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Section: F
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Assignment 1

Instructions:
Explain the feature extraction techniques and extract various types of features from an image using Python.

Image Upload

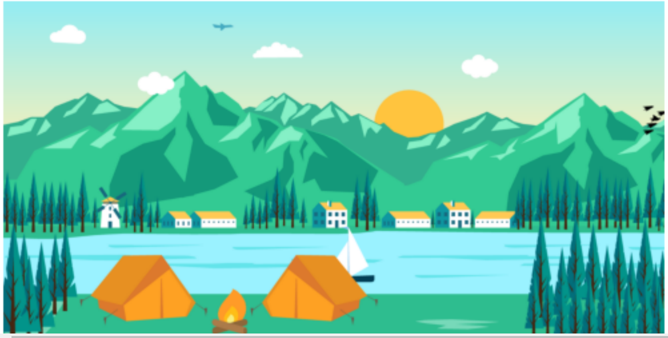
- **Purpose:** The image is loaded from the local machine for further processing.
- **Functionality:**
  - The image is read in BGR format using OpenCV.
  - It is then converted to RGB for visualization.
  - A grayscale version is prepared for techniques requiring single-channel input.
- **Applications:** The image is preprocessed for all subsequent feature extraction techniques.

```
from google.colab import files
import cv2
import matplotlib.pyplot as plt

# Step 1: Upload the image
print("Upload your image file:")
uploaded = files.upload()

# Step 2: Load the uploaded image
image_path = list(uploaded.keys())[0]  # Get the file name
image = cv2.imread(image_path)  # Load image in BGR format (OpenCV default)
image_rgb = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)  # Convert to RGB
gray_image = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)  # Convert to Grayscale

# Original Image
plt.imshow(image_rgb)
plt.title("Original Image")
plt.axis('off')
plt.show()
```

```
Upload your image file:
```
Choose Files ImageForF…xtraction.png
- **ImageForFeatureExtraction.png**(image/png) - 434045 bytes, last modified: 12/14/2024 - 100% done

```
Saving ImageForFeatureExtraction.png to ImageForFeatureExtraction.png
```

Original Image



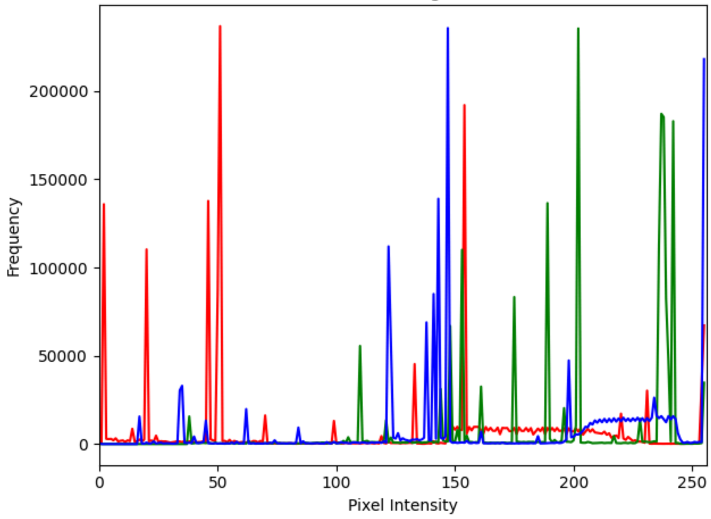
Feature 1: Color Histogram

- **Technique:** Color Histogram
- **Purpose:** The distribution of pixel intensities for each color channel (Red, Green, and Blue) is analyzed.
- **Functionality:**
  - Histograms are calculated for each color channel using `cv2.calcHist`.
  - These histograms are plotted to show the frequency of pixel intensities.

- **Applications:**
  - Image retrieval is facilitated.
  - Color-based classification or segmentation is enabled.
  - Dominant colors in an image are detected.

```
# Feature Extraction: Color Histogram
def extract_color_histogram(image_rgb):
    # Plot side-by-side (0, 0) and (0, 1)
    fig, axes = plt.subplots(1, 2, figsize=(12, 5))

    # Original Image (0, 0)
    axes[0].imshow(image_rgb)
    axes[0].set_title("Original Image")
    axes[0].axis('off')

    # Generated Histogram
    colors = ('r', 'g', 'b')
    for i, color in enumerate(colors):
        hist = cv2.calcHist([image_rgb], [i], None, [256], [0, 256])
        axes[1].plot(hist, color=color)
    axes[1].set_xlim([0, 256])
    axes[1].set_title("Color Histogram")
    axes[1].set_xlabel("Pixel Intensity")
    axes[1].set_ylabel("Frequency")

    plt.tight_layout()
    plt.show()

extract_color_histogram(image_rgb)
```

Original Image

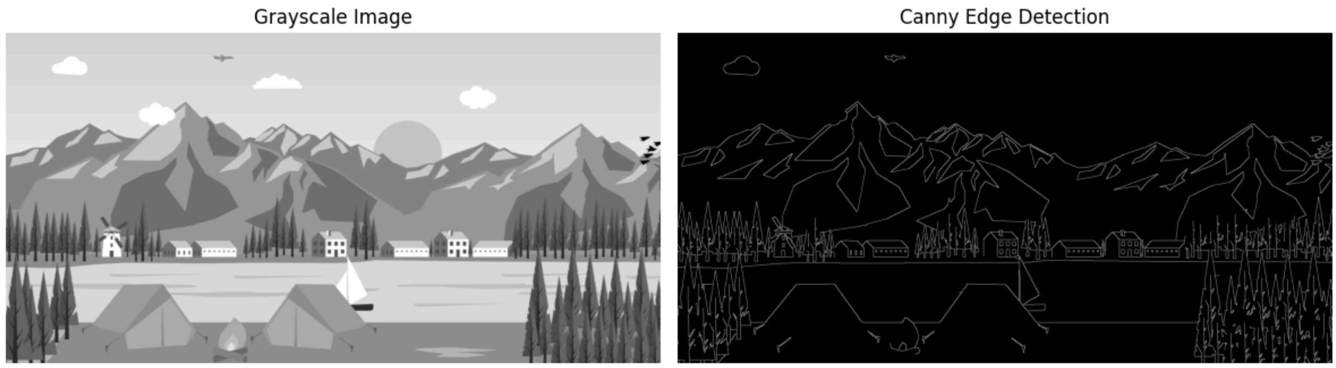


Feature 2: Edge Detection (Canny)

- **Technique:** Canny Edge Detection
- **Purpose:** The boundaries of objects are identified by detecting regions where intensity changes sharply.
- **Functionality:**
  - Gradient-based edge detection is applied, with thresholds set for strong and weak edges.
  - A binary image is generated, highlighting the detected edges.
- **Applications:**
  - Object detection is supported.
  - Contour extraction is enabled for shape analysis.
  - Lane detection is facilitated for autonomous vehicles.

```
# Feature Extraction: Edge Detection
def extract_edges(gray_image):
    # Perform Canny edge detection
    edges = cv2.Canny(gray_image, 100, 200)

    # Plot side-by-side (0, 0) and (0, 1)
```

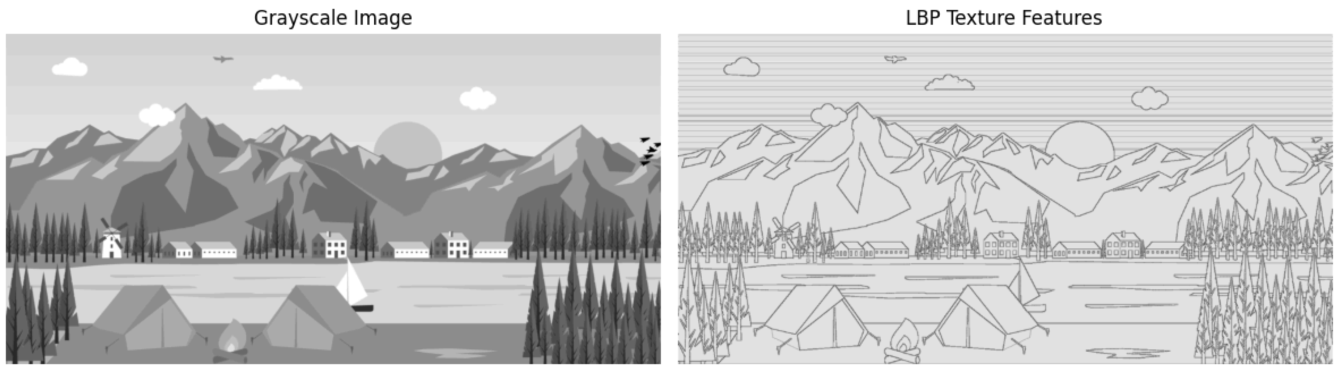
```
    fig, axes = plt.subplots(1, 2, figsize=(12, 5))

    # Original Image
    axes[0].imshow(gray_image, cmap='gray')
    axes[0].set_title("Grayscale Image")
    axes[0].axis('off')

    # Generated Edges
    axes[1].imshow(edges, cmap='gray')
    axes[1].set_title("Canny Edge Detection")
    axes[1].axis('off')

    plt.tight_layout()
    plt.show()

extract_edges(gray_image)
```



Feature 3: Texture Features (LBP)

- **Technique:** Local Binary Patterns (LBP)
- **Purpose:** Texture information is extracted by encoding local pixel intensity patterns.
- **Functionality:**
  - The intensity of a pixel's neighbors is compared relative to its own value.
  - A binary pattern is generated for each pixel, representing texture details.
- **Applications:**
  - Texture classification is performed.
  - Facial recognition is supported by detecting unique facial textures.
  - Surface inspection is enabled in manufacturing processes.

```
from skimage.feature import local_binary_pattern

# Feature Extraction: Local Binary Patterns (LBP)
def extract_texture_features(gray_image):
    # Compute LBP
    radius = 1
    n_points = 8 * radius
    lbp = local_binary_pattern(gray_image, n_points, radius, method="uniform")

    # Plot side-by-side (0, 0) and (0, 1)
    fig, axes = plt.subplots(1, 2, figsize=(12, 5))

    # Original Image
    axes[0].imshow(gray_image, cmap="gray")
    axes[0].set_title("Grayscale Image")
    axes[0].axis('off')

    # Generated LBP Features
    axes[1].imshow(lbp, cmap="gray")
    axes[1].set_title("LBP Texture Features")
    axes[1].axis('off')

    plt.tight_layout()
    plt.show()

extract_texture_features(gray_image)
```



Feature 4: Keypoint Detection (SIFT)

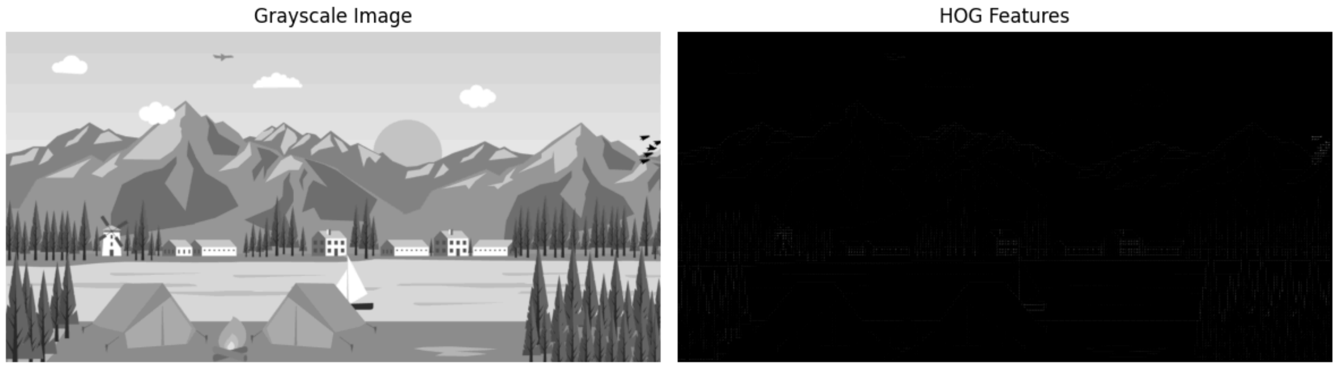
- **Technique:** Scale-Invariant Feature Transform (SIFT)
- **Purpose:** Distinctive keypoints in the image are detected, ensuring invariance to scale, rotation, and illumination.
- **Functionality:**
  - Keypoints are identified using a difference-of-Gaussian approach.
  - Descriptors that represent these keypoints are computed.
  - The detected keypoints are visualized as markers or circles.
- **Applications:**
  - Object recognition and tracking are enabled.
  - Image stitching, such as in panoramic photos, is facilitated.
  - Feature-based image matching is supported.

```
# Feature Extraction: Keypoint Detection (SIFT)
def extract_keypoints(gray_image, image_rgb):
    sift = cv2.SIFT_create()
    keypoints, descriptors = sift.detectAndCompute(gray_image, None)
    sift_image = cv2.drawKeypoints(image_rgb, keypoints, None, flags=cv2.DRAW_MATCHES_FLAGS_DRAW_RICH_KEYPOINTS)

    # Plot side-by-side (0, 0) and (0, 1)
    fig, axes = plt.subplots(1, 2, figsize=(12, 5))

    # Original Image
    axes[0].imshow(image_rgb)
    axes[0].set_title("Original Image")
    axes[0].axis('off')

    # Generated SIFT Keypoints (0, 1)
    axes[1].imshow(sift_image)
    axes[1].set_title("SIFT Keypoints")
    axes[1].axis('off')

    plt.tight_layout()
    plt.show()

extract_keypoints(gray_image, image_rgb)
```

Feature 5: Shape Features (HOG)

- **Technique:** Histogram of Oriented Gradients (HOG)
- **Purpose:** Shape information is encoded by capturing the distribution of gradient orientations.
- **Functionality:**
    - The image is divided into small cells.
    - Gradient histograms are computed for each cell.
    - These histograms are normalized across blocks for consistency.
    - A feature vector representing the image’s shape is produced.
- **Applications:**
    - Pedestrian detection is supported.
    - Object detection is enabled in images or videos.
    - Image classification tasks are performed.

```
from skimage.feature import hog

# Feature Extraction: HOG
def extract_hog_features(gray_image):
    hog_features, hog_image = hog(
        gray_image,
        orientations=9,
        pixels_per_cell=(8, 8),
        cells_per_block=(2, 2),
        visualize=True,
        channel_axis=None
    )

    # Plot side-by-side (0, 0) and (0, 1)
    fig, axes = plt.subplots(1, 2, figsize=(12, 5))

    # Original Image
    axes[0].imshow(gray_image, cmap="gray")
    axes[0].set_title("Grayscale Image")
    axes[0].axis('off')

    # Generated HOG Features
    axes[1].imshow(hog_image, cmap="gray")
    axes[1].set_title("HOG Features")
    axes[1].axis('off')

    plt.tight_layout()
    plt.show()

extract_hog_features(gray_image)
```



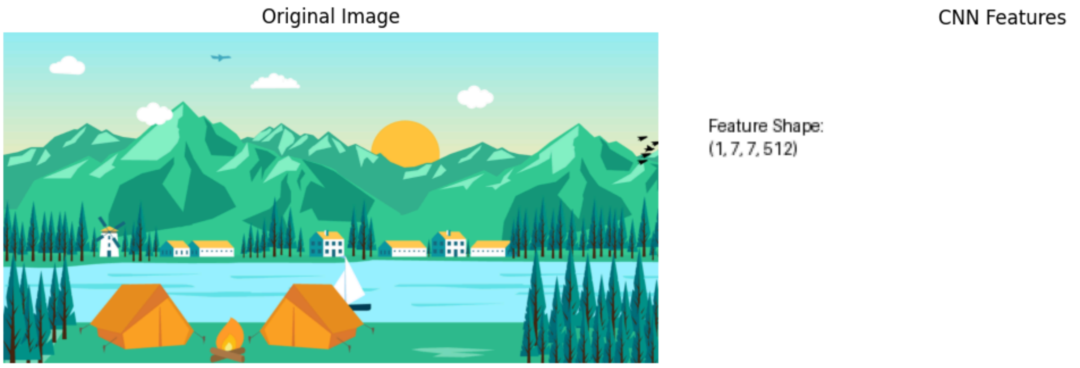
Feature 6: Deep Learning Features (VGG16)

- **Technique:** Pre-Trained Convolutional Neural Networks (VGG16)
- **Purpose:** High-level semantic features are extracted using a pre-trained deep learning model.
- **Functionality:**
    - A pre-trained VGG16 model from TensorFlow/Keras is loaded.
    - The image is resized to match the input size required (224x224 pixels).
    - Features are extracted from the convolutional layers (excluding the fully connected layers).
    - A high-dimensional feature tensor is generated.
- **Applications:**
    - Image classification tasks are supported.

- Object detection is integrated as part of a larger pipeline.
- Transfer learning is enabled for tasks like image segmentation.

```
from tensorflow.keras.applications import VGG16
from tensorflow.keras.applications.vgg16 import preprocess_input
import matplotlib.pyplot as plt
import numpy as np
import cv2
from PIL import Image, ImageDraw

# Feature Extraction: VGG16
def extract_cnn_features(image_rgb):
    model = VGG16(weights="imagenet", include_top=False)

    # Preprocess the image for VGG16
    resized_image = cv2.resize(image_rgb, (224, 224))
    image_array = np.expand_dims(resized_image, axis=0)
    image_array = preprocess_input(image_array)
    features = model.predict(image_array)

    # Create a blank image for text display
    text_image = Image.new('RGB', (400, 200), color='white')
    draw = ImageDraw.Draw(text_image)

    # Add text about feature shape
    text_content = f"Feature Shape:\n{features.shape}"
    draw.text((20, 50), text_content, fill="black")

    # Convert the PIL image to a NumPy array for Matplotlib
    text_image_np = np.array(text_image)

    # Plot side-by-side: Original Image and Generated Output Info
    fig, axes = plt.subplots(1, 2, figsize=(12, 5))

    # Original Image
    axes[0].imshow(image_rgb)
    axes[0].set_title("Original Image")
    axes[0].axis('off')

    # Generated Output Info as Image
    axes[1].imshow(text_image_np)
    axes[1].set_title("CNN Features")
    axes[1].axis('off')

    plt.tight_layout()
    plt.show()

extract_cnn_features(image_rgb)
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_n
58889256/58889256 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 1s 881ms/step
```



Section	Feature Extraction Technique	Purpose	Applications
Feature 1	Color Histogram	The pixel intensity distribution for each color channel is analyzed.	Image retrieval, classification, segmentation are enabled.
Feature 2	Canny Edge Detection	Object boundaries are identified.	Object detection, contour analysis, and lane detection are facilitated.
Feature 3	Local Binary Patterns (LBP)	Texture information is encoded.	Texture classification and facial recognition are supported.
Feature 4	SIFT	Distinctive keypoints are detected.	Image matching, object recognition, and stitching are performed.
Feature 5	Histogram of Oriented Gradients	Shape and edge direction information is encoded.	Pedestrian detection and object classification are supported.

Section	Feature Extraction Technique	Purpose	Applications
Feature 6	Pre-Trained CNN (VGG16)	High-level features are extracted using deep learning.	Transfer learning and image classification are performed.