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Course Title — Machine Vision
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Q-1 Explain motion estimation and its general methodologies also explain how it will be useful for video tracking.

Ans **Motion estimation**

* Motion estimation is the process of determining motion vectors that describe the transformation from one 2D image to another, usually from adjacent frames in a video sequence. It is an ill-posted problem as the motion is in three dimensions but the images are a projection of the 3D Scene onto a 2D plaire.
* The motion vector may related to the whole image or specific parts, such as rectangular blocks, arbitrary shaped patches or even per pixel.

The general methodologies for motion estimation in machine vision can be categorized into two main approaches :-

① **Global motion estimation**

This approach assumes that the entire image or scene undergoes a similar motion. It estimates a global transformation or motion model that can be applied to the entire image or a significant portion of it.

1.1. **Block matching**

This is a widely used technique where the image is divided into small blocks or regions, and matching algorithms are applied to find the best matching block between consecutive frames.

Mean difference (MAD) $= \frac{1}{N^2} \sum_{i=0}^{n-1} \sum_{j=0}^{n-1} |C_{ij} - R_{ij}|$

Mean Square Error $= \frac{1}{N^2} \sum_{i=0}^{n-1} \sum_{j=0}^{n-1} (C_{ij} - R_{ij})^2$

Peak Signal-to-noise ratio (PSNR) $= 10 \log_{10} \frac{(\text{Peak to peak value of original data})^2}{MSE}$

1.2 Phase Correlation

This technique utilizes fourier transforms to estimate the phase shift between images. By calculating the cross power spectrum between two frames, the phase corelation method can determine the displacement between corresponding features in the frequency domain, which relates to the motion in the spatial domain.

The inverse fourier transform of a complex exponential is a Kronecker delta, i.e. a single peak

$$r(x,y) = \delta(x + \Delta x, y + \Delta y)$$

1.3. Optical Flow

Optical flow methods estimate the dense motion field by tracking the apparent motion of every pixel or a dense set of feature points between frames.

$$\frac{\partial I}{\partial x} V_x + \frac{\partial I}{\partial y} V_y + \frac{\partial I}{\partial t} = 0$$

thus,

$$I_x V_x + I_y V_y = -I_t$$

$$\nabla I \cdot \vec{V} = -I_t$$

Local Motion Estimation

To approach assumes that different regions of an image or scene can undergo different motions.

Feature - based tracking

This method tracks specific features or keypoints across frames, such as corners, edges, or other distinctive points.

Dense Feature tracking

Similar to feature - based tracking, dense feature tracking estimates motion for every pixel in the image.

How motion estimation will be useful in video tracking :-

Motion estimation plays a crucial role in video tracking as it enables the continuous tracking of objects or targets in a video sequence.

① Initialization

② Predictive Tracking

③ Motion - Based Track Vectorization

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④ Occlusion Handling
⑤ Track Maintenance and Correction

Overall, motion estimation in video tracking provides critical information about the target's motion, aiding in initialization, prediction, verification, occlusion handling and track maintenance.

Q.2 How Clustering can be used for image segmentation?

Ans Clustering algorithms can be utilized for image segmentation by grouping similar pixels or regions together based on their characteristics.
Here's how clustering can be applied :-

① Color - based Segmentation

Clustering can be used for color-based image segmentation. Pixels with similar color properties are grouped together to form segments.

② Texture - based Segmentation

Clustering can also be used for texture - based image segmentation. Texture features, such as local binary patterns, Gabor filters, or Haralick features, can be extracted from the image.

③ Feature - based Segmentation

Clustering can be employed to segment image based on multiple features, including color, texture, intensity and Spatial information.

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④ Superpixel Segmentation

Superpixels are compact and homogeneous regions that oven Segment an image. Clustering technique Such as SLIC or watenshed algorithms can be employed to group pixels together based on Colon Similarity.

Python Implementation

```
#KMEANS IMAGE SEGMENTATION
import numpy as np
import cv2
import matplotlib.pyplot as plt
from Sklearn.cluster import KMeans
%matplatlib inline
image_1 = cv2.imread("/Content/image_1.jpg", cv2.IMREAD_
                                               UNCHANGED)
image_2 = cv2.imread("/Content/image_2.jpg", cv2.IMREAD_
                                               UNCHANGED)
Vector_1 = image_1.reshape((-1,3))
Vector_2 = image_2.reshape((-1,3))
Kmean_1 = KMeans(n_clusters=5, random_state=0, n_int=5).
                 fit(vector_1)
C = np.uint8(Kmeans_1.cluster_centers_)
Seg_data = c[Kmeans_1.labels.flatten()]
Seg_image = seg_data.reshape((image_1.shape))
```

```
Plt.imshow(Seg_image)
Plt.pause(1)
Kmeans_2= KMeans(n_clusters=5, random_state=0, n_init...
        .fit(vector_2)
C=np.uint8(Kmeans_2.cluster_centers_)
Seg_data = C[Kmeans_2.labels_.flatten()]
Seg_image= Seg_data.reshape((image_2.shape))
Plt.imshow(Seg_image)
Plt.pause(1)
```

Q-3 Explain image Gradient, also explain its use in the edge detection.

Ans

Image Gradient

The gradient of an image can be computed using various gradient operators, with the most common ones being the Sobel, Prewitt, and Scharr operators.
These operators calculate the derivation of the image intensity in the horizontal and vertical directions.
The gradient magnitude and direction can then be obtained by combining the horizontal and vertical gradients.

mathematical calculation of image gradient

Let's take a 3*3 image and try to find an edge using an image gradient. We will start by taking a center pixel around which we want to detect the edge.

we have 4 main neighbors of the center pixel, which are:

(i)- $P(x, y-1)$ top pixel
(ii)- $P(x+1, y)$ right pixel
(iii)- $P(x-1, y)$ left Pixel
(iv)- $P(x, y+1)$ bottom Pixel

Change of intensity in the x direction is given by:-

Gradient in Y direction = PR - PL

Change of intensity in the Y direction is given by:-

Gradient in Y direction = PB - PT

Gradient for the image function is given by:-

$$\Delta I = [\delta I/\delta x, \delta I/\delta y]$$

The gradient can be represented by two components:-
① Gradient magnitude
② Gradient direction

Gradient Magnitude

$$\text{gradient magnitude} = \sqrt{((\text{change in } x)^2 + (\text{change in } y)^2)}$$

$$\text{magnitude} = \text{Sqrt}((Gx)^\wedge 2 + (Gy)^\wedge 2)$$

where
Gx → horizontal gradient
Gy → vertical gradient

Gradient Direction

The gradient direction can be calculated using the arctangent of the ratio of the vertical and horizontal gradients:

direction = atan2(Gy, Gx)

The gradient direction can be represented using angles or vector components, depending on the specific applications.

Gradient orientation represents the direction of the change of intensity level in the image.

Gradient orientation = $\tan^{-1}[(\delta I/\delta y)/(\delta I/\delta x)] * (180/\pi)$

Edge detection using image gradients typically involves the following steps :-

① Gradient Computation :-

Calculate the gradient of image using gradient operators, such as the Sobel or prewitt operators. This involves calculating the partial derivatives of the image in the horizontal and vertical directions.

② Gradient Magnitude

Compute the magnitude of the gradient by combining the horizontal and vertical gradients. This represents the strength or intensity of the intensity change in each pixel's neighborhood.

③ Thresholding :-

Apply a threshold to the gradient magnitude image to identify regions with high gradient values. This helps separate the edge pixel from the res of image

4. Edge Localization

Refine the detected edges by localizing them more accunately. This can be achieved using techniques like non-maximum Suppression, which Suppresses non-maximal gradient responses and keeps only the local maximum gradient Values along the edges.

5 Edge Linking

Connect the localized edge pixel to form Continuous edges or Contours. This is often done using techniques like edge linking with hysteresis, which Considers the gradient values and connectivity to determine whether adjacent pixels should be linked as part of the same edge.

By leveraging image gradients, edge detection algo Can determines, identify and highlights the boundaries or transitions between objects or regions in an image.

Edge detection has numerous applications in image processing, Computer vision, and pattern recognition, Serving as fundamental step in tasks like object detection, image Segmentation and feature extraction.

Q-4 Explain the region-based Segmentation, which illustrate its properties.

Ans

Region based Segmentation

Region based Segmentation is a technique in image processing and computer vision that divides an image into meaningful and coherent regions or Segments based on certain criteria or properties.

There are two variants of region-based Segmentation:-

① Top-down approach

② Bottom up approach

③ Similarity measures

④ Region merging techniques

There are many regions merging technique such as Watershed algorithm, Split and merge algorithm, etc.

Here's an overview steps involved in region-based Segmentation :-

① Initial Segmentation

The process begins by dividing the image into an initial set of regions or Superpixels.

② Region Similarity Measures

once the initial Segmentation is obtained, region Similarity measures are computed to evaluate the Similarity between adjacent regions.

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③ Region Merging or Splitting

Based on the computed similarity measures, regions are merged or split to form more coherent and meaningful segments.

④ Stopping Criteria

The iteration continues until a stopping criterion is met.

⑤ Post-Processing

Post-processing steps may be applied to refine and improve the segmentation results.

Properties of Region based Segmentation

Region-based segmentation in image processing and computer vision possesses several important properties that contribute to its effectiveness and utility.

① Homogeneity

Region based segmentation aims to create homogeneous regions or segments by grouping pixel with similar characteristics together.

② Connectivity

Region-based segmentation considers spatial connectivity, ensuring that pixels within the same segment are connected to each other.

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③ Boundary Smoothing

Region-based Segmentation tends to produce smoth and well-defined boundaries between Segments.

④ Robustness to Noise

Region based Segmentation methods are generally more robust to noise compared to edge-based methods.

⑤ Flexibility and Adaptability

Region-based Segmentation can be flexible and adaptable to different type of images and applications.

⑥ Global Information

Region based Segmentation captures global information about the image by considering the properties of entire regions.

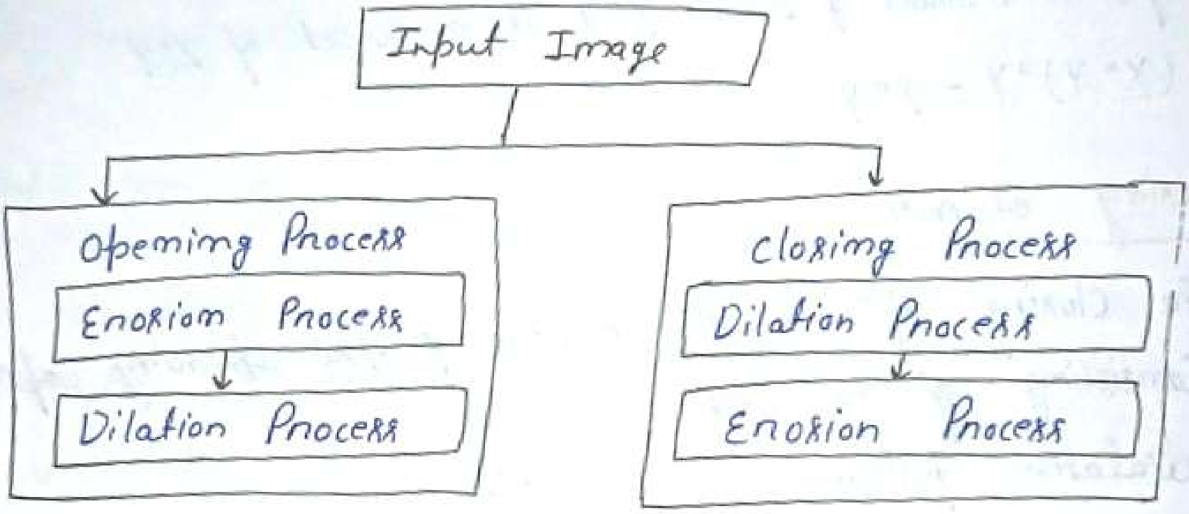
⑦ Hierarchical Representation

Region-based Segmentation can provide a hierarchical representation of the image, where Segments can be organized into a tree-like structure based on their Similarities and relationships. This hierarchical representation allows for multi-Scale analysis and Supports the extraction of different level of details from the image.

Q-5 Explain opening and closing morphology operations and their uses in image Processing

Ans

Opening and closing are dual operations used in Digital image processing for restoring an eroded image.



Opening operation

⇒ opening is generally used to restore or recover the original image of the maximum possible extent.

⇒ The opening operation Consists of two Sequential steps :-
erosion followed by dilation.

Erosion
Each foreground pixel is replaced with the minimum value in its neighborhood. This process erodes or Shrinks the boundaries of objects, removing small or thin structures.

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Dilation

Each foreground pixel is replaced with the maximum value in its neighborhood.

Opening is denoted by

$$A \circ B = (A \ominus B) \oplus B$$

Properties of opening are:-

1. $X \circ Y$ is a subset (subimage of X)
2. If X is a subset of Z then $X \circ Y$ is a subset of $Z \circ Y$
3. $(X \circ Y) \circ Y = X \circ Y$

Closing operation:-

⇒ The closing opⁿ is the reverse of the opening opⁿ, consisting of two steps: dialation followed by erosion.

⇒ It is used to fill holes, close gaps and smooth object boundaries.

Dialation

Each foreground pixel is replaced with the maximum value in its neighborhood, similar to the opening opⁿ.

Erosion

Each foreground pixel is replaced with the minimum value in its neighborhood.

Closing is denoted by

$$A \bullet B = (A \oplus B) \ominus B$$

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Properties of closing are:-

1. X is a subset subimage of X·Y
2. $(X \cdot Y) \cdot Y = X \cdot Y$

Application of opening opn

1. Noise Removal
2. object Segmentation
3. Image Restoration

Application of closing opn

1. Hole filling
2. Object Reconstruction
3. Smoothing

Both opening and closing operations are basic morphological operations that can be used in combination or in specific sequence to achieve desired image processing goals.