

Classification of Nuts Using Deep Learning

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Abstract: Nut, hard-shelled seeds enclosing a single edible oily kernel, are generally used for human consumption. Nuts may be consumed as shelled whole nuts or, after blanching, roasted. There are many types of nuts such as: almonds, walnuts, pecans, hazelnuts, cashews, pistachios, macadamia nuts, and brazil nuts. Nut classification has numerous applications across industries, agriculture, and services. For instance, it can streamline sorting in nut processing facilities, assist supermarket cashiers in identifying nut types and pricing, and help consumers choose nuts that align with their dietary needs. In this paper, Using a public dataset of 2,850 images of Nuts, we trained a deep convolutional neural network to classify 5 types of nuts (Chestnut, Hazelnut, Nut Forest, Nut Pecan, Walnut). A deep learning technique that extensively applied to image recognition was used. We used 70% from image for training and 15% from image for validation 15% for testing. Our trained model achieved an accuracy of 100% on a held-out test set, demonstrating the feasibility of this approach.

Keywords: Nut, Deep Learning, Classification, CNN

1. INTRODUCTION

Consuming nut is an important way to improve your health and reduce the risk of various diseases. Nut are an excellent source of vitamins, minerals, and fiber, making them a valuable addition to a healthy diet. Including nuts in your diet regularly may help lower the risk of heart disease, cancer, and diabetes[1]. CNNs are a type of neural network that are particularly well-suited for image recognition tasks, as they are able to automatically learn features from the input data [2]-[3]. This allows them to extract useful information from images, such as edges, textures, and shapes, and use it to classify the images. Additionally, CNNs can be trained using a large dataset of images, which allows them to learn from diverse examples and improve their performance [4]. In this research, I focus on identifying and classifying five different types of nuts, allowing us to explore their nutritional value and the many health benefits they offer. The five types of nut we classify in this study are Chestnut, Hazelnut, Nut Forest, Nut Pecan, and Walnut.

2. Nut benefit for health[5]:

1. Chestnut

Chestnut is a dried fruit with a high content of vitamins (B6 and thiamine), selenium, proteins, and minerals. It contains calcium, phosphorus, and magnesium, which promote the development and health of the skeletal system, and is a source of vitamin B6 and B1, which contribute to the proper functioning of the nervous system. In fact, half a cup of raw chestnuts gives you 35 to 45 percent of your daily intake of vitamin C.



2. Hazelnut

Hazelnut is the nut from the hazel tree (*Corylus avellana*). It is rich in monounsaturated fatty acids and is commonly eaten as food. Hazelnut contains oil, protein, fiber, and antioxidants. The antioxidants in hazelnut might have heart health benefits.

People use hazelnut for obesity, high cholesterol, heart disease, dementia, and other purposes, but there is no good scientific evidence to support these uses.



3. Nut Forest

A type of edible nut that typically comes from trees growing in forested or wild environments. These nuts are rich in healthy fats, protein, and fiber, making them a nutritious snack. Nut Forest varieties often contain essential vitamins and minerals such as vitamin E, magnesium, and potassium. These nutrients help support heart health, improve brain function, and reduce inflammation. Like other nuts, Nut Forest types are also packed with antioxidants, which help protect the body against oxidative stress and chronic diseases.



4. Nut Pecan

Pecan is a rich, flavorful nut that comes from a species of hickory tree native to northern Mexico and the southern United States. It has a healthful nutritional profile and offers a wide range of health benefits. Nut Pecan is considered a nutrient-dense food, packed with essential vitamins and minerals that support overall wellness. It contains high levels of vitamin A, which is vital for healthy skin, vision, and immune function. Nut Pecan also provides B-complex vitamins such as folate, niacin, riboflavin, thiamine, and vitamin B6—nutrients that play a crucial role in energy metabolism, brain health, and nerve function.



5. Walnut

Walnuts have higher antioxidant activity than any other common nut. This activity comes from vitamin E, melatonin and plant compounds called polyphenols, which are particularly high in the papery skin of walnuts. A preliminary, small study in healthy adults showed that eating a walnut-rich meal prevented oxidative damage of “bad” LDL cholesterol after eating, whereas a refined-fat meal didn’t. That’s beneficial because oxidized LDL is prone to build up in your arteries, causing atherosclerosis.



3. BACKGROUND:

3.1 DEEP LEARNING:

Deep learning is a subset of machine learning in artificial intelligence that has networks of learning skills from uneducated or unstructured data, and artificial intelligence (AI) that imitates the way humans gain certain types of knowledge[6]. Deep learning is an important element of data science, which includes statistics and predictive modeling. It is extremely beneficial to data scientists who are tasked with collecting, analyzing and interpreting large amounts of data; deep learning makes this process faster and easier [7]. Deep learning is a technique can be used for Nut classification from image files . Deep learning algorithms have mostly been used to enhance computer capabilities in tasks that mimic human abilities, such as image classification. In deep learning, each level learns to transform its input data into a slightly more abstract and composite representation. In an image recognition application, the raw input may be a matrix of pixels; the first representational layer may abstract the pixels and encode edges; the second layer may compose and encode arrangements of edges; the third layer may encode a nose and eyes; and the fourth layer may recognize that the image contains a face.

This research paper explores the use of deep learning techniques for the classification of five nut type varieties: Chestnut, Hazelnut, Walnut, Nut Pecan, and Forest Nut. The proposed approach leverages advanced Convolutional Neural Network (CNN) architectures, integrated with transfer learning strategies, to accurately identify and distinguish between nut categories based on their visual attributes, including color, contour, dimensional features, and shell texture. The objective is to develop a high-performance classification model that contributes to efficient nut recognition systems in agricultural and industrial contexts.

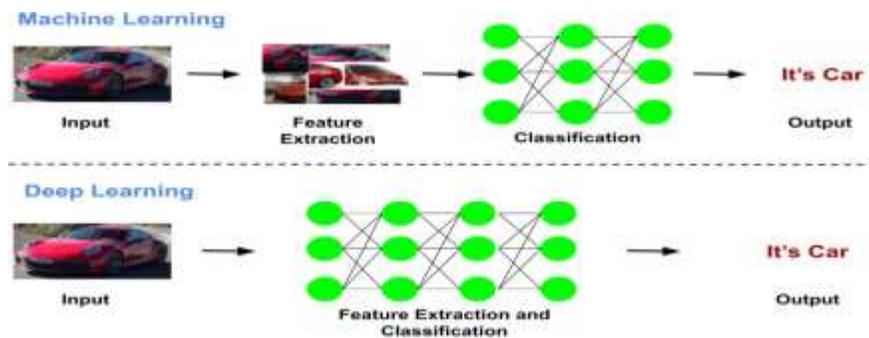


Figure 1:Machine Learning and Deep Learning

In deep learning, a computer model learns to perform classification tasks directly from images, text, or sound. Deep learning models can achieve state-of-the-art accuracy, sometimes exceeding human-level performance. Models are trained by using a large set of labeled data and neural network architectures that contain many layers.[8]

Deep learning techniques, particularly convolutional neural networks (CNNs), have shown great promise in accurately classifying Nut based on images. However, the performance of these models is limited by the availability and diversity of the training data. Additionally, the practical implementation of these models on a large scale is hampered by the requirement for specialized hardware and the need for extensive computing resources.[9]

3.2 Convolutional Neural Network(CNN):

Convolutional neural network is a type of artificial neural network that uses multiple perceptron that analyze image inputs and have learnable weights and bases to several parts of images and able to segregate each other. One advantage of using Convolutional Neural Network is it leverages the use of local spatial coherence in the input images, which allow them to have fewer weights as some parameters are shared. CNNs have been extensively applied in a range of different fields, including computer vision , speech processing , Face Recognition [10-12].

The features of using CNN for image assertion are discussed in this paper. Tenacity in the form of changes and mutilation in the image, lower system needs, best and easier management.

A convolutional neural network's architecture is a multi-layered feed-forward neural network created by successively stacking multiple hidden layers on top of each other. Convolutional neural networks can learn hierarchical features because of their successive structure [13-16]. This architecture has been particularly designed based on the explicit assumption that raw data are two-dimensional (images) that enables us to encode certain properties and also to reduce the number of hyper parameters[17-20].

With most algorithms that handle image processing, the filters are typically created by an engineer based on heuristics.

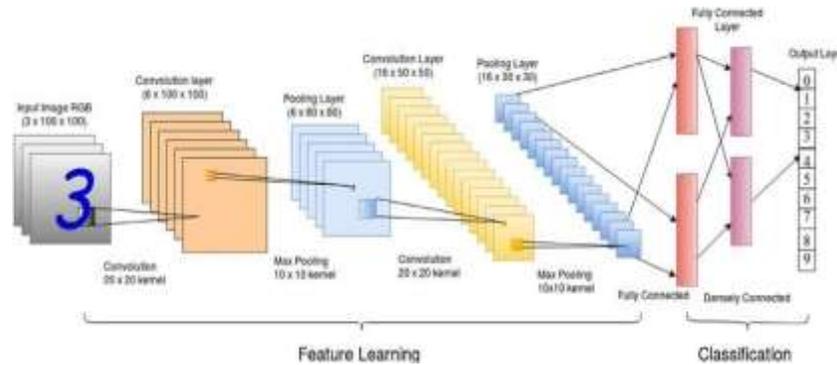


Figure 2: Convolutional neural network for MNIST digit recognition

As shown in Figure 2, the Convolutional Neural Network (CNN) converts the input image into multiple abstract representations that differ from the original, capturing more task-relevant features. A CNN acts as a multi-layered feature extractor, where each convolutional layer progressively refines the data to better suit the classification objective.

3.2.1 VGG 16 Architecture:

Is a convolutional neural network model that helps in learning basic design concepts. VGG16 was found to be the design with the best performance on the ImageNet dataset, achieving a top-5 test accuracy of 92.7% across over 14 million images in 1000 categories[21]. Due to its proven effectiveness in large-scale image classification, we adopt VGG16 as the backbone model for classifying five types of nuts in this study.

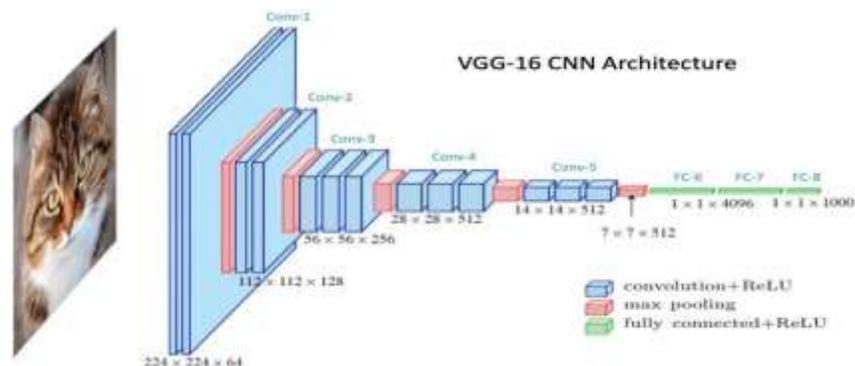


Figure 3: VGG-16 Architecture

Let's analyse the basic architecture of this system :

The input to the first convolutional block in the VGG16 architecture is a fixed-size RGB image of dimensions 224x224x3. The image is passed through two convolutional layers, each consisting of 64 filters with a small receptive field of 3x3, which is the minimal size effective for capturing spatial hierarchies such as left/right, up/down, and center. As the image

passes through these layers, the output feature map dimensions become $224 \times 224 \times 64$. This output is then forwarded to a max pooling layer with a stride of 2, which reduces the spatial dimensions and helps in controlling overfitting and computation cost. After the first pooling operation, the output is passed to the second convolutional block, which consists of two convolutional layers with 128 filters of size 3×3 , followed by another max pooling layer with a stride of 2.

The third and fourth convolutional blocks each contain three convolutional layers — the third block with 256 filters and the fourth and fifth blocks with 512 filters, all maintaining the 3×3 kernel size. Each of these blocks is also followed by a max pooling layer that reduces the spatial dimensions. After the convolutional and pooling layers, the output is flattened and fed into three fully connected layers. The first two fully connected layers have 4096 neurons each, and the final layer contains 1000 neurons (in the original ImageNet version) with a softmax activation function for classification.

3.3 TRANSFER LEARNING:

Transfer learning is an approach to machine learning where a model trained on one task is used as the starting point for a model on a new task. This is done by transferring the knowledge that the first model has learned about the features of the data to the second model.

In deep learning, transfer learning is often used to solve problems with limited data. This is because deep learning models typically require a large amount of data to train, which can be difficult or expensive to obtain.[22-23]



Figure 4: Transfer Learning

As shown in Figure 4, in the above image, the first diagram represents training a model from scratch while the second diagram represents using a model already trained on cats and dogs to classify the different class of vehicles, thereby representing transfer learning.

Types of Transfer Learning:

Transfer learning can be classified into two types:

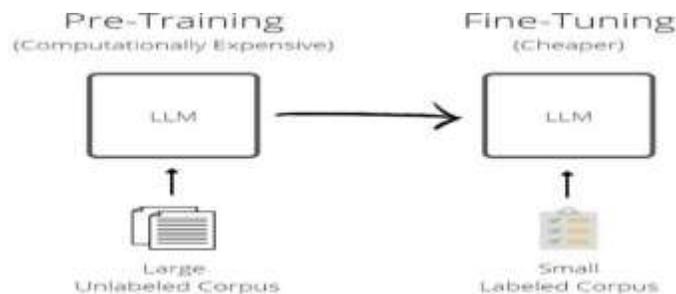


Figure 5: Type of Transfer Learning

- **Pre-Training :** A pre-trained model is a machine learning model that has been trained on a large dataset of data. This dataset is typically much larger than the dataset that will be used to train the final model. The pre-trained model learns to extract features from the data, and these features can be used to train the final model more quickly and efficiently. There are many popular pre-trained architectures, but some of the most common include: VGG (Visual Geometry Group) - ResNet (Residual Network) - BERT (Bidirectional Encoder Representations from Transformers)
- **Fine-Training :** Is a machine learning technique in which a pre-trained model is further trained on a new dataset to improve its performance on a specific task. The pre-trained model is typically trained on a large dataset of general data, while the new dataset is specific to the task at hand.

4. RELATED WORK:

In the study of (Alfarra, Classification of Pineapple Using Deep Learning) the model used deep learning to classify Two Pineapple (Pineapple and mini Pineapple) with a dataset that contains 1,311 images use 946 images for training, 197 images for validation and 168 images for testing. The trained model achieved an accuracy of 100% on test set [24].

In the study of (Elsharif, Potato Classification Using Deep Learning) a dataset of 2400 images of potatoes, was train a deep convolutional neural network to identify 4 types (Red, Red Washed, Sweet, and White). The accuracy of test data on trained data reached 99.5% [25].

In the study of (Alsaqqa, Using Deep Learning to Classify Different types of Vitamin) built a model using deep learning convolutional neural networks depend on a per trained model VGG16 fine tune CNN Model to classify five types of vitamins(Vitamin A, Vitamin B, Vitamin C, Vitamin D, Vitamin E) a dataset contains a set of 15213 sample images for 5 different class of vitamins use 9736 sample images for training, 3043 sample images for validation and 2434 sample images for testing belonging to 5 category from different Vitamins. model achieved a high classification accuracy of 99%, demonstrating its effectiveness in identifying different types of vitamins [26].

5. Study Objective :

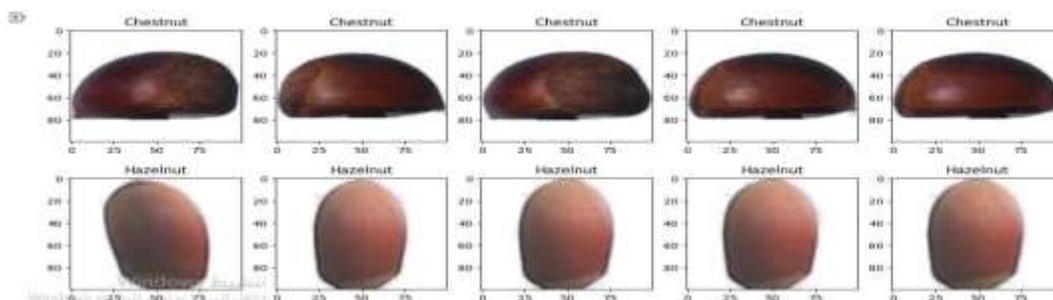
1. Demonstrating the feasibility of using deep convolutional neural networks to classify 5 different types of Nut.
2. To train and fine-tune the deep learning model using the collected dataset, employing data augmentation techniques to enhance model robustness.
3. To evaluate the performance of the developed model using standard metrics such as accuracy, precision, recall, and F1- score.

6. METHODOLOGY :

In this section, we evaluate the proposed solution as the selected VGG16 architecture, as well as the design choices, evaluation methods, and implementation details.

6.1 DATASET:

The dataset for nut classification was collected from Kaggle website. Each image was cropped to 128, 128pixels. For each type of Nut use 70% from image for training and 15% from image for validation 15 % for testing. The generated model was trained based on the training set and evaluated using the test set.



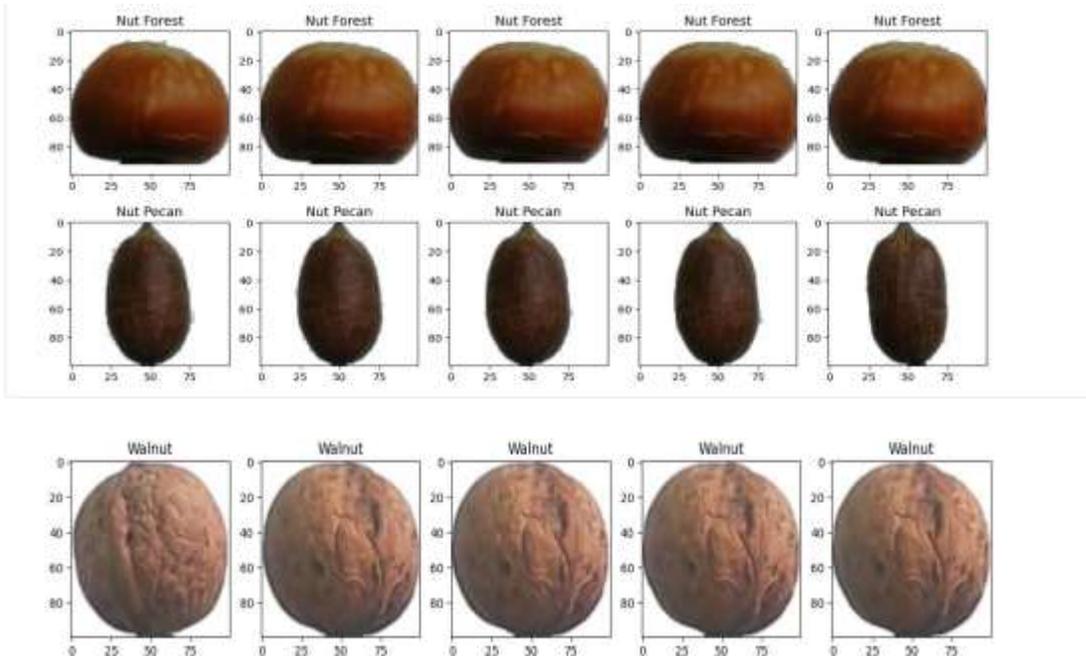


Figure 6: Dataset Images

6.2 Deployment :

We deployed our trained model on Google Colab to take advantage of its high computational power and the ability to share and collaborate on the same notebook. We also saved the model to a google drive for future use.

Model: "functional"

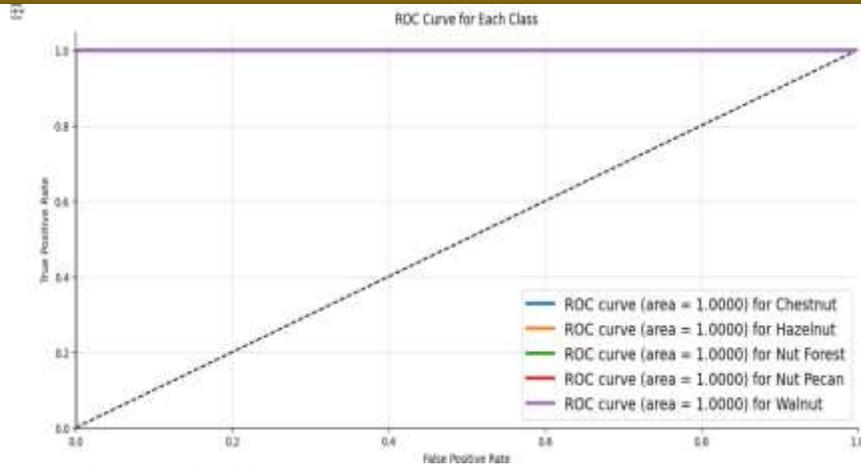
Layer (type)	Output Shape	Param #
input_layer (InputLayer)	(None, 128, 128, 3)	0
block1_conv1 (Conv2D)	(None, 128, 128, 64)	1,792
block1_conv2 (Conv2D)	(None, 128, 128, 64)	36,928
block1_pool1 (MaxPooling2D)	(None, 64, 64, 64)	0
block2_conv1 (Conv2D)	(None, 64, 64, 128)	73,856
block2_conv2 (Conv2D)	(None, 64, 64, 128)	147,584
block2_pool1 (MaxPooling2D)	(None, 32, 32, 128)	0
block3_conv1 (Conv2D)	(None, 32, 32, 256)	295,168
block3_conv2 (Conv2D)	(None, 32, 32, 256)	590,080
block3_conv3 (Conv2D)	(None, 32, 32, 256)	590,080
block3_pool1 (MaxPooling2D)	(None, 16, 16, 256)	0
block4_conv1 (Conv2D)	(None, 16, 16, 512)	1,180,160
block4_conv2 (Conv2D)	(None, 16, 16, 512)	2,359,808
block4_conv3 (Conv2D)	(None, 16, 16, 512)	2,359,808
block4_pool1 (MaxPooling2D)	(None, 8, 8, 512)	0
block5_conv1 (Conv2D)	(None, 8, 8, 512)	2,359,808
block5_conv2 (Conv2D)	(None, 8, 8, 512)	2,359,808
block5_conv3 (Conv2D)	(None, 8, 8, 512)	2,359,808
block5_pool1 (MaxPooling2D)	(None, 4, 4, 512)	0
global_max_pooling2d (GlobalMaxPooling2D)	(None, 512)	0
dense (Dense)	(None, 5)	2,565

Total params: 14,717,253 (56.14 MB)
 Trainable params: 14,717,253 (56.14 MB)
 Non-trainable params: 0 (0.00 B)

Figure 7: Architecture of the proposed model

6.3 EVALUATION:

To ensure that our predicted outputs closely represented actual probabilities, we employed the sigmoid activation function in the final layer of our model. The task was formulated as a binary classification problem, and performance was evaluated using the Area Under the Receiver Operating Characteristic Curve (ROC), which quantifies the alignment between the predicted probabilities and the true binary labels.



6.4 Training and validation of VGG16 Model:

In order to evaluate our model, We experimented to determine the best way to combine the available dataset into training and validation using basic hold-out validation and k-fold cross validation. To assess its reliability, we performed five independent trials, each utilizing a different random split for validation. we came to the conclusion that the straightforward hold- out validation method was inappropriate for this dataset and chose to utilize the k-fold cross validation method instead .

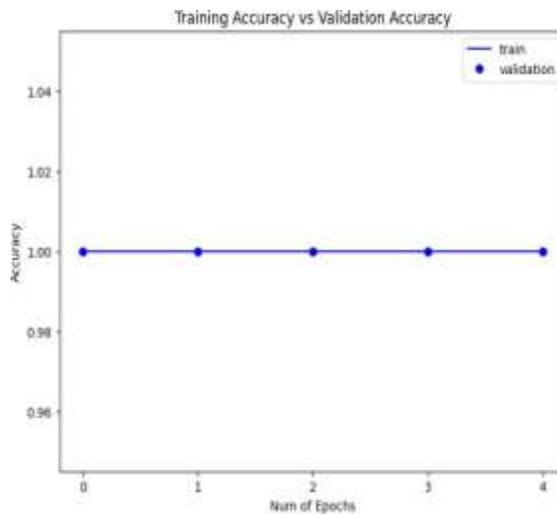


Figure 8: Training and validation accuracy of the model

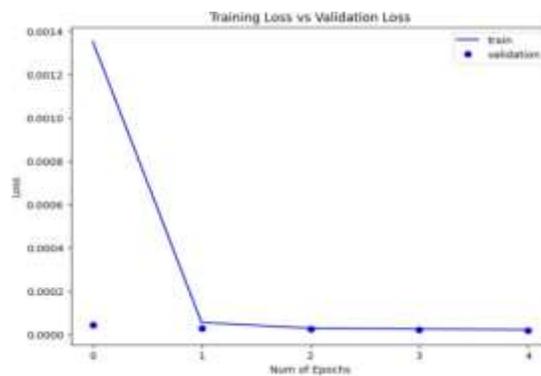


Figure 9: Training and validation loss of the model

7. Comparison of Classification Performance:

To evaluate the effectiveness of these models, the as-proposed method was compared with the existing methods for modern deep learning. The models were evaluated on the test set by the accuracy rate, and avg F1-score.

	precision	recall	f1-score	support
Chestnut	1.0000	1.0000	1.0000	57
Hazelnut	1.0000	1.0000	1.0000	55
Nut Forest	1.0000	1.0000	1.0000	27
Nut Pecan	1.0000	1.0000	1.0000	20
Walnut	1.0000	1.0000	1.0000	102
accuracy			1.0000	261
macro avg	1.0000	1.0000	1.0000	261
weighted avg	1.0000	1.0000	1.0000	261

Figure 10: Comparison of Classification Performance

8. Confusion Matrix:

This matrix offers a comprehensive view of our classification outcomes, with each row representing the true class of the peppers and each column indicating the model's predictions.

[57 0 0 0 0]
[0 55 0 0 0]
[0 0 27 0 0]
[0 0 0 20 0]
[0 0 0 0 102]

Figure 11: confusion matrix

9. CONCLUSION

Nut classification is an important task in various fields such as industry and agriculture. In this study, we proposed an approach that utilizes deep learning to classify images of 5 different types of nuts from the Kaggle website. We used a pre-trained CNN model, VGG16. In this paper, we trained the proposed model, validated it, and tested its performance using an unseen dataset for testing. The accuracy rate we achieved was 100%. This indicates that our proposed model can effectively classify different types of nuts accurately and with full performance. For future work, we will generalize the evaluation of the proposed framework to include more classes (using additional types of nuts). We will also investigate the effect of various parameters such as the activation function, pooling function, optimization method, and loss function. The proposed framework can also be deployed in a cloud-based environment.

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