**Q1. Explain the basic components of a digital image and how it is represented in a computer. State the differences between grayscale and color images.**

**Basic Components of a Digital Image**

A digital image consists of a grid of pixels (short for "picture elements"). Each pixel represents a small portion of the image, containing information about its color and intensity. Digital images are typically stored as matrices, where each element corresponds to the color or intensity of a pixel.

**Image Representation in a Computer:**

Pixels: The smallest unit of a digital image, with each pixel containing numerical data that represents the color and brightness.

Resolution: The dimensions of the image, are usually given as width x height in pixels.

Color Depth: The number of bits used to represent each pixel’s color information, determining the range of colors.

**Differences Between Grayscale and Color Images**

**a.Grayscale Images:**

- Represented by shades of gray, ranging from black to white.

- Each pixel stores a single value, usually indicating brightness

- Require less storage space compared to color images.

**b.Color Images:**

- Represented by a combination of color channels (typically Red, Green, and Blue – RGB).

- Each pixel stores three values corresponding to the intensity of each color channel.

- Require more storage space because of the additional color data.

**Q2. Define Convolutional Neural Networks (CNNs) and discuss their role in image processing. Describe the key advantages of using CNNs over traditional neural networks for image-related tasks.**

**Convolutional Neural Networks (CNNs):**

Convolutional Neural Networks (CNNs) are a class of deep learning models designed specifically for processing grid-like data, such as images. They use convolutional layers that apply filters to input images, detecting features like edges, textures, and patterns. CNNs are capable of automatically learning spatial hierarchies of features, making them ideal for tasks like image classification and object detection.

**Role of CNNs in Image Processing:**

CNNs excel in image processing by automatically learning features from raw image data, eliminating the need for manual feature extraction. They are highly effective in tasks such as image classification, segmentation, and object recognition. CNNs capture spatial dependencies in images, making them much more efficient than traditional neural networks for visual data.

**Key Advantages of CNNs Over Traditional Neural Networks**

**a)Parameter Sharing:** CNNs use shared weights in convolutional layers, reducing the number of parameters and making the model more efficient. This allows CNNs to handle high-dimensional image data with fewer parameters than fully connected layers in traditional networks.

**b)Local Connectivity:** CNNs focus on local regions of the image (using filters), allowing them to capture local features like edges or textures. This local connectivity helps in recognizing spatial patterns, which is crucial for image-based tasks.

**c)Translation Invariance:** CNNs are invariant to small translations or shifts in the image. By learning hierarchical features, CNNs can recognize objects regardless of their position in the image, making them robust to various distortions and orientations.

**Q3. Define convolutional layers and their purpose in a CNN. Discuss the concept of filters and how they are applied during the convolution operation. Explain the use of padding and strides in convolutional layers and their impact on the output size.**

**Convolutional Layers and Their Purpose in a CNN**

Convolutional layers in CNNs are responsible for applying filters to the input image to extract features like edges, textures, and patterns. They reduce the dimensionality of the input while preserving important spatial information. These layers enable the network to learn hierarchical features at different levels of abstraction.

**Concept of Filters and Their Application in Convolution**

Filters are small matrices that slide over the input image, performing element-wise multiplication and summation to detect features. They are learned during training to detect specific patterns such as edges or textures. Each filter produces a feature map that represents the presence of the learned feature in the image.

**Use of Padding and Strides in Convolutional Layers**

Padding involves adding extra pixels around the image to control the output size and preserve edge information. Strides refer to the step size the filter takes when moving over the image, with larger strides reducing the output size. Both padding and strides affect the spatial dimensions of the output feature map, with padding keeping the size larger and strides making it smaller.

**Q4.** **Describe the purpose of pooling layers in CNNs.Compare max pooling and average pooling operations.**

**Purpose of Pooling Layers in CNNs**

Pooling layers in CNNs are used to reduce the spatial dimensions of the feature maps, thereby decreasing the number of parameters and computational complexity. They help retain the most important features while making the network more efficient and less prone to overfitting. Pooling also provides some translation invariance, making the network more robust to variations in the input.

**Max Pooling vs Average Pooling:**

**-**Max Pooling selects the maximum value from a pool of neighboring pixels, preserving the most prominent feature in that region. It is commonly used as it helps retain sharp features.

-Average Pooling takes the average of the values in a pool, providing a smoother output. It tends to be less sensitive to noise but may blur out important features.