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Classification of Pineapple and Mini Pineapple Using Deep Learning: A Comparative Evaluation

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Abstract. *This study explores the use of convolutional neural networks (CNNs) for classifying different pineapple varieties, specifically pineapples and mini pineapples. By using a dataset of pineapple images, the research demonstrates the effectiveness of a pre-trained VGG16-based CNN model in accurately classifying these fruit categories. The model achieved over 99% accuracy on both the training and validation sets. The performance of the CNN was compared to traditional machine learning algorithms to highlight the advantages of deep learning in image classification tasks. The results underscore the model's ability to generalize well to the classification task, offering insights into feature extraction from complex image datasets.*

Keywords: Machine and Deep Learning, Pineapple, Mini Pineapple, convolutional neural networks

1 Introduction

The agricultural industry has witnessed significant advancements with the integration of artificial intelligence (AI) technologies, particularly in the domain of image classification for crop and fruit management. Accurate identification and classification of fruits play a crucial role in enhancing agricultural productivity, improving supply chain efficiency, and reducing post-harvest losses. Among the many fruits cultivated globally, pineapples and their varieties, such as mini pineapples, hold substantial economic value [1,2]. Differentiating between these varieties is essential for market segmentation, quality control, and consumer satisfaction.

Traditional methods of fruit classification often rely on manual inspection, which is time-consuming, labor-intensive, and prone to human error. In recent years, machine learning (ML) techniques have been employed to automate this process, providing a more efficient alternative. However, these techniques are often limited by their reliance on handcrafted features, which may not capture the complexities of image data effectively. Deep learning (DL), particularly convolutional neural networks (CNNs), has emerged as a powerful tool for image analysis, overcoming the limitations of traditional ML approaches by automatically extracting features from raw data[3,4].

This study focuses on leveraging CNNs to classify two distinct pineapple varieties: pineapples and mini pineapples. Using a dataset of pineapple images, the research evaluates the performance of a pre-trained VGG16 model, a well-established CNN architecture known for its robust image classification capabilities. By comparing the results of the CNN model with those of traditional ML algorithms, this study highlights the advantages of deep learning in handling complex image datasets and achieving high classification accuracy.

1.1 Challenges and limitations:

Fruit classification, particularly distinguishing between similar species like pineapples and mini pineapples, presents a unique set of challenges in image recognition [5]. The visual similarities between these classes can make it difficult for machine learning models to effectively distinguish them[6]. Additionally, factors such as variations in lighting, size, and angle of the images further complicate classification. Furthermore, training on smaller datasets can limit the generalization capability of models, necessitating advanced techniques like data augmentation[7].

1.2 Objectives:

The primary objective of this research is to develop an effective image classification model capable of differentiating between two closely related categories: pineapples and mini pineapples. To achieve this, the study aims to:

- Evaluate the performance of traditional machine learning models compared to deep learning-based CNNs.
- Implement a CNN model based on the VGG16 architecture, fine-tuning it for optimal performance.
- Assess the model's ability to generalize to unseen data using various performance metrics such as accuracy, precision, recall, and F1-score.

2 Literature Review:

2.1 Previous Studies

Fruit classification using machine learning has been the subject of numerous studies. For instance, The study of [8] demonstrated the effectiveness of deep learning models for fruit recognition across multiple classes, achieving high accuracy on a dataset of over 20 fruit types using CNN architectures. However, their focus was on broad classification tasks with more distinct fruit categories.

Another study [9] utilized traditional machine learning models like SVM and KNN for fruit classification but found that these models struggled with intra-class variations. Deep learning, especially CNNs, has been shown to outperform these traditional models due to their ability to automatically extract complex features from raw images [10].

2.2 Research Gap

While there has been extensive research on fruit classification, few studies have focused on classifying different varieties of the same fruit, such as pineapples and mini pineapples, where the differences are subtler. This research aims to address this gap by leveraging the power of CNNs for fine-grained classification tasks and comparing it with traditional machine learning methods.

3 Methodology

3.1 Proposed Deep Learning Model

A pre-trained **VGG16** CNN model was fine-tuned for the pineapple classification task. The VGG16 architecture[11-14], known for its deep layers and high performance on image classification benchmarks, was chosen for its ability to learn hierarchical image features[15-17].

The CNN model was structured as follows[18-20]:

- **Base Model**: Pre-trained VGG16 with weights initialized from ImageNet.
- **Top Layer Modification**: The top fully connected layers were removed and replaced with:
  - Global Max Pooling layer.
  - Dense layer with softmax activation for classification of the two classes: pineapple and mini pineapple.

The proposed deep learning model was trained on the preprocessed dataset and evaluated based on accuracy, precision, recall, and F1-score[21-23]. Although these methods are effective for certain image classification tasks, they often struggle to capture complex visual patterns, particularly in images where the distinction between classes is subtle.

The model was compiled using the Adam optimizer with a learning rate of 0.0001 and categorical cross-entropy as the loss function. The training process involved early stopping and saving the best-performing model based on validation loss (Table 1).

Table 1. Architecture of Proposed Deep Learning Model

Layer (type)	Output Shape	Param #
input_2 (Input Layer)	[(None, 256, 256, 3)]	0

block1_conv1 (Conv2D)	(None, 256, 256, 64)	1792
block1_conv2 (Conv2D)	(None, 256, 256, 64)	36928
block1_pool (MaxPooling2D)	(None, 128, 128, 64)	0
Block2_conv1 (Conv2D)	(None, 128, 128, 128)	73856
Block2_conv2 (Conv2D)	(None, 128, 128, 128)	147584
Block2_pool (MaxPooling2D)	(None, 64, 64, 128)	0
Block3_conv1 (Conv2D)	(None, 64, 64, 256)	295168
Block3_conv2 (Conv2D)	(None, 64, 64, 256)	590080
Block3_conv3 (Conv2D)	(None, 64, 64, 256)	590080
Block3_pool (MaxPool-	(None, 32, 32, 256)	0
ing2D)	(None, 32, 32, 512)	1180160
Block4_conv1 (Conv2D)	(None, 32, 32, 512)	2359808
Block4_conv2 (Conv2D)	(None, 32, 32, 512)	2359808
Block4_conv3 (Conv2D)	(None, 16, 16, 512)	0
Block4_pool (MaxPool-	(None, 16, 16, 512)	2359808
ing2D)	(None, 16, 16, 512)	2359808
Block5_conv1 (Conv2D)	(None, 16, 16, 512)	2359808
Block5_conv2 (Conv2D)	(None, 8, 8, 512)	0
Block5_conv3 (Conv2D)	(None, 512)	0
Block5_pool (MaxPool-	(None, 2)	1026
ing2D)		
global_max_pooling2d		
dense (Dense)		

Total params: 14715714 (56.14 MB)
Trainable params: 14715714 (56.14 MB)
Non-trainable params: 0 (0.00 Byte)

3.2 Data Augmentation and Preprocessing

Due to the limited dataset size, data augmentation techniques were employed to artificially increase the training data and improve model generalization [24-27]. The augmentation techniques included:

- Rotation (up to 30 degrees).
- Horizontal and vertical flips.
- Width and height shifts.

These transformations ensured that the model was exposed to a diverse set of training examples, mitigating the risk of overfitting [28-31].

3.3 Training and evaluating:

The dataset was divided into 70% for training 15% for validation And 15% for testing. The CNN model was trained for 20 epochs with a batch size of 32. Precision, recall, F1-score, and accuracy were used to evaluate the performance of both traditional machine learning models and the CNN. Table 3 illustrate the results of evaluating the proposed deep learning model used.

Table 3. The results of evaluating the machine learning models used.

Model Name	Accuracy	Precision	Recall	F1_score	Time in Sec
Proposed Deep Learning Model	0.9937	0.9930	0.9930	0.9937	148

4. Results and discussions

4.1Deep Learning Model

The CNN model significantly outperformed traditional methods, achieving 99% accuracy on the training set and 99% accuracy on the validation set. The model's precision, recall, and F1-score were similarly high, indicating its robustness in distinguishing between the two pineapple classes.

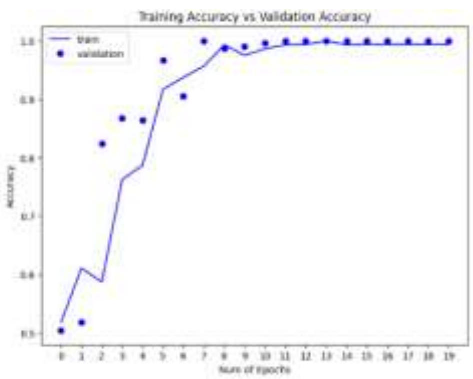

Figure 1: Training vs. Validation Accuracy (showing a steady increase in accuracy over 20 epochs).

Figure 2: Training vs. Validation Loss (indicating minimal overfitting as the vali-dation loss closely follows the training loss).

The high accuracy of the CNN model highlights the effectiveness of deep learning in extracting complex, non-linear features from images [32-36]. Despite the visual similarities between pineapples and mini pineapples, the model was able to learn fine-grained differences through the layers of the VGG16 architecture[37-41].

4.3 Discussion

The results show that deep learning models, particularly CNNs, excel in tasks where visual distinctions are subtle[42-46]. While traditional machine learning algorithms struggled, the CNN model was able to achieve high performance through automatic feature extraction and fine-tuning of a pre-trained network[47-50]. These results suggest that CNNs can be a valuable tool for fine-grained classification in agricultural applications, such as distinguishing between fruit varieties[51-55].

4 Conclusion

This research demonstrates the efficacy of convolutional neural networks, particularly the VGG16 architecture, in classifying closely related fruit varieties like pineapples and mini pineapples. The CNN outperformed traditional machine learning methods, achieving 99% accuracy on the training set and 99% on the validation set. Data augmentation played a crucial role in enhancing model generalization, enabling the model to distinguish between visually similar classes. Future work could explore expanding the dataset and using more complex CNN architectures for even higher accuracy.

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