Report on Image Classification Project

Submitted By

Md. Mehedi hasan (BSSE 1037)

Submitted To

Emon Kumar Dey

Assistant Professor

Institute of Information Technology

University of Dhaka

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Table of Contents

1. Introduction

A key task that can categorize an image based on its visual information is image classification. The objective is to categorize the image by giving it a certain label. It is assumed that each image will only have one class. The class to which an image belongs is predicted by image classification models when they receive an image as input.

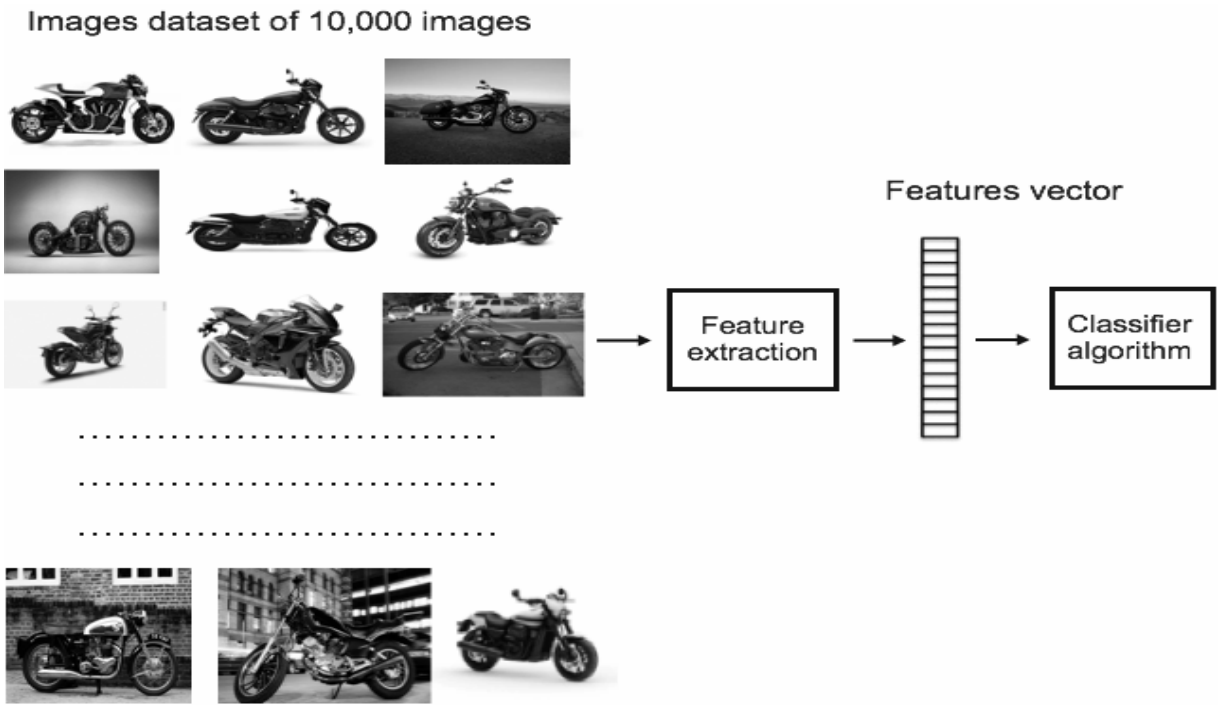


Figure 1.1: Image classification

Source:https://freecontent.manning.com/the-computer-vision-pipeline-part-4-feature-extraction/

1.1 Feature Extraction

For image classification, firstly we need to extract features from images.

Some techniques of feature extraction are :

- Hough transform
- Local Binary Pattern (LBP)
- Histogram of Oriented Gradients (HOG)

1.2 Image Classification Metrics

It is a model by which we can determine how well a model performs. A metric that is defined for each class will be evaluated.

- **Precision**

  It is the proportion of data predicted by the ML model to belong to the class that was actually part of the class in the validation data.

- **Recall**

  Recall tells us what proportion of the data from the validation set belonging to the class was identified correctly (as belonging to the class).

- **F1 Score**

  F1 Score helps us achieve a balance between precision and recall to get an average idea of how the model performs.

1.3 Classification of object

It categorizes detected objects into predefined classes by using a suitable classification technique that compares the image patterns with the target patterns. Few classifier are :

- Support Vector Machine
- Random Forest Algorithm

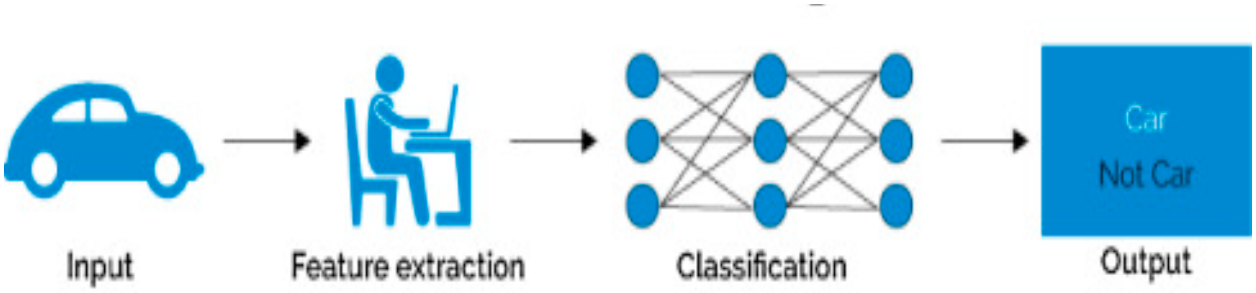


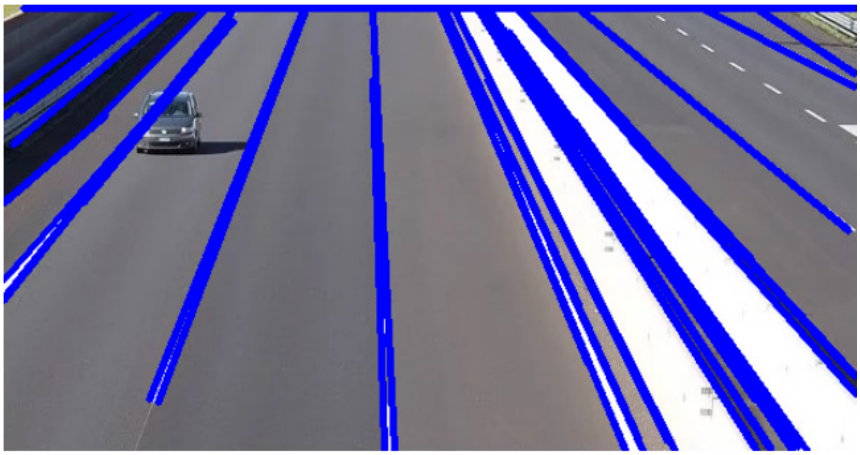
Figure 1.2: An overview of image classification

Source: https://ars.els-cdn.com/content/image/1-s2.0-S1746809418300399-gr19.jpg

2. Background

2.1 Hough Transform

A feature extraction method for digital image processing, computer vision, and image analysis. To detect undesirable examples of objects inside a particular class, it employs a voting process. a technique for dividing elements of a specific form inside a photograph. It is used to find straight, regular curves.



Source:https://www.analyticsvidhya.com/blog/2022/06/a-complete-guide-on-hough-transform/

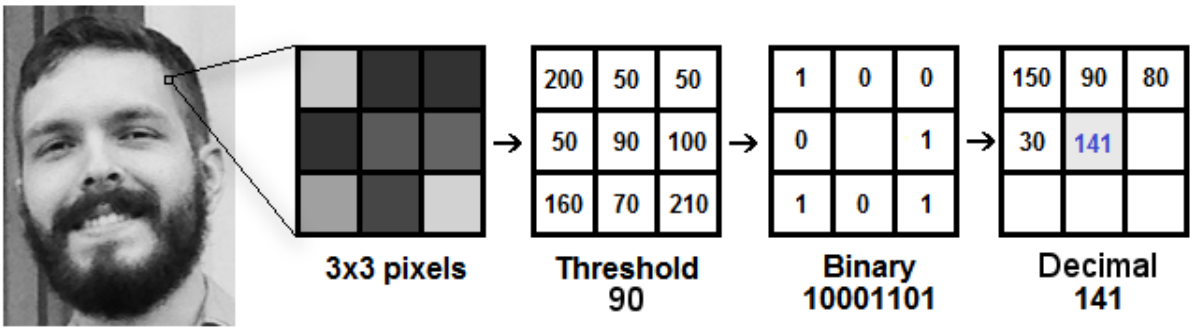
Due to errors in the image data or the edge detector, as well as spatial differences between the ideal line, circle, or ellipse and the noisy edge points recorded by the edge detector, there may be missing points or pixels on the necessary curves. As a result, it is usually challenging to combine the retrieved edge features into a suitable set of lines, circles, or ellipses.

2.2 Local Binary Patterns (LBP)

In texture analysis, major advancements have been made (rough, smooth, silky, or bumpy). By thresholding the neighborhood pixels and using the result as a binary integer, it identifies the pixels in a picture.

The LBP texture operator has gained popularity in a number of applications, including visual inspection, image retrieval, remote sensing, biomedical image analysis, motion analysis, environment modeling, and outdoor scene analysis, due to its discriminative capability and computational simplicity.

Facial Recognition is a well-known application.



Source: https://editor.analyticsvidhya.com/uploads/658641%20J16_DKuSrnAH3WDdqwKeNA.png

- The image is turned into a grayscale. For each pixel in the grayscale image, a neighborhood of size r surrounding the central pixel is selected. In the output 2D array, which has the same width and height as the input picture, an LBP value is then computed for this center pixel.
- Threshold center pixel and if the intensity of the center pixel is greater than or equal to its neighbor, then we set the value to 1; otherwise, we set it to 0.
- Given a 3 x 3 neighborhood, we have 8 neighbors that we must perform a binary test on. The results of this binary test are stored in an 8-bit array, which we then convert to decimal.
- Repeated for each pixel
- Computes a histogram over LBP output

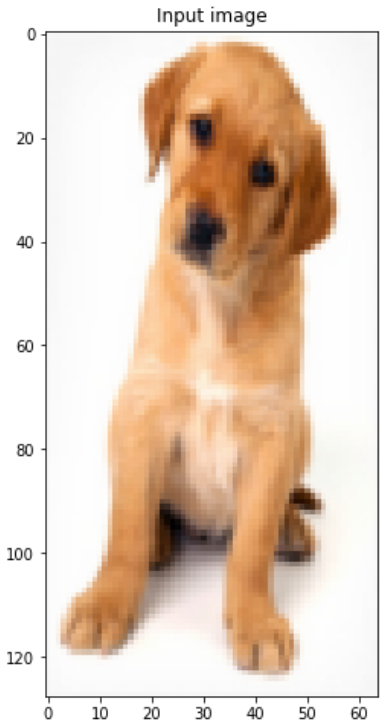
It captures extremely fine-grained details in the image.

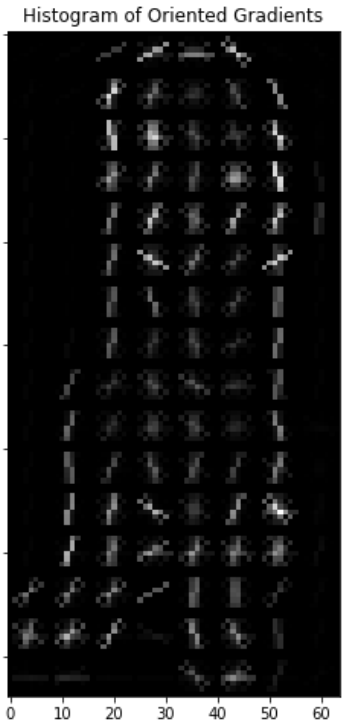
2.3 Histogram of Oriented Gradients (HoG)

In Histogram of Oriented Gradients a feature descriptor that is employed in order to detect objects. In essence, it records the instances of gradient orientation in the localized portion of an image. When computing the features, it works well as a gradient's magnitude and angle.

- **Feature descriptor**

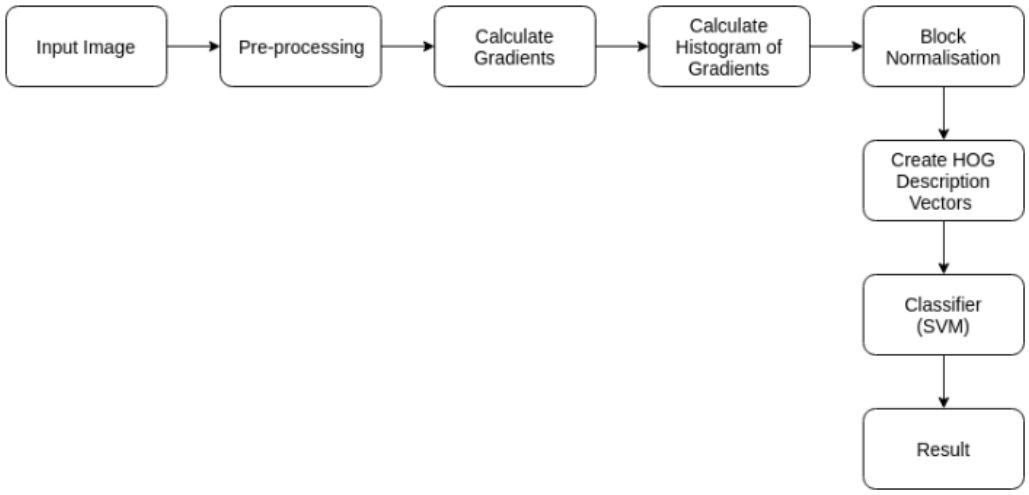
  It is a simplified representation of the image that contains only the most important information about the image.





Source:https://www.analyticsvidhya.com/blog/2019/09/feature-engineering-images-introduction-hog-feature-descriptor/

Steps performed to do Hog:



Source:https://iq.opengenus.org/object-detection-with-histogram-of-oriented-gradients-hog/

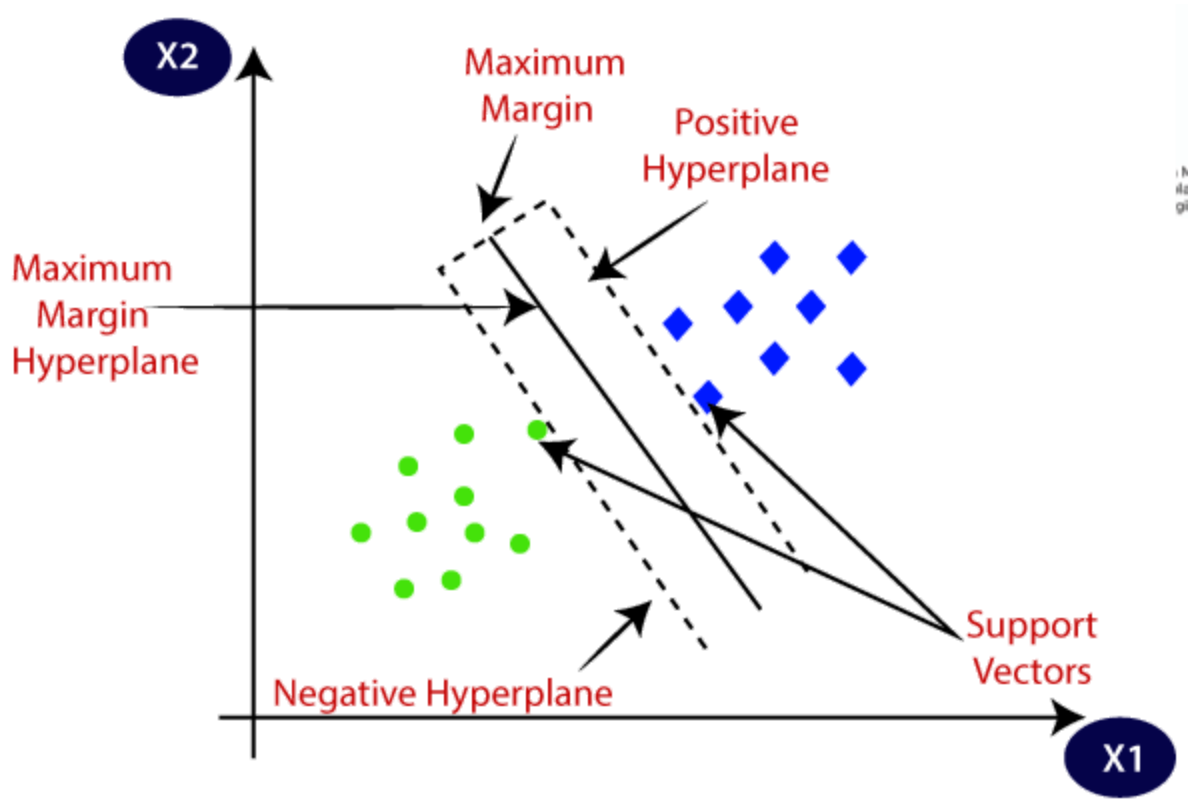
2.4 Support vector machine (SVM)

A fast and dependable classification algorithm that performs very well with a limited amount of data to analyze. Perhaps you have dug a bit deeper, and ran into terms like linearly separable, kernel trick and kernel functions.

E.g. detect cancerous cells based on millions of images

Key points:

- It is a supervised machine learning approach
- Algorithms for two-group classification problems. But it can be modified into multigroup classification.
- Using this we find a hyperplane in an N-dimensional space which clearly classifies the data points
- It handles both classification and regression on linear and non-linear data



Source:https://www.javatpoint.com/machine-learning-support-vector-machine-algorithm

Here are the steps regularly found in machine learning projects:

- Import the dataset
- Explore the data to figure out what they look like
- Pre-process the data
- Split the data into attributes and labels
- Divide the data into training and testing sets
- Train the SVM algorithm
- Make some predictions
- Evaluate the results of the algorithm

2.5 Random Forest Algorithm

A supervised learning approach based on ensemble learning incorporates many classifiers to address complicated issues and improve the performance of the model. In order to increase the projected accuracy of a given dataset, it uses many decision trees on different subsets of that dataset and takes the average.

Instead than relying on a single decision tree, it gathers the results from each tree and bases the final result on the forecasts that received the most votes. It eliminates the overfitting problem in decision trees and has little to no connection between the various models.

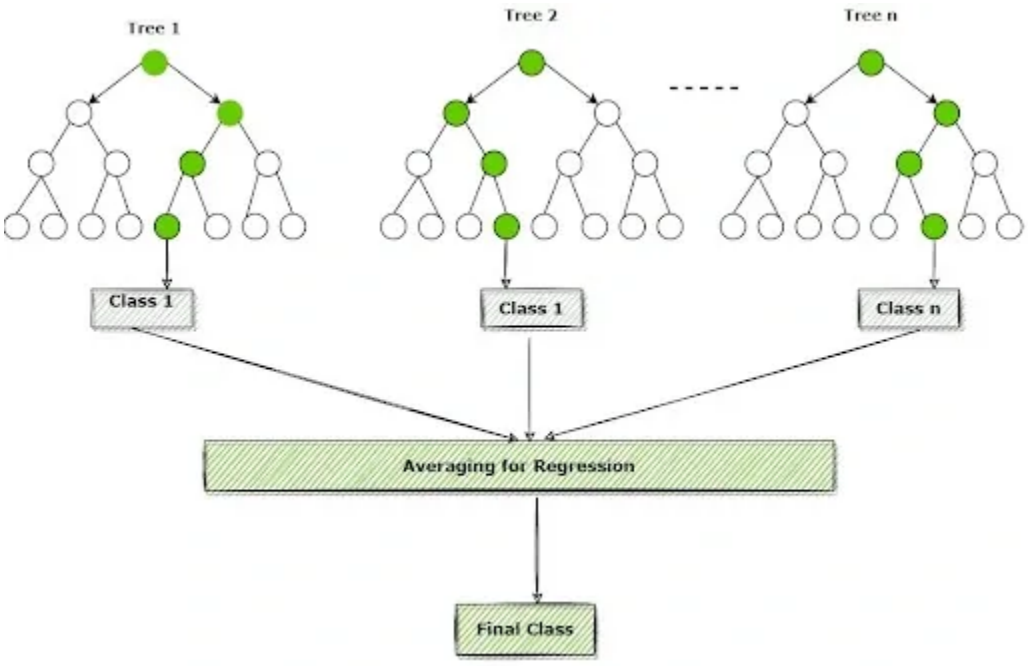


Figure: Random Forest Algorithm

Source: https://www.turing.com/kb/random-forest-algorithm

The following steps can be used to demonstrate the working process:

Step 1: Pick M data points at random from the training set.

Step 2: Create decision trees for your chosen data points (Subsets).

Step 3: Each decision tree will produce a result. Analyze it.

Step 4: For classification and regression, accordingly, the final output is based on Majority Voting or Averaging, accordingly.

3. Methodology

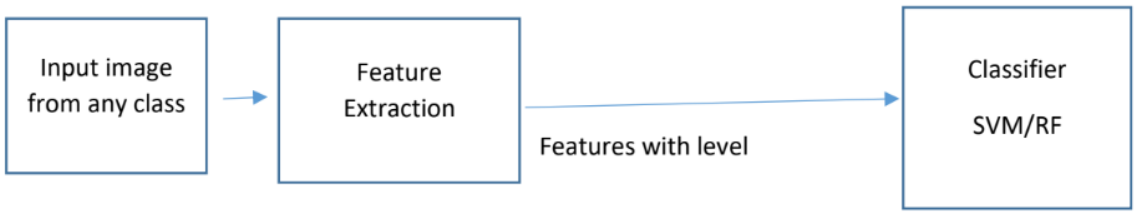


Figure 1: Training the Classifier

1. Dataset

- Collected it from kaggle.
  Source: https://www.kaggle.com/datasets/prasunroy/natural-images
- The dataset has at least 8 different classes with 500+ images of each class. For simplicity, we have taken 3 classes (Fruit, motorbike and person) for further analysis.

2. Training/Testing set preparation

We have manually separated images of each class into training and testing dataset. The number of training and testing images are mentioned below:

	Training data	Testing data
Fruit	803	197
Motor-bike	616	172
Person	803	183

3. Feature extraction

- Extracted features from each training/testing image.
- Applied the Local Binary Pattern (LBP) and Histogram of Oriented (HoG) Gradient separately

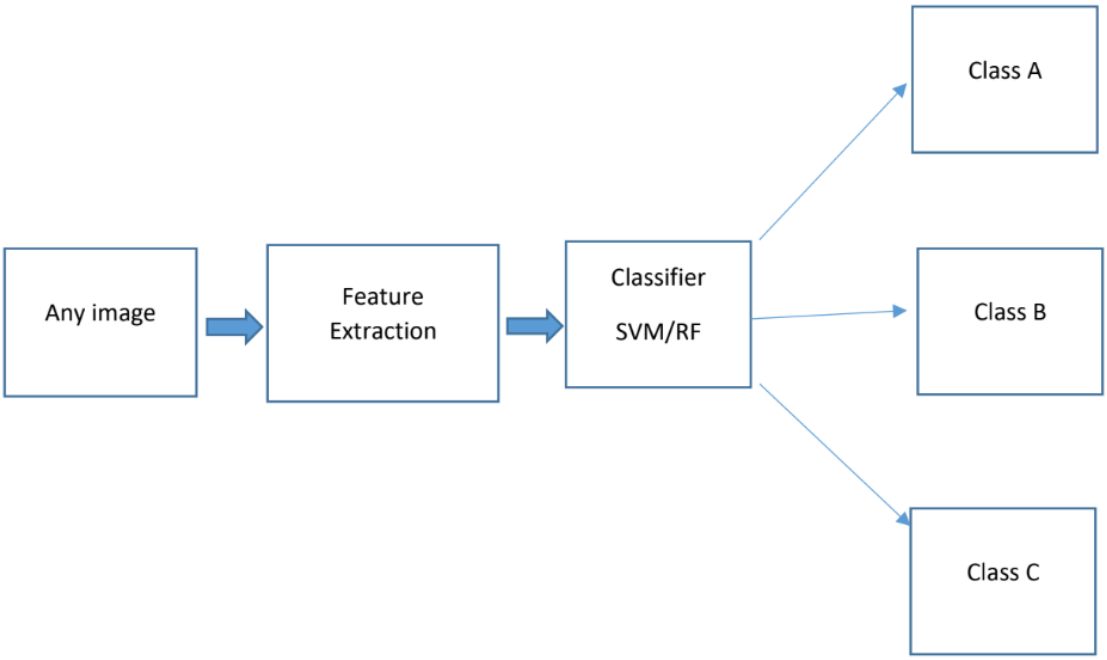


Figure 2: Testing the Classifier

4. Training

- Used both classifiers i.e, Support Vector Machine (SVM) and Random Forest (RF) for training purposes using the extracted features of the training images.
- Assigned a label (say, Class A, Class B, or Class C) to each individual image while training.

5. Testing

- Tested the 20% images of our dataset and found the accuracy for each class
- Compared results in terms of accuracy among the methods of feature extraction (Hough feature, LBP, and HoG)
- Evaluated confusion matrix
- For proper understanding and visualization, various graphs are plotted

4. Results and Discussion

Here we will present the results of different calculation:

Confusion matrix for LBP and Random Forest classifier:

```
LBP Accuracy: 0.9619565217391305
```

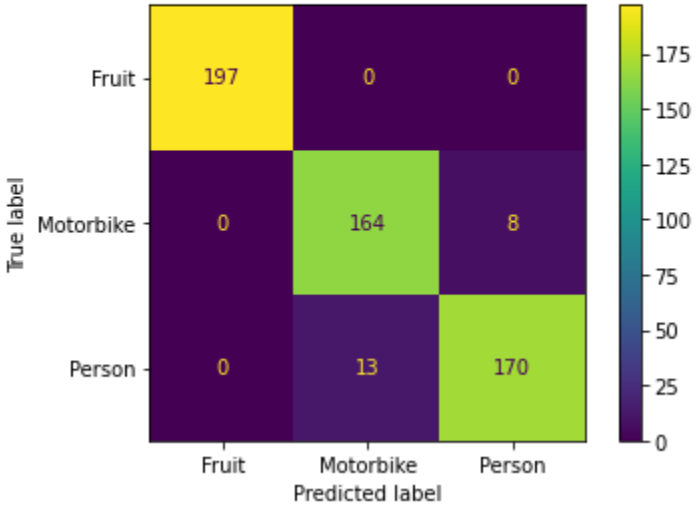


Figure 4.1: Confusion matrix for LBP and Random Forest classifier

Confusion matrix for LBP and Support Vector Machine (SVM):

```
0.9945652173913043
```

Figure 4.2: Confusion matrix for LBP and SVM

Confusion matrix for HOG and Random Forest classifier:

```
HOG Accuracy: 0.9963768115942029
```

Figure 4.3: Confusion matrix for HOG and RF

Confusion matrix for HOG and SVM:

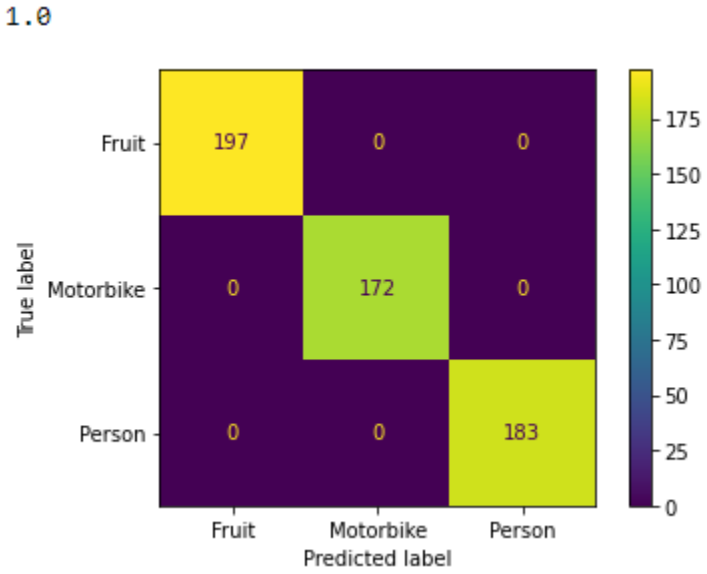


Figure 4.4: Confusion matrix for HOG and SVM

Here, we have conducted SVM and RF as multiclass classifiers. Both of them performed well. Among them, Histogram of Oriented feature extractor and Support Vector Machine classifier combinedly performed the best with 100% accuracy.

5. Conclusion

Working on this project was a wonderful learning experience for us. This project took us through various phases of image processing and gave us a real insight into how image classification's feature extraction and algorithms were applicable and helpful in the real world. Three feature extraction methods (Hough transformation, Local Binary pattern, Histogram of Oriented Gradients) and two classification algorithms (Random Forest, Support Vector Machine) have been discussed here along with their computational results. We have tried to use some visualization so that our work can be better understood through some data analysis plots.