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Vegetable Classification Using Deep Learning

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Abstract: *Vegetables are an essential component of a healthy diet and play a critical role in promoting overall health and well-being. Vegetables are rich in important vitamins and minerals, including vitamin C, folate, potassium, and iron. They also provide fiber, which helps maintain digestive health and prevent chronic diseases. We are proposing a deep learning model for the classification of vegetables. A dataset was collected from Kaggle depository for Vegetable with 15000 images for 15 different classes. The data was preprocessed, normalized and split into three sets (train, valid, test). The proposed model was trained and validated using the train and valid sets and accuracy of both training and validation was very high. For the evaluation of the proposed model we utilized these metrics: accuracy, F1-score, precision, Recall and time required for testing. We then tested the proposed model using the test set. The result of the testing was accuracy (99.95%), F1-score (99.95%), precision (99.95%), Recall (99.95%) and time required for testing the test set was 1.38 seconds.*

Keywords: deep learning, Vegetable, DenseNet121, CNN

INTRODUCTION

Vegetables are an essential component of a healthy diet and play a critical role in promoting overall health and well-being. Some of the key benefits of consuming vegetables include [1]:

- Nutritional Value: Vegetables are rich in important vitamins and minerals, including vitamin C, folate, potassium, and iron. They also provide fiber, which helps maintain digestive health and prevent chronic diseases.
- Antioxidants: Vegetables contain antioxidants, which are compounds that help protect the body against damage caused by harmful molecules known as free radicals.
- Weight Management: Vegetables are low in calories and high in fiber, making them an ideal food choice for those looking to maintain or lose weight.
- Disease Prevention: Regular consumption of vegetables has been linked to a reduced risk of many chronic diseases, such as heart disease, stroke, and certain types of cancer.
- Improved Digestion: Vegetables contain fiber, which promotes regular bowel movements and helps maintain digestive health.

In conclusion, incorporating a variety of vegetables into your diet is an important step in promoting overall health and well-being. By including vegetables in your meals, you can provide your body with the nutrients it needs to function optimally, reduce your risk of chronic diseases, and improve your overall health [2].

Vegetables can be classified into several groups based on their characteristics and nutritional content. One common way of classifying vegetables is by their botanical classification, which groups them according to their growth habit and edible parts. For example, root vegetables such as carrots and beets are grown for their underground roots, while leafy vegetables like spinach and lettuce are grown for their leaves. Another classification method is based on their culinary use, such as grouping them as staples, side dishes, or garnishes. Nutritional classification categorizes vegetables based on their nutrient content, such as dark green leafy vegetables that are high in vitamins and minerals, and starchy vegetables like potatoes and corn, which are rich in carbohydrates. Regardless of the method of classification, all vegetables play an important role in a balanced and healthy diet by providing essential vitamins, minerals, and fiber [3].

Deep learning can be used for the classification of vegetables. Deep learning is a subfield of machine learning that uses artificial neural networks, which are inspired by the structure and function of the human brain, to perform tasks such as image recognition, speech recognition, and natural language processing [4]-[8].

For vegetable classification, we can use a Convolutional Neural Network (CNN), which is a type of deep learning [9]-[13] model that is well-suited for image classification tasks. We would train the CNN on a large dataset of labeled images of vegetables, where each image is assigned a class label corresponding to the type of vegetable in the image.

During training, the network learns to extract relevant features from the images and make predictions based on those features. The goal is to train the network to predict the correct class label for an input image with high accuracy [14]-[18].

Once the network is trained, you can use it to classify new images of vegetables. The network will take an input image, process it through its layers, and output a predicted class label along with a confidence score for each class [19]-[23].

There are many publicly available datasets of vegetable images that we can use to train and test your CNN. Additionally, there are also many pre-trained deep learning models [24]-[28] that we can use as a starting point for our own vegetable classification task.

We are proposing the deep learning CNN model: DenseNet121 for the classification of the 15 type of vegetables using the dataset that was collected Kaggle.

2 Literature

There are many studies in the literature dealing with vegetables classification, a few of them use deep learning customized Convolutional Neural Network [29]-[30] as the method for the classification. Most of the previous studies use different datasets, with different number of classes. The accuracies of the previous studies ranged from 94.35% to 99.00%. Table 1 summarizes the previous studies found in the literature review in terms of publication year, methods used, dataset images, labels, and best accuracy achieved.

Table 1 summarizes the previous studies

Reference	Year	Methods	Dataset	# of classes	Result(s)
[1]	2018	InceptionV3	1200 images	4	Accuracy: 99.00%
[2]	2018	GaborLBP	21000 images	15	Accuracy: 98.50%
[3]	2018	Customized CNN	1200 images	4	Accuracy: 94.00%
[31]	2018	ANN	21000 images	15	Accuracy: 90.00%
[32]	2019	Customized VGG-16	21000 images	15	Accuracy: 99.75%
[33]	2019	K-NN	21000 images	15	Accuracy: 97.50%
[34]	2020	Naïve Bayes	6783 images	12	Accuracy: 98.30%
[35]	2020	AlexNet	6783 images	12	Accuracy: 98.12%
[36]	2021	GoogleNet	6600 image	6	Accuracy: 98.82%
[37]	2021	CNN	3924 images	24	Accuracy: 95.50%
[38]	2021	Customized CNN	6783 images	12	Accuracy: 97.40%
[39]	2021	Customized CNN	21000 images	15	Accuracy: 97.50%
[40]	2021	Customized CNN	10756 images	20	Accuracy: 95.67%
[41]	2021	Customized CNN	90483 images	131	Accuracy: 94.35%
[42]	2022	CNN	1200 images	4	Accuracy: 96.00%

3. Methodology

3.1 Dataset

The dataset for Vegetable images was collected from Kaggle depository. The dataset consists of 15000 images of 15 classes of vegetables: Tomato, Bean, Bottle_Gourd, Carrot, Cucumber, Pumpkin, Cauliflower, Capsicum, Broccoli, Papaya, Brinjal, Cabbage, Bitter_Gourd, Radish, and Potato. The data was pre-processed and normalized. The dataset was split into 3 sets: training, validation and testing. The ratio of splitting was 70x15x15 as in Table 2. Samples of the dataset are shown in Figure 2.

Table 2. Summarizes the distribution of Images

Class	Training Images	Validation Images	Testing Images	Total
Carrot	700	150	150	1000
Cauliflower	700	150	150	1000
Broccoli	700	150	150	1000
Tomato	700	150	150	1000
Cucumber	700	150	150	1000
Pumpkin	700	150	150	1000
Bean	700	150	150	1000
Capsicum	700	150	150	1000
Bottle_Gourd	700	150	150	1000
Papaya	700	150	150	1000
Radish	700	150	150	1000

Cabbage	700	150	150	1000
Bitter_Gourd	700	150	150	1000
Brinjal	700	150	150	1000
Potato	700	150	150	1000
Total	10500	2250	2250	15000

Figure 1. Samples from the Vegetable Dataset

3.2 Proposed Model

The deep learning CNN model is DenseNet121. DenseNet121 is a deep convolutional neural network architecture that is a variation of the DenseNet architecture. It was introduced in the paper "Densely Connected Convolutional Networks" by Gao Huang, Zhuang Liu, Kilian Q. Weinberger, and Laurens van der Maaten.

The main idea behind DenseNet is to connect each layer to every other layer in a feed-forward fashion, allowing for an implicit deep supervision. The 121 in the name DenseNet121 refers to the number of layers in the network. DenseNet121 has a total of 121 layers, including convolutional, pooling and transition layers.

DenseNets have been applied in various computer vision tasks such as image classification, semantic segmentation, and object detection, achieving state-of-the-art results in some cases. They are also popular in medical imaging applications due to their ability to handle large amounts of dense data [44].

The architecture of DenseNet121 can be divided into several parts (Figure 2):

1. Input Layer: This is the first layer of the network that takes in an image of size (224, 224, 3) in the case of image classification on the ImageNet dataset.
2. Convolutional Layers: The network starts with a convolutional layer followed by batch normalization and ReLU activation.
3. Dense Blocks: The heart of the DenseNet architecture lies in its dense blocks. A dense block contains several consecutive layers, and each layer's output is concatenated with the outputs of all previous layers in the block. This dense connection allows for more efficient flow of information throughout the network and helps to mitigate the vanishing gradient problem that is common in deep networks.
4. Transition Layers: In between dense blocks, transition layers are used to reduce the size of feature maps and control the number of parameters in the network. These layers contain a convolutional layer followed by pooling.
5. Classifier: The final part of the DenseNet121 architecture is the classifier, which takes the output from the final transition layer and applies a fully connected layer followed by a softmax activation function to produce the final output.

Overall, DenseNet121 is a dense, deep network that is designed to handle high-dimensional data and extract complex features from input images. The dense connections and efficient flow of information make it a popular choice for a variety of computer vision tasks [45].

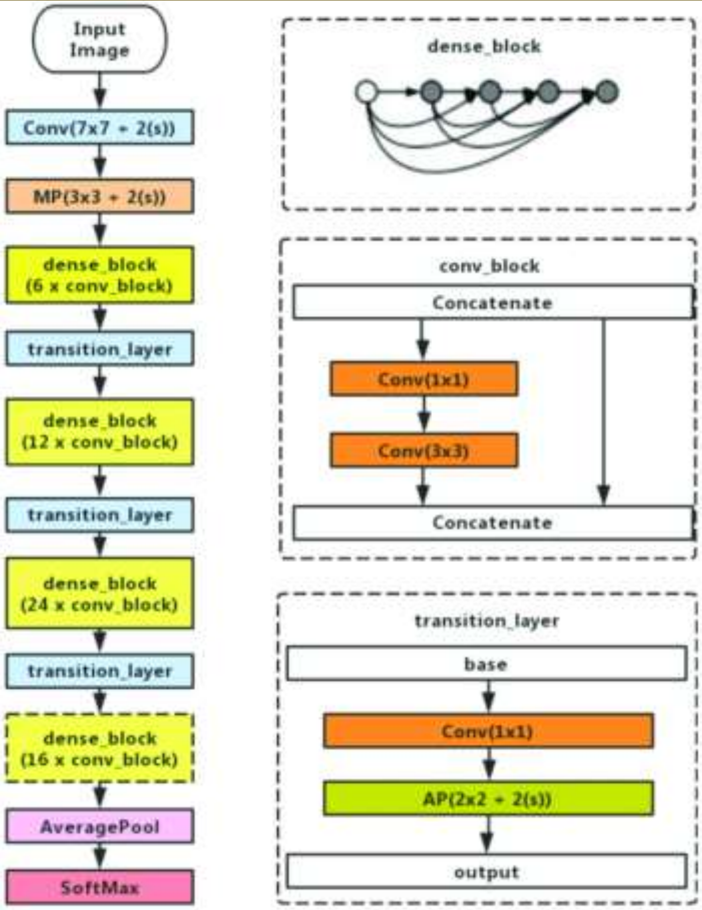

Figure 2. Architecture of DenseNet121

3.3 Evaluation Criterion

The evaluation metrics that were used in the evaluation of the proposed deep learning model are as in equation (1) – (4) [46]-[50].

$$\text{Precision} = \frac{\text{TP}}{\text{TP + FP}} \tag{1}$$

$$\text{Recall} = \frac{\text{TP}}{\text{TP + FN}} \tag{2}$$

$$F1 - score = 2 * \frac{\text{Precision x Recall}}{\text{Precision + Recall}} \tag{3}$$

$$\text{Accuracy} = \frac{\text{TN + TP}}{\text{TN+FP+ TP + FN}} \tag{4}$$

Results and discussion

The proposed model DenseNet121 was trained and validated for 40 epochs. The training accuracy was (99.95%), Training Loss (0.0014), Validating Accuracy (99.60%), and Validating Loss (0.0138). The history of the last 20 epochs of training and validation accuracy and loss are shown in Figure 3 and Figure 4.

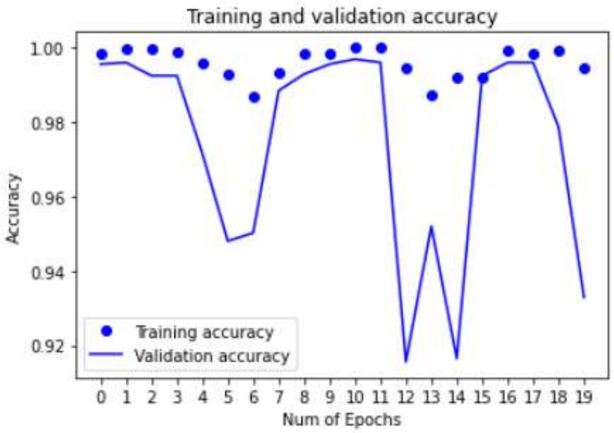

Figure 3. Training and validation accuracy of the proposed model

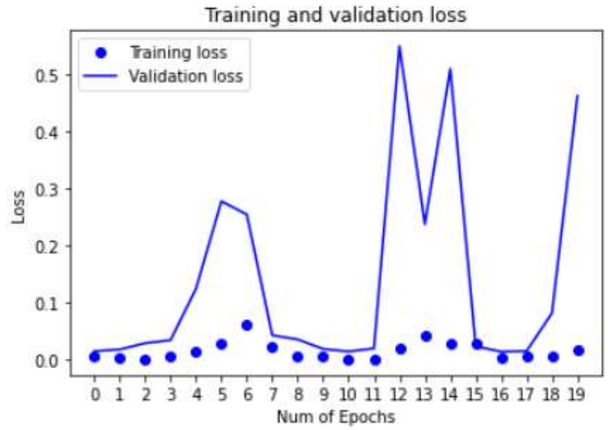

Figure4. Training and validation loss of the proposed model

After finishing the training and validation of the proposed model, it was evaluated using the kept aside test set. The testing accuracy (99.87%) and Testing Loss (0.0039)

The proposed model was evaluated further using F1-score, Recall, and Precision for each label in the dataset. The result of these measures are shown in the classification report of the proposed model (Figure 5). The overall of the proposed model accuracy (99.95%), Precision (99.95%), Recall (99.95%), F1-score (99.95%).

	precision	recall	f1-score	support
Bean	1.0000	1.0000	1.0000	154
Bitter_Gourd	1.0000	1.0000	1.0000	132
Bottle_Gourd	1.0000	1.0000	1.0000	144
Brinjal	0.9922	1.0000	0.9961	128
Broccoli	1.0000	1.0000	1.0000	153
Cabbage	1.0000	1.0000	1.0000	159
Capsicum	1.0000	1.0000	1.0000	153
Carrot	1.0000	1.0000	1.0000	144
Cauliflower	1.0000	1.0000	1.0000	133
Cucumber	1.0000	1.0000	1.0000	130
Papaya	1.0000	1.0000	1.0000	162
Potato	1.0000	1.0000	1.0000	148
Pumpkin	1.0000	1.0000	1.0000	143
Radish	1.0000	1.0000	1.0000	146
Tomato	1.0000	0.9928	0.9964	139
accuracy			0.9995	2168
macro avg	0.9995	0.9995	0.9995	2168
weighted avg	0.9995	0.9995	0.9995	2168

Figure 5. Classification Report of the proposed model

We measured ROC curve of each class in the dataset and all classes got 100% as in Figure 6.

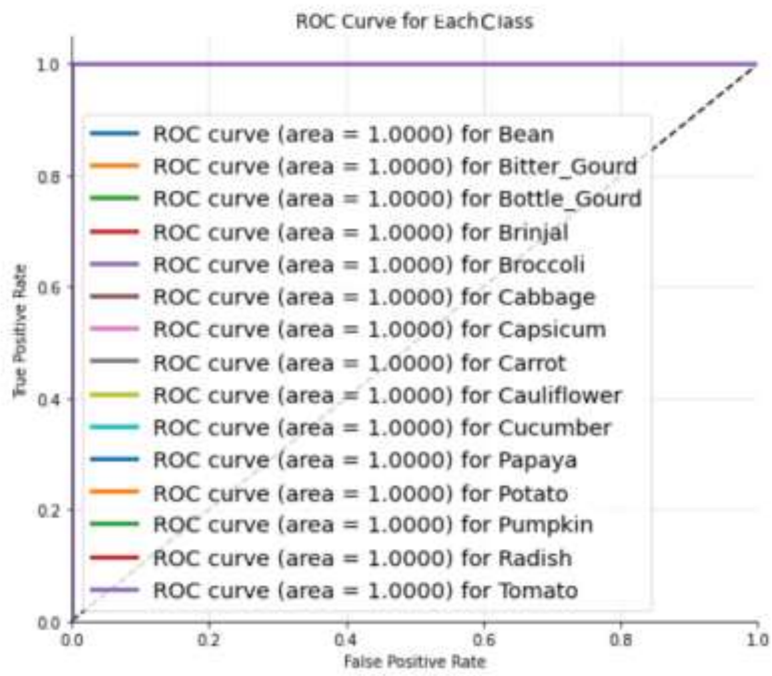

Figure 6. The Roc curve of each class of the dataset

Last we measured the heat map (Convulsion Matrix) as in Figure 7. It seems the proposed the model learned the vegetable dataset very well.

```
[154   0   0   0   0   0   0   0   0   0   0   0   0   0   0]
[  0 132   0   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0 144   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0 128   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0 153   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0 159   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0 153   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0 144   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0 133   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0 130   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0 162   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0 148   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0 143   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0 146   0]
[  0   0   0   1   0   0   0   0   0   0   0   0   0   0 138]
```

Figure 7. Heat Map of the proposed model

After evaluating the proposed mode, we made a comparisons of the current study with the previous studies in the literature as can be seen if Table 3.

Table 3 Comparison between current study with the previous studies

Referenc e	Year	Methods	Dataset Information	# of classes	Result(s)
[1]	2018	InceptionV3	1200 images	4	Accuracy:
[2]	2018	GaborLBP	21000	15	Accuracy:

[3]	2018	Customized CNN	1200 images	4	Accuracy:
[31]	2018	ANN	21000	15	Accuracy:
[32]	2019	Customized VGG-16	21000	15	Accuracy:
[33]	2019	K-NN	21000	15	Accuracy:
[34]	2020	Naïve Bayes	6783	12	Accuracy:
[35]	2020	AlexNet	6783	12	Accuracy:
[36]	2021	GoogleNet	6600 image	6	Accuracy:
[37]	2021	CNN	3924 images	24	Accuracy:
[38]	2021	Customized CNN	6783 images	12	Accuracy: [illegible]
[39]	2021	Customized CNN	21000	15	Accuracy: [illegible]
[40]	2021	Customized CNN	10756 [illegible]	20	Accuracy: [illegible]
[41]	2021	Customized CNN	90483	131	Accuracy:
[42]	2022	CNN	1200 images	4	Accuracy:
Current Study	**2023**	**Customized DeneseNet121**	**15000 images**	**15**	**Accuracy: 99.95%**

4. Conclusion and future work

Vegetables are an important constituent of a healthy diet and play a serious role in promoting overall health and well-being. Vegetables are rich in significant minerals and vitamins, including folate, potassium, vitamin C, and iron. The aim of this study is to propose a deep learning for the classification of vegetable images. The dataset was collected from Kaggle depository for Vegetable with 15000 images for 15 different classes. The data was preprocessed, normalized and split into three sets (train, valid, test). The proposed model was trained and validated using the train and valid sets and accuracy of both training and validation was very high. For the evaluation of the proposed model we used these metrics: accuracy, F1-score, precision, Recall and time required for testing. We then tested the proposed model using the test set. The result of the testing was accuracy (99.95%), F1-score (99.95%), precision (99.95%), Recall (99.95%) and time required for testing the test set was 1.38 seconds. That means the proposed model can generalize and not memorizes the images.

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