Seminar Report

On

Fruit Classification using Machine Learning

By

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Under the guidance
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CERTIFICATE

This is to certify that **Yogesh Amar Kanwade** from **Third Year Computer Engineering** has successfully completed his/her seminar work titled **"Fruit Classification using Machine Learning"** at Marathwada Mitra Mandal's College of Engineering, Pune in the partial fulfillment of the Bachelors Degree in the Engineering.

Date:
Place: MMCOE, Pune

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Abstract

The fruits and vegetables in our nation are very diverse. Fruits and vegetables make up a sizable portion of the market produce in India and around the world. They are also among the top commodities on the international import/export markets and have a significant economic impact. These levels of diversity and high productivity also pose certain challenges. One among these challenges is fruit classification. Fruit classification is a challenging process. Fruit categorization has always been done manually. They have their own drawbacks. As a result of technological improvement, computer programmes are emerging as an alternative to conventional ways. We can try to create an automatic fruit categorization system using machine learning. Fruit has an uneven shape, a wide range of sizes, and a diversity of colours, making it difficult to identify. However, developing an efficient classification system will counter these difficulties. Since the entire process will be enhanced, everyone involved, from farmers to customers, will benefit. Such systems can be further improved to do the task of fruit grading along with fruit classification.

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Technical Keywords

1.1 Domain Name

Data Science

1.2 Technical Keywords

A) Machine Learning
B) Data Science
C) Convolutional Neural Networks
D) Fruit Classification
E) Fruit Recognition
F) Fruit Grading
G) Smart Agriculture

Chapter 2

Introduction

Our country has a wide variety of fruits and vegetables. India is the world's largest fruit producer and is referred to as the fruit basket of the world. Mangoes, grapes, apples, oranges, fresh bananas, guavas, litchi, papayas, and watermelons are some of the most common fruits cultivated in India. India has a wide variety of fruits to offer. There are up to 50 native fruits in the nation. Additionally, the number of native variety increases to a staggering 400 when you factor in their wild relatives and related species. Around the globe, a major share of the market output is comprised of fruits and vegetables. They also rank among the most popular commodities on global import and export markets and have a major economic impact. These high levels of variety and production also present certain difficulties. Classification of fruits is one of these difficulties. It might be difficult to classify fruits. Fruit classification has traditionally been carried out by manual methods that involve human input. They each have their own limitations. Manual methods are time consuming and are labour intensive. This overall increases the load of expenses during entire process. With advancement in technology, computer programs have started to emerge as an alternative approach to traditional methods. The use of computer programs is not only seen in other fields but also in the field of agriculture. Computer programmes are becoming more and more popular as an alternative to traditional methods as a consequence of technological advancement. By using machine learning, we may attempt to construct an automated fruit classification system that requires less human input and emerges as an efficient method. Everyone involved, from farmers to buyers, will gain from the improved process, which will benefit all parties. Here I am making use of keras and tensorflow library to build a convolutional neural network which will classify fruits into 4 groups. I am using a dataset present on kaggle : https://www.kaggle.com/datasets/mbkinaci/fruit-images-for-object-detection .

2.1 Domain Description

In 2022, the Fresh Fruits segment should generate USD 95.53 billion in revenue. The market is anticipated to expand by 7.27 percent yearly (CAGR 2022-2027). When compared globally, India generates the largest income (USD 95.53 billion in 2022). Machine Learning can be defined as the capability of a machine to imitate intelligent human behavior. Data Science is a field that involves analysing data on particular parameters in order to get actionable insights. Combining the fields of data science and machine learning with that of agriculture sector will provide enormous benefits. This project is a learning step towards the same direction. Across the globe, there have been a number of researches and studies regarding integration of machine learning into the agricultural sector. In pre-harvesting machine learning can be used to capture the parameters of soil, seeds quality, fertilizer application, pruning, genetic and environmental conditions and irrigation. Focusing on each component, the ultimate goal is to minimize the overall losses in production, improve quality of produce and develop a sustainable system. Image processing can be used in detecting disease in plants and pests.

2.2 Problem Definition

Classification of fruits is a complicated task. Traditionally, manual methods were used for fruit classification. They have their own disadvantages such as they will consume more time, requires extensive workforce and has probability of human negligence and inefficiency. With advancement in technology, computer programs have started to emerge as an alternative approach to traditional methods. The use of computer programs is not only seen in other fields but also in the field of agriculture. With the use of machine learning we can attempt to develop an automated fruit classification system that requires minimum human input. Fruits come in variety of shapes an sizes. This variation in their attributes can be difficult to counter with the use of one or two features. But every parameter can be calculated and analyzed to a certain degree. In order to develop a highly accurate fruit classification technique we need to analyze multiple parameters. This will, in turn make the algorithm more complicated but give much better results.

2.3 Motivation

The fruits and vegetables in our nation are very diverse. Fruits and vegetables make up a sizable portion of the market produce in India and around the world. They are also among the top commodities on the international import/export markets and have a significant economic impact. A difficulty also is presented by that of the wide diversity of fruits as well as the high production rates. Fruit classification is an example of them. Fruit classification is a challenging process. Fruit categorization has always been done manually. They have their own shortcomings, involving the need for a large workforce, increased time consumption, and a chance of human error and inefficiency. As a result of technological advancement, software applications are starting to transform conventional ways. Agriculture is one domain where computer programmes are used, in addition to several other sectors. We can attempt to develop an automatic fruit classification system applying machine learning concepts that requires minimal human input. To overcome these obstacles, an effective classification system must be created. Everyone involved, from farmers to customers, will gain from the improved process, which will in turn benefit all parties. Such systems can be further enhanced to grade fruits on the basis of qualities like ripeness, scars and disfigurement, and color.

Chapter 3

Literature Survey

3.1 Existing Methods/Tools/Techniques

There is a lot of proof for research and analysis in the domain of fruit recognition and classification. Various research have been performed for developing a standalone fruit classification system.

As put forward by Huai-Kuei Wu*, Jui-Sheng Wang and Yuan-Hsin Chen in the paper published in 2nd IEEE International Conference on Architecture, Construction, Environment and Hydraulics 2020, titled "Development of Fruit Grading System Based on Image Recognition", a full fleged fruit recognition and grading system is discussed. The system architecture consists of:
1.Identification host:
a. STM32F7 microcontroller
b. touch LCD panel
c. OV9655 camera
d. Wi-Fi module
2. Transmission mechanism:
a. A stepping motor and
b. An electric push rod.

The stepping motor receives the control signal from STM32F746 to drive the conveyor belt and realize the operation of the transmission mechanism. After the fruit grading is completed, the electric push rod pushes the fruit to different fruit baskets according to the grade. The database is used to store fruit grading information for use as a reference for fruit harvest analysis and planting. Users can use the touch interface on the top of the identification host to perform various operations and settings. The users can use the system settings to adjust the grading parameters. The main menu shows the identification host, including recognition start, system settings, history grading records, and fruit history pictures. The system setting screen allows for the adjustable parameters which include fruit size, fruit color threshold, and percentage of allowable black points on fruit.

3.2 Literature Survey

[1] Yanfeng Tang, Yawan Zhang, and Ying Zhu, "A Research on the Fruit Recognition Algorithm Based on the Multi-Feature Fusion", 2020 5th International Conference on Mechanical, Control and Computer Engineering(ICMCCE).

This paper proposes a fruit recognition algorithm based on two features : color and shape. For this paper two data sets have been used. The first step here is image preprocessing. It helps in improving operability of the image. Image segmentation is core part of image preprocessing. It is done to obtain shape information of the target body. The next step is of feature extraction. Beginning with color extraction, HSV color model is used. Representing chromaticity, saturation and brightness the HSV color model is closer to peoples perception of colors as compared to RGB color model. Secondly, for shape feature extraction three parameters are analyzed, they are : perimeter, roundness and area of the target shape. Techniques used for shape feature extraction are :

a) Perimeter : refers to the length of entire boundary. It is expressed by number of pixels of the edge image extracted using canny arithmatic.

b) Area : is represented by number of pixels which is occupied by the segemnted image after binarization.

c) Roundness : is measured by ratio of short side to the long side of the bounding rectangle. The roundness value of a standard circle should be 1. Fruits are not the shape of a standard circle so their value of roundness will be less than 1. The closer the fruit shape to a standard circlce, higher will be its roundness value.

In this paper the area features are extracted from the binary images and the perimeter and roundness features are extracted from edge images. A back propagation neural network is used to make the final prediction. The accuracy achieved by this feature fusion algorithm is more than single feature recognition algorithm.

[2] Dewi Agushinta R. and Henny Medyawati, Ihsan Jatnika and Hustinawaty, “A Method of Cloud and Image-Based Tracking for Indonesia Fruit Recognition”.

Augmented Reality (AR) is a variation of Virtual Environments (VE), or well known as Virtual Reality (VR). VR technology allows users to join a virtual environment. The main purpose of AR is to create a modern environment by combining real and virtual environments’ interactivity so the users feel that the environment created is real. By the help of AR technology (such as computing vision and object recognition), the real environment around will be able to interact in digital form (virtual). Information about the environment and the object can be added to the AR system which then that information showed on the real-world screen in real time as if the information is real.This paper introduces the concept or design of making AR application, not the implementation. Objects used are original fruits from various regions in Indonesia. The system begins with the process of retrieving a marker through the device’s camera for detection. Once the fruit marker is detected, the system needs information on the type of fruit as the database of each fruit and sent to the cloud server service for checking. The device will get data about the corresponding object and marker and will display the object on the device. The process to detect markers by cloud recognition method is done by uploading images to the Vuforia server first. This image will be used as the marker of AR. Vuforia will also calculate the intensity of color in the form of bits and conduct edge detection for improved results. If the value requested by device equals to the value on the server then the authorization in using marker will be given by Vuforia server and the marker will be displayed, but if it does not match it will display error message depending on the error detected.

[3] Liuchen Wu, Ruibo Chen, Hui Zhang, Junfei Yi, “Fruit Classification using Convolutional Neural Network via Adjust Parameter and Data Enhancement”, 12th International Conference on Advanced Computational Intelligence (ICACI) Dali, China, August 14-16, 2020.

This paper proposes a method of fruit automatic recognition and classification based on convolutional neural network. First, we obtained two color fruit image data set (public data set and self made data set). The public data sets is composed of fruit images with simple background, while the fruit images in the self-made data set are taken in a complex environment. Then, on the basis of convolutional neural network, we conducted several research experiments through parameter adjustment, and achieved the highest average classification accuracy of 99.8% on the public data set. In the self-made data set, the classification accuracy is 90.2%. Finally, we improved the classification accuracy of the self-made data set from the original 90.2% to 98.9% by adopting appropriate data enhancement techniques. For self made data set, the paper proposes using combination of enhancement techniques. The first is a combination of random cropping and random flip, the second is a combination of enhanced brightness and random flip, the third is a combination of random crop and enhanced brightness, and the fourth is a combination of random crop, random flip and enhanced brightness. Through results it can be said that data enhancement does not mean that the more data you enhance, the better the classification effect of fruit images will be. Only by finding appropriate enhancement times and data enhancement methods can the best classification effect be achieved. Compared with the whole data enhancement classification experiment, the three data enhancement methods in improving the classification effect of convolutional neural networks on self-made data sets, there are randomly flip ¿ enhance brightness ¿ randomly crop randomly. And after combining the two data enhancement methods of random flip and enhanced brightness, the classification accuracy of the self-made data set reached 98.1%

[4] Huai-Kuei Wu, Jui-Sheng Wang and Yuan-Hsin Chen, “Development of Fruit Grading System Based on Image Recognition”, 2nd IEEE International Conference on Architecture, Construction, Environment and Hydraulics 2020.

The stepping motor receives the control signal from STM32F746 to drive the conveyor belt and realize the operation of the transmission mechanism. After the fruit grading is completed, the electric push rod pushes the fruit to different fruit baskets according to the grade. The database is used to store fruit grading information for use as a reference for fruit harvest analysis and planting. Users can use the touch interface on the top of the identification host to perform various operations and settings. The users can use the system settings to adjust the grading parameters. The main menu shows the identification host, including recognition start, system settings, history grading records, and fruit history pictures. The system setting screen allows for the adjustable parameters which include fruit size, fruit color threshold, and percentage of allowable black points on fruit.
The system architecture consists of:

1.Identification host:

a. STM32F7 microcontroller
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d. Wi-Fi module

2. Transmission mechanism:

a. A stepping motor and
b. An electric push rod

[5] Wei Ni and Rihui Li, "Research on Recognition Technology of Fruit based on Simulated Annealing Algorithm and Neural Network", 2021 IEEE Asia-Pacific Conference on Image Processing, Electronics and Computers (IPEC).

This paper proposes a fruit grading algorithm based on simulated annealing algorithm and neural network. When the BP neural network model is used to attain the optimal solution, it is easy to fall into the local optimal solution. In order to solve this problem, the simulated annealing algorithm is introduced to expand the weight of updated space of the network. In this paper, apple is selected as the research object. Firstly, the feature model for Apple classification is established, and then the corresponding BP neural network model is established. Finally, the simulated annealing algorithm is used to optimize the neural network algorithm. Compared with the common BP neural network algorithm and RBF neural network algorithm, this algorithm has better recognition efficiency. Size is usually one of the most important parameters of fruit grading. In this paper, the diameter and circumference of fruit are selected as the characteristic indexes to measure the fruit size. For example, for apples, the larger the size, the higher the fruit grade. The color of fruit is closely related to maturity, so the color of fruit is selected as the characteristic index to measure the maturity of fruit. The learning process of BP neural network is composed of two processes: error back propagation and signal forward propagation. The signal forward propagation is from the input layer through the hidden layer to the output layer. The error back propagation is from the output layer to the input layer through the hidden layer, and the weights of each connection are continuously adjusted. In order to jump out of the local optimal solution that may get through the BP neural network in the process of obtaining the optimal solution of the weight, the simulated annealing algorithm (SA) is needed to optimize the weight and finally get the global optimal solution.

Sr.no	Title of paper	Year	Authors	Advantages	Limitations
1.	A Research on the Fruit Recognition Algorithm Based on the Multi-Feature Fusion	2020	Yanfeng Tang, Yawan Zhang, and Ying Zhu	1.Uses HSV color model that is closer to people's perception 2.Uses multiple features	1.Time spent is more. 2.Low recognition rate in fruits with similar size and color.
2.	A Method of Cloud and Image-Based Tracking for Indonesia Fruit Recognition	-	Dewi Agushinta R. and Henny Medyawati, Ihsan Jatnika and Hustinawaty	1.A mobile application is convenient to use.	1.Input image will vary which can make identification difficult
3.	Fruit Classification using Convolutional Neural Network via Adjust Parameter and Data Enhancement	2020	Liuchen Wu, Ruibo Chen, Hui Zhang, Junfei Yi	1.Uses data enhancement techniques	1.Halcon encapsulates the pre-training network
4.	Development of Fruit Grading System Based on Image Recognition	2020	Huai-Kuei Wu, Jui-Sheng Wang and Yuan-Hsin Chen	1.Adjustable parameters like fruit size, color threshold, and percentage of allowable black points	1.Does not mention accuracy of the proposed system
5.	Research on Recognition Technology of Fruit based on Simulated Annealing Algorithm and Neural Network	2021	Wei Ni and Rihui Li	1.Prevents finding only the local optimal solution. 2.Accuracy is higher than BPNN.	1.Loses training speed due to introduction of annealing algorithm.

Chapter 4

Mathematical Model

Convolution

Kernel convolution is not only used in CNNs, but is also a key element of many other Computer Vision algorithms. It is a process where we take a small matrix of numbers (called kernel or filter), we pass it over our image and transform it based on the values from filter. Subsequent feature map values are calculated according to the following formula, where the input image is denoted by f and our kernel by h. The indexes of rows and columns of the result matrix are marked with m and n respectively.

$$G[m,n] = (f * h)[m,n] = \sum_j \sum_k h[j,k] f[m-j, n-k]$$

Figure 4.1: Convolution Formula

Activation Functions

An activation layer accepts the input volume and applies the AF given [44]. Since an element-specific activation function is applied, the activation layer output is always the same as the input dimension. We use a non-linear activation layer after each ConV layer in a CNN. We have numerous activation functions such as the sigmoid function, tanh function (hyperbolic tangent), ReLU (rectified linear unit function), ELU, or any other Leaky ReLU variants. Activation functions used in this paper's model are:

a) ReLU : A Rectified Linear Unit (A unit employing the rectifier is also called a rectified linear unit ReLU) has output 0 if the input is less than 0, and raw output otherwise. That is, if the input is greater than 0, the output is equal to the input. The operation of ReLU is closer to the way our biological neurons work. ReLU is non-linear and has the advantage of not having any backpropagation errors unlike the sigmoid function, also for larger Neural Networks, the speed of building models based off on ReLU is very fast opposed to using Sigmoids.

$$f(x) = max(x, 0)$$

Figure 4.2: ReLU f(x)

b) Softmax : Softmax is a very interesting activation function because it not only maps our output to a [0,1] range but also maps each output in such a way that the total sum is 1. The output of Softmax is therefore a probability distribution. The softmax function is often used in the final layer of a neural network-based classifier. Mathematically Softmax is the following function where z is vector of inputs to output layer and j indexes the the output units from 1,2, 3 . . . . k :

$$\sigma(\mathbf{z})_j = \frac{e^{z_j}}{\sum_{k=1}^{K} e^{z_k}} \quad \text{for } j = 1, \ldots, K.$$

Figure 4.3: Softmax function

Chapter 5

Proposed System Architecture

5.1 System Architecture

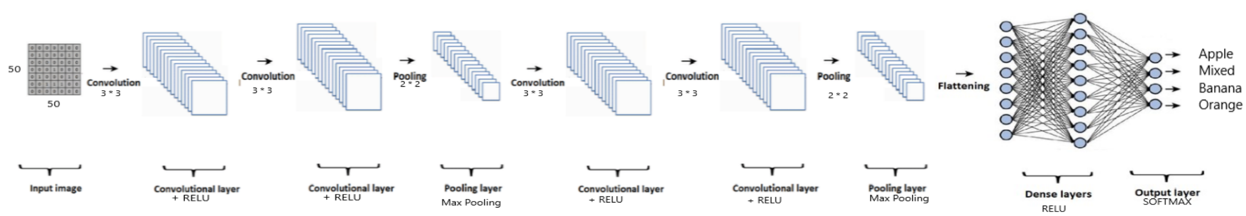

Figure 5.1: System Architecture

The images from the data set are of size 50 * 50. The color model used is RGB and thus there are three color channels. The first layer is a convolution layer. A convolution is a linear operation that involves the multiplication of a set of weights with the input. The filter is smaller than the input data and the type of multiplication applied between a filter-sized patch of the input and the filter is a dot product. The output generated is known as feature map because it represents where a certain kind of feature is found in the image. The size of the filters is 3 * 3 and there are 32 such filters. The activation function used through out for convolution layers is ReLU. After another convolution layer we are using a max pooling layer.

Max pooling is a pooling operation that selects the maximum element from the region of the feature map covered by the filter. Thus, the output after max-pooling layer would be a feature map containing the most prominent features of the previous feature map. In max pooling layer the padding is set to same. This ensures that the output has he same size as the input.

This is followed by a dropout layer. Dropout is basically a type of regularization which aims to prevent overfitting. Random dropouts make sure that no single node in the network "activates" when presented with a specific pattern. Overfitting is a concept in data science, which occurs when a statistical model fits exactly against its training data. When this happens, the algorithm unfortunately cannot perform accurately against unseen data, defeating its purpose. Then a combination of convolution and max pooling layers are used to enhance the network.

Then we flatten the output from max pooling layer and feed it to dense layer. Flattening is used to convert all the resultant 2-Dimensional arrays from pooled feature maps into a single long continuous linear vector. The dense layer's neuron in a model receives output from every neuron of its preceding layer, where neurons of the dense layer perform matrix-vector multiplication. Dense Layer is used to classify image based on output from convolutional layers.

In the final dense layer we have used softmax activation function. It is usual practice to add a softmax layer to the end of the neural network, which converts the output into a probability distribution. Softmax converts the scores to a normalized probability distribution, which can be displayed to a user or used as input to other systems. For this reason it is usual to append a softmax function as the final layer of the neural network.

5.2 Design with UML Diagrams

5.2.1 Component Diagram

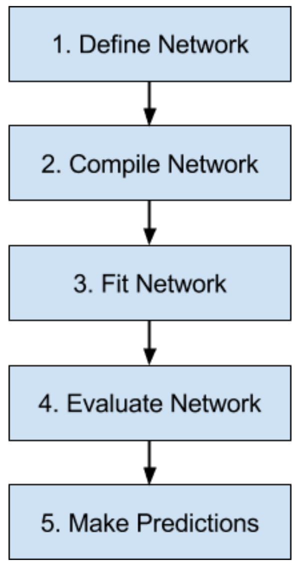

Figure 5.2: Life Cyle for Neural Network

1. Define Network : The first step is to define your neural network. Neural networks are defined in Keras as a sequence of layers. The container for these layers is the Sequential class.

Code snippet:

```
model = Sequential()
model.add(Conv2D(filters = 32, kernel_size = (3,3), input_shape = (50, 50, 3), padding = 'same',
activation = 'relu'))
model.add(Conv2D(32, (3, 3), activation="relu"))
model.add(MaxPooling2D(pool_size = (2,2)))
model.add(Dropout(0.2))
model.add(Conv2D(64, (3, 3), padding = 'same', activation="relu"))
model.add(Conv2D(64, (3, 3), activation="relu"))
model.add(MaxPooling2D(pool_size = (2,2)))
model.add(Dropout(0.3))
model.add(Flatten())
model.add(Dense(256, activation = 'relu'))
model.add(Dropout(0.5))
model.add(Dense(4, activation = 'softmax'))
```

2. Compile Network : Once we have defined our network, we must compile it. Compilation is always required after defining a model. Compilation requires a number of parameters to be specified, specifically tailored to training your network. Specifically the optimization algorithm to use to train the network and the loss function used to evaluate the network that is minimized by the optimization algorithm. We can also specify metrics to collect while fitting your model in addition to the loss function. Generally, the most useful additional metric to collect is accuracy for classification problems. The metrics to collect are specified by name in an array.
Code snippet:
from tensorflow.keras.optimizers import Adam optimizer = Adam(learning_rate=0.001)
model.compile(optimizer = optimizer, loss = 'categorical_crossentropy', metrics = ['accuracy'])

3. Fit Network : Once the network is compiled, it can be fit, which means adapt the weights on a training dataset. Fitting the network requires the training data to be specified, both a matrix of input patterns X and an array of matching output patterns y. The network is trained using the backpropagation algorithm and optimized according to the optimization algorithm and loss function specified when compiling the model. The backpropagation algorithm requires that the network be trained for a specified number of epochs or exposures to the training dataset.
Code snippet:
history = model.fit(X_train, y_train, batch_size = 32, epochs = 100, validation_split = 0.2, shuffle = True)

4. Evaluate Network : Once the network is trained, it can be evaluated. The network can be evaluated on the training data, but this will not provide a useful indication of the performance of the network as a predictive model, as it has seen all of this data before. We can evaluate the performance of the network on a separate dataset, unseen during testing. This will provide an estimate of the performance of the network at making predictions for unseen data in the future.
Code snippet:
score, accuracy = model.evaluate(X_test, y_test) print('Test score achieved:', score) print('Test accuracy achieved:', accuracy)

5. Make Predictions : Finally, once we are satisfied with the performance of our fit model, we can

use it to make predictions on new data. This is as easy as calling the predict() function on the model with an array of new input patterns.
Code snippet:
pred = model.predict(X_test)
The predictions will be returned in the format provided by the output layer of the network.

5.2.2 Activity Diagram

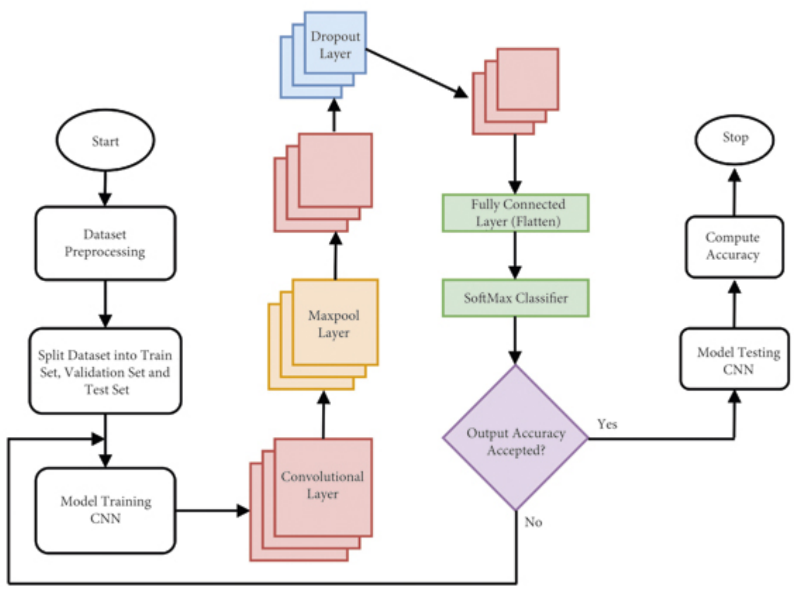

Figure 5.3: Activity Diagram

We start by image preprocessing. Then the dataset is split into training and testing parts. The training dataset is used for training the neural network. Neural network learns from the training dataset. The testing dataset is used to test the neural network and make predictions. Testing dataset is not seen by the neural network before. Then we define our neural network. All its layers along with their parameters are specified. Then we evaluate our model. This step shows us the accuracy of the model. If the accuracy is acceptable we can use the neural network for making predictions. However, if the accuracy is not acceptable we can go back to defining our neural network. Here it can be tweaked accordingly and we continue with the process as shown in the activity diagarm.

5.3 Important Source Code

The CNN model used in the project is decribed in the code as follows:

```
model = Sequential()
model.add(Conv2D(filters = 32, kernel_size = (3,3), input_shape = (50, 50, 3), padding = 'same',
activation = 'relu'))
model.add(Conv2D(32, (3, 3), activation="relu"))
model.add(MaxPooling2D(pool_size = (2,2)))
model.add(Dropout(0.2))
model.add(Conv2D(64, (3, 3), padding = 'same', activation="relu"))
model.add(Conv2D(64, (3, 3), activation="relu"))
model.add(MaxPooling2D(pool_size = (2,2)))
model.add(Dropout(0.3))
model.add(Flatten())
model.add(Dense(256, activation = 'relu'))
model.add(Dropout(0.5))
model.add(Dense(4, activation = 'softmax'))
```

The summary of the model is as follows:

```
model.summary()
Model: "sequential"
```

Layer (type)	Output Shape	Param
conv2d (Conv2D)	(None, 50, 50, 32)	896
conv2d_1 (Conv2D)	(None, 48, 48, 32)	9248
max_pooling2d (MaxPooling2D)	(None, 24, 24, 32)	0
dropout (Dropout)	(None, 24, 24, 32)	0
conv2d_2 (Conv2D)	(None, 24, 24, 64)	18496
conv2d_3 (Conv2D)	(None, 22, 22, 64)	36928
max_pooling2d_1 (MaxPooling2D)	(None, 11, 11, 64)	0
dropout_1 (Dropout)	(None, 11, 11, 64)	0
flatten (Flatten)	(None, 7744)	0
dense (Dense)	(None, 256)	1982720
dropout_2 (Dropout)	(None, 256)	0
dense_1 (Dense)	(None, 4)	1028

Summary of the neural network

The batch size and epochs used in model training are defined in below code snippet:

```
history = model.fit(X_train, y_train, batch_size = 32, epochs = 100, validation_split = 0.2, shuffle
= True)
```

5.4 Testing Code

```
fig, axs= plt.subplots(2,2, figsize=[10,10])
fig.subplots_adjust(hspace=.01)

count=0

for i in range(2):
for j in range(2):

img = cv2.imread(path_test[count])
img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
img = cv2.resize(img, (250,200))
```

```
result = np.argsort(pred[count])[::-1]

i_max = -1
max_val = ””
for (k,val) in enumerate(fruits.keys()):

if(pred[count][k] ¿ i_max):
i_max = pred[count][k]
max_val = val

txt = str(max_val) + ” with Probability ”+ str(”{:.4}%”.format(i_max*100)) + ” %”

axs[i][j].imshow(img)
axs[i][j].set_title(txt)
axs[i][j].axis(’off’)

count+=1

plt.suptitle(”All predictions are shown in title”, fontsize = 18)
plt.show()
```

5.5 Result screenshot and Analysis

The evaluation of the trained model shows that:

```
score, accuracy = model.evaluate(X_test, y_test)
print(’Test score achieved:’, score)
print(’Test accuracy achieved:’, accuracy)

2/2 [==============================] - 0s 33ms/step - loss: 0.9819
- accuracy: 0.9000
Test score achieved: 0.9818870425224304
Test accuracy achieved: 0.8999999761581421
```

The prediction made by the model can be viewded below:

Figure 5.4: Result

Chapter 6

Advantages / Disadvantages

6.1 Advantages

1. Reduction in labour cost. As traditional methods for fruit classification or grading require extensive workforce, much capital is spent on hiring labour.

2. Reduction in required amount of capital. As computer programs need minimum human input after setup, the overall cost of operations is decreased. Once setup, machine learning programs learns from previous data and needs no additional human input.

3. Allows businesses to grow. Using efficient techniques makes the journey of fruits from farms to consumers less complex thus in turn boosting profits for involved parties.

4. Flexible nature allows for other applications. The machine learning program ca be integrated into any system and can be used in various places. This allows for other use like educational use of such program which will make learning more fun.

5. Saves time during process of classification. As the machine learning program requires minimum input once setup, the labour can be employed for some other tasks which requires human attention.

6.2 Disadvantages

1. As the size of data set increases, training time increases. Results have shown that as we train the model for multi-feature recognition, with addition of nodes, training time increases significantly. Thus, Training machine learning algorithms so that fruit classification can be carried out with acceptable accuracy requires time.

2. Selection of a proper data set plays a crucial role. Accuracy of our model depends on the selected data set. The trained algorithm might give variable results if training data set that is used is insufficient for correct predictions.

3. Cost of setting up a computer-aided automatic fruit classification system is high. This might be an obstacle on its way to became successful on a large scale. Initially, business owners might be reluctant to try such systems due to expensive setup cost.

4. Difficult to setup in remote areas with no proper resources. Implementing a computer-aided automatic fruit classification system requires resources. Lack of resources can make the system setup difficult.

5. Errors, by humans or by machines - that are a brain child of humans, cannot be ignored. A computer program can rarely be trusted entirely. There might be a loophole in the system that may cause system to malfunction or to operate with questionable efficiency.

Chapter 7

Applications

1. Use in supermarkets and retail stores
In supermarkets and retail stores human labour is used to scan fruits using either barcodes or manual techniques and calculate the price and help customers checkout. This can be further improved by implementing automatic checkout systems for fruit system using fruit recognition.

2. Integrating into Augmented Reality
Augmented reality along with virtual reality is said to be next big thing. Fruit Recognition algorithms can be implemented along these to give real time information of a fruit.

3. Developing a mobile application
A standalone mobile application can be developed which stores fruits' information as well as gives real time information regarding the fruit scanned through device camera.

4. Educational usage
Traditionally children learn about fruits through media like print media, television or through visually applied learning. To improve children's interest and knowledge about fruits, fruit recognition models can be used in educational institutes. This will pave the way of interactive learning through the help of technology.

5. Agricultural applications
Today the term Smart Agriculture can be heard around quite frequently. An automated computer-aided program like fruit classification can be a step towards Smart Agriculture. This will benefit all parties and truly bring a new phase in agricultural practices.

Chapter 8

Conclusion and Future Work

Due to the advancements in the field of computer science we are able to try and develop such systems that aim at making our lives more easier and productive. Machine Learning and Data Science is a vast field used in a number of sectors. It can be also used to develop agricultural systems. My project here aims at proposing a fully automated, computer aided fruit classification system. With the help of convolutional neural network I have tried classifying fruits into four different categories.In the future this shall be expanded to create a system that can identify and classify almost every fruit. There is evidence of a lot of research in this field. However, due to certain limitations we currently do not see any fruit recognition applications being used on a large scale. Fruits come in a variety of shapes and sizes making it difficult to implement a proper system which produces accurate results. Also, cost of setting up a computer-aided automatic fruit classification system is high. This might be an obstacle on its way to became successful on a large scale. Implementing a computer-aided automatic fruit classification system requires resources. Lack of resources can make the system setup difficult. A fruit recognition system can be further enhanced to add the feature of fruit grading. By doing so we can expect profits to rise up and benefit everyone involved from producers to consumers. Already the term smart agriculture is making a lot of buzz. I believe we are not far from seeing a tech driven agricultural revolution.

Chapter 9

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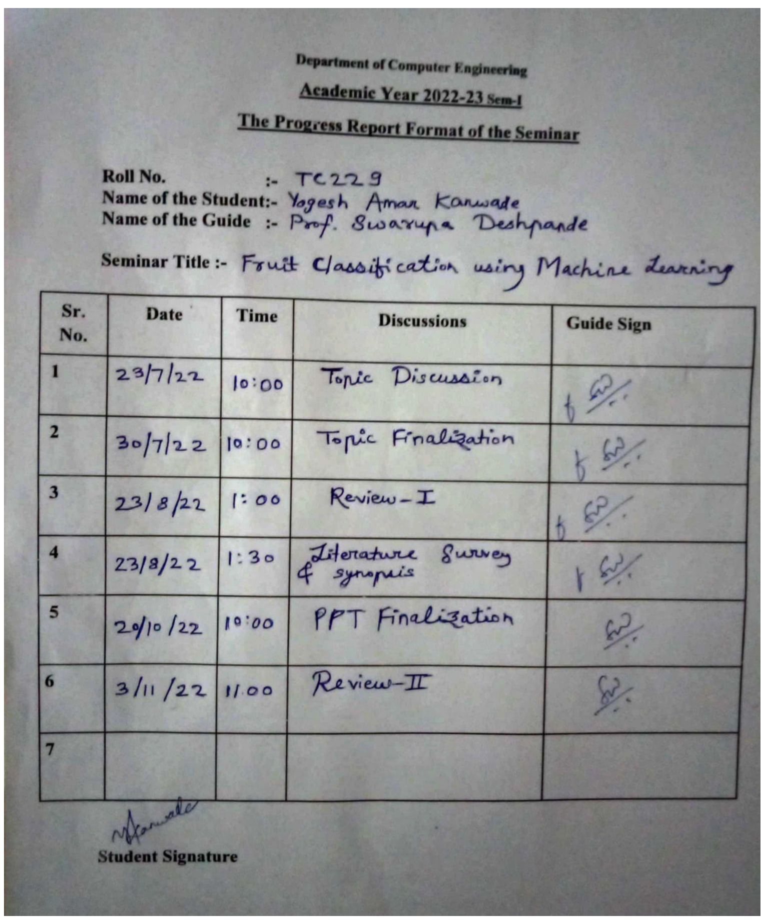
Chapter 10

Appendix

10.1 Log Report



Department of Computer Engineering

Academic Year 2022-23 Sem-I

The Progress Report Format of the Seminar

Roll No. :- TC229
Name of the Student:- Yogesh Aman Karwade
Name of the Guide :- Prof. Swarupa Deshpande

Seminar Title :- Fruit Classification using Machine Learning

Sr. No.	Date	Time	Discussions	Guide Sign
1	23/7/22	10:00	Topic Discussion	
2	30/7/22	10:00	Topic Finalization	
3	23/8/22	1:00	Review-I	
4	23/8/22	1:30	Literature Survey & synopsis	
5	20/10/22	10:00	PPT Finalization	
6	3/11/22	11:00	Review-II	
7				

Student Signature

Figure 10.1: Log Report