REPORT

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TASK 1

Introduction

An image is a visual representation of something. It can be two-dimensional, three-dimensional, or somehow otherwise feed into the visual system to convey information. They may be captured by optical devices – such as cameras, telescopes, microscopes, and natural objects and phenomena, such as the human eye or water.

A digital image is an image composed of picture elements, also known as pixels, each with finite, discrete quantities of numeric representation for its intensity or gray level that is an output from its two-dimensional functions fed as input by its spatial coordinates denoted with x, y on the x-axis and y-axis, respectively.

Image processing is a technique for applying various procedures to an image in order to improve it or extract some relevant information from it. It is a kind of signal processing where the input is an image and the output can either be another image or features or characteristics related to that image. Image processing is one of the technologies that is currently expanding quickly. It is a primary subject of research in both the engineering and computer science fields.

Basically, image processing involves the following three steps:

Importing the image using image acquisition tool;

Analyzing and altering the image;

Producing a report or altered image as a result of the analysis.

Fig_1.a: The original image

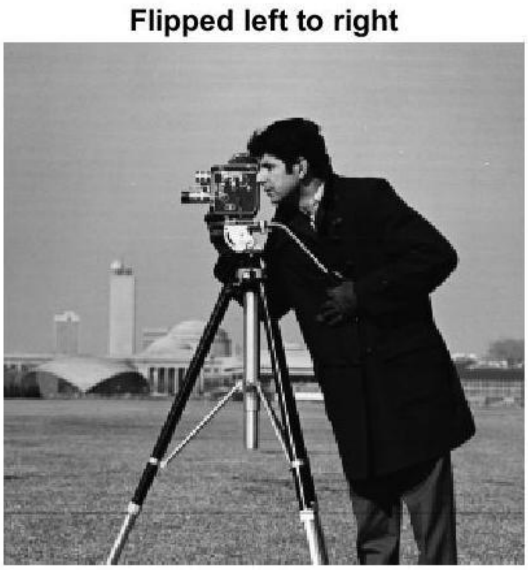

Fig_1.b: Processed Output (flipped L to R)

Analog and digital image processing are the two categories of image processing techniques. Hard copies like prints and images can use analog image processing. When applying these visual techniques, image analysts employ several interpretational fundamentals. Computer-based digital picture alteration is made possible with the use of digital image processing tools. When employing digital technique, all forms of data must go through three general phases: pre-processing, augmentation, and presentation; and information extraction.

Histogram of Oriented Gradient (HOG)

In the constantly developing field of machine learning, once-optimal algorithms are frequently updated within ten to twenty years to make room for more effective techniques. Even though the Histogram of Oriented Gradients detection method (abbreviated HOG) is one of these outdated algorithms and is about a decade old, it is still widely used today and produces excellent results. The Histogram of Oriented Gradients method is mainly utilized for face and image detection to classify images. This field has a numerous amount of applications ranging from autonomous vehicles to surveillance techniques to smarter advertising.

The preliminary steps involved in HOG are further discussed.

1. Feature Descriptors- The representation of an image that simply extracts useful information and disregards unnecessary information from the image. For HOG feature descriptors, we also transform the image's dimensions (width, height, and channels) into a feature vector with a user-selected length of n. These images may be challenging to examine, but they are ideal for image classification algorithms like SVMs to give accurate results. Gradients are extremely important for checking for edges and corners in an image (through regions of intensity changes) since they often will pack much more information than flat regions.

2. Preprocessing- It is important to standardize the image before processing to be able to obtain optimum results.

3. Calculating the Gradients- To make the HOG feature descriptor, firstly the respective horizontal and vertical gradients must be calculated to provide the histogram that can be used later in the algorithm. This can be done by simply filtering the image through kernels.

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Fig_2: Sample Kernel

Kernels like these are often used in image classification mainly in convolutional neural networks in order to find the edges and important points in a particular image. Then, the magnitude and the direction of the gradients can simply be found by using the following formulas.

$$Magnitude, \boldsymbol{M} = \sqrt{Gradient_{x-axis}^2 + Gradient_{y-axis}^2}$$

$$Angle, \boldsymbol{\theta} = \tan^{-1}\left(\frac{Gradient_{y-axis}}{Gradient\ _{x-axis}}\right)$$

It is important to note that the magnitude of the gradient increases wherever there is a sharp change in intensity. To summarize, understand that gradients have a magnitude and direction where the magnitude is calculated through the maximum of the magnitude of the gradients from the three color channels and the angle is calculated from the angle corresponding to the maximum gradient out of the three channels evaluated.

4. Making A Histogram from These Gradients- To move on to the next step of the HOG algorithm, make sure that the image is divided into cells so that the histogram of gradients can be calculated for each

cell. Feature descriptors will allow for a concise and succinct representation of specific patches of the images. An 8x8 cell can simply be explained using 128 numbers. By further converting these numbers to calculate histograms, we allow for an image patch that is much more robust to noise and more compact.

5. Block Normalization- Lighting variations are another major factor that can mess up how these gradients are calculated. Therefore, the descriptor should be devoid of lighting variations so that it is unbiased and effective. The typical process of normalization occurs by simply calculating the length of a vector through its magnitude and then simply dividing all elements of that vector with the length.

6. Image Visualization- In many instances, the HOG descriptors are often visualized with the image in contrast in order to get an accurate representation of the shape of the object in the image. This visualization can be extremely useful in understanding where the gradients shift and knowing where the objects are inside of the image.

Code Write-Up

This code is written in python language in Visual Studio Code tool and uses the OpenCV library to perform computer vision tasks, as well as the Numpy library for numerical computing and the scikit-learn library for machine learning algorithms. The code is used to calculate the histogram of oriented gradients (HOG) of an image.

The overview of the whole program:

This is a computer vision code that implements a histogram of oriented gradients (HOG) and a cosine similarity on two images to find their similarity score. The code first sets the current working directory to a specific location using the os.chdir function, and then reads in two images, apple.jpg and grapes.jpg.

The code has three functions: hog, hog_similarity, and hog_occurrences.

The hog function takes an image and the number of directions and grid dimensions as inputs, and calculates the gradient magnitude and direction of the image. The image is divided into cells with the given grid dimensions and a histogram of oriented gradients is calculated for each cell. The histogram is returned as a flattened array.

The hog_similarity function calculates the histograms of two images using the hog function and calculates their cosine similarity. The cosine similarity is a measure of the similarity between two non-zero vectors of an inner product space.

The hog_occurrences function converts two images to grayscale, resizes them to a common size, computes their histograms, normalizes them, and calculates the cosine similarity between the histograms to determine if the objects in the images are similar.

Tracing the flow for Task 1:

The code starts by setting the current directory to a specific path. Then, two images, "apple.png" and "green-grapes.jpg", are read and stored as the variables "img1" and "img2". The "img1" is then converted to grayscale using the "cv2.cvtColor" method.

The main functionality of the code is implemented in the "hog" function, which takes three arguments: "img", "num_directions", and "grid_dimension". The function first calculates the gradient of the image in the x and y directions using the "cv2.Sobel" method. Then, it calculates the gradient magnitude and direction using Numpy's mathematical functions.

Next, the image is divided into cells with a given grid dimension, and a histogram of oriented gradients is calculated for each cell. This is done by determining the gradient information for each cell, and then calculating a histogram of the gradient magnitudes and directions. The histogram is returned as a flattened Numpy array.

The function is executed by calling the "hog" function with the "img1" variable as the input, along with the arguments "9" for "num_directions" and "(8, 8)" for "grid_dimension". The resulting histogram is then printed to the console.

***** Professor, I have also attached Task 2 in this source code, however I understand it is not under consideration during the current submission.***

Snippets from the Program:

Fig_3.a: Input Image1-Apple

Fig_3.b: Input Image2-Grapes

Fig_4.a: Input Image1-Grayscale

Fig_4.b: Input Image2-Grayscale

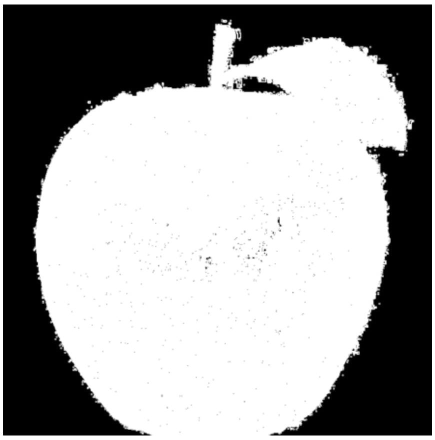

Fig_5.a: Gradient Output for input image1

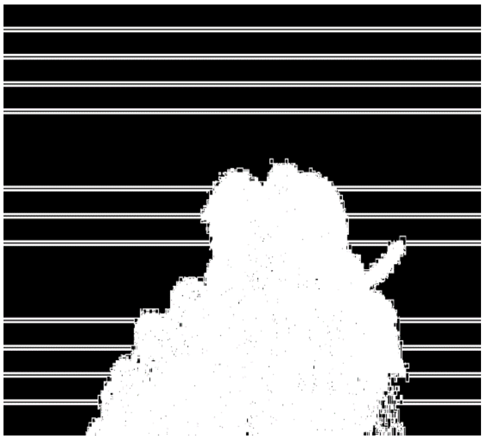

Fig_5.b: Gradient Output for input image2

Result:

Appendix: The Histogram Array output obtained from the code execution.

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1.08176782e+03 1.10341833e+03 3.07249072e+03 1.04626016e+04
5.47473477e+04 2.80207070e+04 7.75458545e+03 2.60693066e+03
4.32043604e+03 2.62216260e+03 7.21743896e+02 1.31324829e+03
2.68743481e+03 3.73218457e+03 2.55946606e+03 3.15299902e+03
6.27024902e+03 1.72599785e+04 6.92590088e+03 4.66275781e+03
5.16507129e+03 4.96908154e+03 2.63556860e+03 1.95992773e+03
1.28438123e+03 2.45343115e+03 3.20284229e+03 3.09445679e+03
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7.52742432e+02 1.08177832e+03 1.36620566e+04 1.52806367e+04
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8.31540039e+02 5.65301270e+02 7.06070557e+02 7.84888672e+02
6.32998718e+02 2.49530457e+02 9.89949417e+00 1.64730087e+02
4.81253082e+02 2.67195862e+02 3.67365051e+02 2.07170685e+02
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1.33068281e+04 1.01582246e+04 2.53820469e+04 7.15601484e+04

4.53719336e+04 2.15606855e+04 1.36704658e+04 1.60822520e+04

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4.93526031e+02 1.11694360e+03 1.57500867e+03 6.45839062e+03

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3.37296875e+04 3.28998828e+04 3.53113906e+04 4.55102500e+04

8.05065625e+04 9.10067969e+04 6.63489219e+04 5.50291016e+04

5.09548867e+04 2.37099180e+04 2.29434707e+04 2.06946895e+04

3.28051953e+04 7.42355938e+04 5.61176250e+04 2.52560273e+04

1.71725508e+04 6.40000000e+02 0.00000000e+00 0.00000000e+00

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Cosine similarity: 0.38560712523967383

The images are not similar with a score of: 0.0028288043

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