is a derivative-based filter that uses two 3x3 kernels to calculate the gradient of an image. The first kernel calculates the gradient in the x-direction, while the second kernel calculates the gradient in the y-direction[5]. The Sobel operator is very similar to the Prewitt operator, but it has a slightly better noise reduction capability.<br>The Prewitt operator is also a derivative-based filter that uses two 3x3 kernels to calculate the gradient of an image. The first kernel calculates the gradient in the x-direction, while the second kernel calculates the gradient in the y-direction[1]. The Prewitt operator is used for detecting edges horizontally and vertically. | (3) |
| 8 | | The geometric mean filter is better at removing Gaussian type noise and preserving edge features than the arithmetic mean filter. The geometric mean filter achieves smoothing comparable to the arithmetic mean filter but tends to | (3) |

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| | | lose less image detail in the process. Therefore, the image restored using the geometric mean filter will be less blurred than that restored using the arithmetic mean filter. | |
| 9 | | Erosion and dilation are two fundamental morphological operations used in image processing. Erosion removes pixels on object boundaries and shrinks the size of objects in an image. Dilation adds pixels to the boundaries of objects in an image and increases the size of objects. The number of pixels added or removed from objects in an image depends on the size and shape of the structuring element used to process the image | (3) |
| 10 | | A structuring element is a matrix that identifies the pixel in the image being processed and defines the neighbourhood used in the processing of each pixel. It is an essential part of morphological dilation and erosion operations. The structuring element is used to probe the input image and create an output image of the same size. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbours.<br>Structuring elements can be created using different shapes such as lines, disks, squares, rectangles, and crosses. The size and shape of a structuring element depend on the specific application. For example, a line-shaped structuring element can be used to detect horizontal or vertical edges in an image. | (3) |
| | | **PART B** | |
| | | ***Answer one full question from each module, each carries 14 marks.*** | |
| | | **Module I** | |
| 11 | a) | The relationship between image size, spatial resolution, and image quality is that the larger the image size, the higher the spatial resolution and the better the image quality. Spatial resolution refers to the number of pixels per unit area in an image. The higher the spatial resolution, the more detail an image can capture. Image quality is also affected by other factors such as contrast, brightness, and noise.<br>Grey level resolution and intensity resolution are both measures of how well an imaging system can distinguish between different levels of brightness in an image. Grey level resolution refers to the number of grey levels that can be distinguished by an imaging system. Intensity resolution refers to the smallest | (7) |

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| | | change in intensity that can be detected by an imaging system. Grey level resolution is usually expressed in bits while intensity resolution is expressed in units of intensity per bit. Detailed explanation required. | |
| | b) | Blocking artifacts and false contours are common image artifacts that can occur during image compression. Blocking artifacts are caused by the block-based nature of image compression algorithms such as JPEG. These algorithms divide an image into blocks and compress each block separately. When the compression ratio is high, the blocks become more visible and can create a checkerboard-like pattern in the image. False contours are caused by the quantization of color values during compression. This can result in a loss of color information and the appearance of banding or posterization in the image. Detailed explanation required. | (7) |
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| 12 | a) | Arithmetic operations on images include addition, subtraction, multiplication, and division. These operations are performed on the pixel values of two or more images to create a new image. For example, adding two images together will result in an image where each pixel is the sum of the corresponding pixels in the original images.<br>Logical operations on images include AND, OR, and NOT operations. These operations are performed on the binary values of two or more images to create a new binary image. For example, performing an AND operation on two binary images will result in a new binary image where each pixel is 1 if both corresponding pixels in the original images are 1.<br>Geometrical operations on images include translation, rotation, scaling, and shearing. These operations are used to transform an image into a new image with a different size or orientation. For example, rotating an image by 90 degrees will result in a new image where each row of pixels in the original image becomes a column of pixels in the new image.<br>Detailed explanation with examples required. | (7) |
| | b) | Image interpolation is the process of estimating the value of a pixel at a non-integer location based on the values of surrounding pixels. It is used to resize an image or to transform an image from one coordinate system to another. Image interpolation is important because it allows us to display images at different | (7) |

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| | | sizes and resolutions without losing important details.<br><br>There are several types of image interpolation methods, including nearest-neighbor interpolation, bilinear interpolation, bicubic interpolation, and Lanczos interpolation. Nearest-neighbor interpolation is the simplest method and involves selecting the value of the nearest pixel to the non-integer location. Bilinear interpolation involves taking a weighted average of the four nearest pixels to the non-integer location. Bicubic interpolation involves taking a weighted average of the 16 nearest pixels to the non-integer location. Lanczos interpolation is a more complex method that involves using a windowed sinc function to interpolate the pixel values. | |
| | | **Module II** | |
| 13 | a) | The Discrete Fourier Transform (DFT) is a mathematical technique used to transform a discrete-time signal from the time domain to the frequency domain. It is widely used in signal processing and image processing applications.<br>The properties of DFT include linearity, time shifting, frequency shifting, and convolution. Linearity means that the DFT of a linear combination of signals is equal to the linear combination of the DFTs of the individual signals. Time shifting means that the DFT of a time-shifted signal is equal to the DFT of the original signal multiplied by a phase factor. Frequency shifting means that the DFT of a frequency-shifted signal is equal to the DFT of the original signal multiplied by another complex exponential. Convolution means that the DFT of the convolution of two signals is equal to the product of their individual DFTs.<br>To prove that a 4x4 matrix is unitary, we need to show that its inverse is equal to its conjugate transpose. Let A be a 4x4 matrix. The inverse of A is denoted by A^-1 and its conjugate transpose is denoted by A^H.<br>If A is unitary, then A^-1 = A^H. To prove this, we can start by computing A*A^H and A^H*A. If these two products are equal to the identity matrix I, then A^-1 = A^H. | (7) |
| | b) | To compute the 2D DFT of a grayscale image, we first need to convert the image into a matrix of pixel values. In this case, the 4x4 grayscale image can be represented by the matrix:<br>[1 1 1 1; 1 1 1 1; 1 1 1 1; 1 1 1 1]<br>Apply DFT and find out the solution. | (7) |

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| 14 | a) | To compute the 2D DCT of an image patch, we first need to convert the image patch into a matrix of pixel values. Apply the DCT and find out the solution | (9) |
| | b) | The Hadamard transform is a linear transformation that maps an input sequence of length N into an output sequence of length N. The transform matrix is a square matrix of size N x N that is defined recursively as follows:<br>H(1) = [1]<br>H(2) = [1 1; 1 -1]<br>H(4) = [H(2) H(2); H(2) -H(2)]<br>The sequency of a signal is a more generalized notion of frequency that can be used to estimate the signal frequencies in the original signal. The Walsh-Hadamard transform returns sequency values which are defined as one half of the average number of zero-crossings per unit time interval. Each Walsh function has a unique sequency value.<br>In the context of Hadamard transform, sequency refers to the number of sign changes in the transformed sequence. The sequency-ordered fast Walsh-Hadamard transform (FWHTw) is obtained by computing the FWHT as above and then rearranging the outputs. | (5) |
| | | **Module III** | |
| 15 | a) | Homomorphic filtering is a technique used for image processing that involves a nonlinear mapping to a different domain in which linear filter techniques are applied, followed by mapping back to the original domain. The homomorphic filtering process consists of five steps:<br>1. A natural log transform (base e)<br>2. The Fourier transform<br>3. Filtering<br>4. The inverse Fourier transform<br>5. The inverse log function (exponential)<br>In homomorphic filtering we first transform the multiplicative components to additive components by moving to the log domain. Then we apply a high-pass filter to the log-transformed image. The high-pass filtering step provides us with an opportunity to simultaneously apply other enhancements to the image. | (5) |
| | b) | Frequency domain filters are different from spatial domain filters as they focus | (9) |

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| | | on the frequency of the images. They are used for two basic operations: smoothing and sharpening. There are three types of frequency domain filters:<br>1. Low pass filter: Low pass filter removes the high frequency components that means it keeps low frequency components. It is used for smoothing the image.<br>2. High pass filter: High pass filter removes the low frequency components that means it keeps high frequency components. It is used for sharpening the image.<br>3. Band pass filter: Band pass filter removes both high and low frequency components and keeps only middle-frequency components.<br>The basic idea behind sharpening an image using a high-pass filter is to enhance edges and other high-frequency components in an image. The basic steps for filtering in the frequency domain are:<br>1. Transform the image into its frequency domain representation using Fourier transform<br>2. Apply a filter to remove unwanted frequencies<br>3. Transform back to spatial domain using inverse Fourier transform<br>Detailed explanation required. | |
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| 16 | a) | Butterworth filters are a type of frequency domain filter that can be used for image enhancement1. Butterworth low-pass filter is used to remove high-frequency noise with minimal loss of signal components in the specified pass-band with order n2. The transfer function of a Butterworth low-pass filter (BLPF) of order n, and with cutoff frequency at distance D0 from the origin, is defined as 3:<br>H(u,v) = 1 / (1 + (D(u,v)/D0)^(2n))<br>where D(u,v) is the distance between point (u,v) and the center of the Fourier transform of an image.<br>Butterworth high-pass filter is used for image sharpening in the frequency domain1. It removes low-frequency components from an image and preserves high-frequency components1. The transfer function of a Butterworth high-pass filter (BHPF) of order n, and with cutoff frequency at distance D0 from the origin, is defined as 1:<br>H(u,v) = 1 / (1 + (D0/D(u,v))^(2n))<br>where D(u,v) is the distance between point (u,v) and the center of the Fourier | (5) |

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| | | transform of an image. Detailed explanation required. | |
| | b) | Frequency domain filters are used for smoothing and sharpening of images by removing high or low frequency components[2]. Smoothing filters remove details from images by suppressing low-frequency components with the effect of making them blurred. Sharpening filters do just the opposite; they emphasize regions with high spatial frequency to highlight details.<br>Low-pass filters are used for smoothing images in the frequency domain by attenuating high-frequency components. High-pass filters are used for sharpening images in the frequency domain by removing low-frequency components. Detailed explanation required. | (9) |
| | | **Module IV** | |
| 17 | a) | The three methods to estimate degradation function used for image restoration are:<br>1. **Blind deconvolution**: This method is used when the degradation function is unknown. It involves estimating both the original image and the degradation function simultaneously. Blind deconvolution is an ill-posed problem and requires additional constraints to be solved.<br>2. **Non-blind deconvolution**: This method is used when the degradation function is known. It involves estimating the original image from the degraded image and the known degradation function.<br>3. **Parametric deconvolution**: This method is used when the degradation function can be modeled by a parametric function. It involves estimating the parameters of the degradation function and then using them to restore the original image. | (8) |
| | b) | Edge detection is a fundamental concept in image processing that involves identifying points in a digital image at which the image brightness changes sharply or has discontinuities. Edge detection can be performed using first-order and second-order derivatives.<br>To find edges from a first order derivative you look for the extrema, and to find edges in second order derivatives you look for zero-crossings. If you take these values in either method, you should end up with a binary image with single pixel edges.<br>Second order operators are used to detect edges by approximating second-order | (6) |

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| | | derivatives of pixel values in an image. A very popular second order operator is the Laplacian operator. The Laplacian of a function f (x, y), denoted by $\nabla^2 f(x,y)$, is defined by :<br>$\nabla^2 f(x,y) = \partial^2 f(x,y)/\partial x^2 + \partial^2 f(x,y)/\partial y^2$ | |
| | | **OR** | |
| 18 | a) | Thresholding-based segmentation is a technique that generates a binary image from a given grayscale image by separating it into two regions based on a threshold value. Segmentation procedures are usually done using two approaches - detecting discontinuity in images and linking edges to form the region (known as edge-based segmenting), and detecting similarity among pixels based on intensity levels (known as threshold-based segmenting).<br>There are various thresholding-based segmentation methods such as global thresholding, variable thresholding, entropy-based thresholding, etc. Global thresholding is one of the simplest methods where a single threshold value is used for the entire image. It works well when the intensity distribution of objects and background are sufficiently distinct. Detailed explanation required. | (8) |
| | b) | Mean filters are used in image restoration process to reduce noise in images[3]. There are various mean filters such as arithmetic mean filter, geometric mean filter, harmonic mean filter, and contraharmonic mean filter.<br>Arithmetic mean filter is the simplest of the mean filters where each pixel in the image is replaced by the average value of its neighboring pixels. Geometric mean filter obtains a greater smoothing effect as compared to the arithmetic mean filter[2]. Harmonic mean filter is used for removing salt-and-pepper noise from images[3]. Contraharmonic mean filter is used for removing noise that has been introduced by some form of signal processing. Detailed explanation required. | (6) |
| | | **Module V** | |
| 19 | a) | Erosion and dilation are two fundamental morphological operations that are used in image processing. They are used to remove or add pixels from an image based on the shape of the structuring element.<br>Erosion is a morphological operation that shrinks the boundaries of the foreground object in an image. It is done by moving the structuring element over the image and checking if all the pixels under the structuring element are | (5) |

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| | | foreground pixels. If all the pixels are foreground pixels, then the center pixel is set to 1 (foreground), otherwise it is set to 0 (background).<br>Dilation is a morphological operation that expands the boundaries of the foreground object in an image. It is done by moving the structuring element over the image and checking if any of the pixels under the structuring element are foreground pixels. If any of the pixels are foreground pixels, then the center pixel is set to 1 (foreground), otherwise it is set to 0 (background). | |
| | b) | The minimum perimeter polygon method is a polygon approximation approach that involves finding a polygon with the shortest possible boundary length that encloses a given set of points. This method can be used to approximate a shape by a polygon with fewer vertices.<br>The minimum perimeter polygon can be found by using an iterative algorithm that starts with an initial polygon and then iteratively removes vertices until the perimeter of the polygon cannot be reduced any further. The algorithm works by removing vertices that do not significantly increase the perimeter of the polygon.<br>Detailed explanation required | (9) |
| | | **OR** | |
| 20 | a) | Morphological operations are a collection of non-linear operations related to the shape or morphology of features in an image. Morphological operations rely only on the relative ordering of pixel values, not on their numerical values, and therefore are especially suited to the processing of binary images.<br>Morphological operations apply a structuring element to an input image, creating an output image of the same size. The structuring element is moved across every pixel in the original image to give a pixel in a new processed image. The value of this new pixel depends on the morphological operation performed. The two most widely used operations are Erosion and Dilation.<br>Erosion is used to erode away boundaries of foreground objects (i.e., objects that we want to segment from an image) by applying a structuring element to the image3. Dilation is used to dilate or expand boundaries of foreground objects by applying a structuring element to the image. Other morphological operations include opening, closing, morphological gradient, black hat and top hat. Detailed explanations required. | (6) |

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| | b) | Boundary representation (B-rep) is a method for representing shapes using the limits. A solid is represented as a collection of connected surface elements, the boundary between solid and non-solid1. B-reps describe a three-dimensional object as a set of surfaces that separate the object interior from the environment.<br>In image processing, boundary extraction is used to extract boundaries of objects in an image. Two boundary representation schemes in image processing are:<br>Chain codes: Chain codes represent boundaries by a connected sequence of straight-line segments of specified length and direction. Examples of chain codes include 4-directional chain codes and 8-directional chain codes.<br>Boundary descriptors: Boundary descriptors represent boundaries by a set of features that describe their shape. Examples of boundary descriptors include Fourier descriptors and Zernike moments. Detailed explanations required. | (8) |
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