

# Deep Convolutional Neural Networks for Automated Classification of Date Fruit Varieties

Husam Abd Rahim Eleyan , Samy S. Abu-Naser

Department Information Technology,  
Faculty of Engineering and Information Technology,  
Al-Azhar University, Gaza, Palestine

**Abstract:** *Accurate identification of date fruit varieties is essential for quality control, market standardization, and automated agricultural processing. This study presents a deep learning-based framework for the multi-class classification of nine date fruit varieties using transfer learning. A convolutional neural network built upon the pre-trained VGG16 architecture was fine-tuned to extract discriminative visual features from RGB images and perform robust variety classification. The dataset consists of thousands of labeled images representing diverse date types, and comprehensive preprocessing procedures, including normalization, resizing, and data augmentation—were applied to improve model generalization and mitigate overfitting. The proposed model was evaluated using accuracy, loss, and F1-score metrics to ensure balanced performance assessment across classes. Experimental results demonstrate stable convergence behavior and reliable generalization, achieving approximately 69% validation accuracy in a challenging nine-class classification task. The findings confirm that transfer learning significantly enhances feature representation capability in agricultural image analysis while reducing training complexity. This work contributes to the development of intelligent vision-based systems for automated date fruit identification and provides a scalable foundation for smart agriculture applications, post-harvest automation, and digital quality assessment.*

**Keywords:** Date types, classification, VGG16

## Introduction

Date fruits represent one of the most economically significant agricultural commodities in many regions of the world, particularly in the Middle East and North Africa (MENA), where date palm cultivation has been practiced for thousands of years. Dates play a vital role in food security, rural livelihoods, and national economies, as they are widely consumed both fresh and in processed forms such as dried dates, syrups, and confectionery products. The global demand for high-quality date fruits has increased steadily due to their nutritional value, long shelf life, and cultural importance. Consequently, accurate identification and classification of date varieties have become essential for ensuring quality control, determining market value, facilitating export operations, and maintaining product standardization across supply chains[1-3].

The classification of date fruits into their respective varieties is traditionally performed through visual inspection by skilled workers based on attributes such as size, shape, color, texture, and surface patterns[3-6]. Although this manual approach can be effective when conducted by experienced personnel, it is inherently labor-intensive, time-consuming, and costly, particularly when applied to large-scale production and commercial sorting facilities. Moreover, manual classification is subjective in nature and prone to inconsistencies arising from human fatigue, variations in lighting conditions, and the subtle visual similarities between different date varieties. These limitations often result in classification errors, reduced processing efficiency, and potential economic losses, especially in export markets where strict quality standards must be met.

With the rapid advancement of artificial intelligence (AI), computer vision has emerged as a powerful paradigm for automating image-based recognition and classification tasks. In recent years, machine learning and deep learning approaches have demonstrated substantial success in solving complex visual perception problems across diverse domains, including agriculture, medical imaging, and industrial quality inspection. Among these approaches, deep learning models—particularly Convolutional Neural Networks (CNNs)—have achieved state-of-the-art performance in image classification, object detection, and pattern recognition tasks. CNNs are specifically designed to process visual data by exploiting spatial hierarchies through convolutional layers, enabling them to automatically learn discriminative features such as edges, textures, and high-level semantic patterns directly from raw image inputs. This capability eliminates the need for handcrafted feature extraction methods, which were commonly used in traditional computer vision pipelines and often required domain-specific expertise [7–10].

In the context of agricultural applications, deep learning-based image analysis has been successfully applied to tasks such as crop disease detection, fruit grading, yield estimation, and plant species recognition. These developments highlight the strong potential of CNN-based systems to enhance automation, accuracy, and efficiency in agricultural production and post-harvest processing. However, the performance of deep learning models typically depends on the availability of large, well-labeled datasets, which may be difficult or expensive to obtain for certain agricultural products, including specific varieties of date fruits[11-13]. The challenge

becomes more pronounced when dealing with fine-grained classification problems, where inter-class visual differences are subtle while intra-class variability is high due to differences in ripeness, illumination, and imaging conditions.

To address these challenges, transfer learning has gained considerable attention as an effective strategy for improving model performance in scenarios where labeled data are limited. Transfer learning involves utilizing pre-trained deep neural networks that have been trained on large-scale image datasets and adapting them to new target tasks. By reusing learned feature representations from such networks, transfer learning enables the extraction of rich and discriminative visual features while significantly reducing computational cost and training time. Furthermore, this approach mitigates the risk of overfitting and improves generalization performance, making it particularly suitable for agricultural image classification tasks with constrained datasets [14-16].

In this study, a transfer learning-based CNN model is employed to classify nine distinct varieties of date fruits using digital images. The proposed approach aims to provide an automated and reliable solution for date fruit variety recognition, thereby reducing dependence on manual inspection and improving consistency in classification outcomes. The performance of the developed model is evaluated through a comprehensive experimental analysis using standard evaluation metrics for multi-class classification. The study further investigates the challenges associated with fine-grained visual similarity among date varieties and examines the capability of deep learning models to distinguish between visually similar classes. The findings of this research contribute to the growing body of knowledge on intelligent agricultural systems and demonstrate the practical applicability of deep learning and transfer learning techniques in real-world food quality assessment and sorting applications [17-20].

### **Objectives**

The primary objective of this research is to develop and evaluate a deep learning-based framework for the automated classification of nine date fruit varieties using image data. To achieve this goal, the study pursues the following specific objectives:

- To develop a deep learning-based model capable of classifying nine date varieties using image data.
- To evaluate the performance of the proposed model using accuracy, loss, and F-score metrics.
- To analyze training and validation behavior to assess generalization capability.
- To investigate class-wise classification performance and identify challenges related to visual similarity among date varieties.

### **Dataset**

The dataset used in this study consists of images of nine different varieties of dates:

**Meneifi, Ajwa, Shaishe, Rutab, Galaxy, Nabtat Ali, Sugaey, Medjool, and Sokari.**

### **Training Data**

The training dataset contains **5,510 images**, resized to **75 × 75 pixels** with three RGB color channels.

The shape of the training data is:

- **(5510, 75, 75, 3)**

### **Training Labels**

The corresponding labels were encoded using one-hot encoding, resulting in a label shape of:

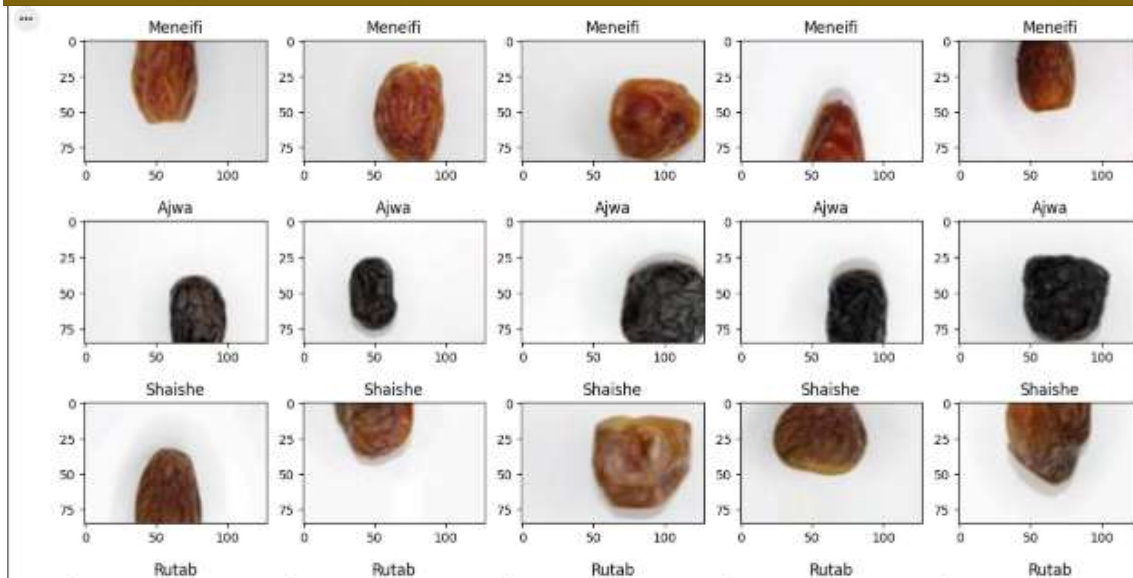
- **(5510, 9)**

### **Testing Data**

The testing dataset includes **1,832 images**, distributed across the nine classes. A portion of the data was used for validation during training.

### **Preprocessing**

All images were resized and normalized before training [21-26]. Data augmentation techniques such as rotation and flipping were applied to improve robustness and reduce overfitting [27-30].



**Figure 1:** Dataset samples of different date varieties.

## Methods

The classification model used in this study is based on **Convolutional Neural Networks (CNNs)** combined with a transfer learning strategy[31-34].

## Architecture

A pre-trained **VGG16** model was employed as a feature extractor[35-38]. The original classification layers were removed, and new layers were added to adapt the model to the date classification task[39-43].

The architecture includes:

- Convolutional layers from VGG16 (frozen during training)
- Global Average Pooling layer
- Fully connected dense layer with 512 neurons
- Batch normalization layer
- Dropout layer for regularization
- Softmax output layer with nine neurons

## Activation Function

The Softmax activation function was used in the output layer to generate probability distributions for multi-class classification[44-50].

## Optimizer and Loss Function

The model was trained using the **Adam optimizer** and **categorical cross-entropy** loss function[51-57].

## Training Process

Training was conducted for multiple epochs, and model performance was monitored using validation accuracy and loss[58-62].

Model: "functional"

Layer (type)	Output Shape	Param #
input_layer (InputLayer)	(None, 75, 75, 3)	0
block1_conv1 (Conv2D)	(None, 75, 75, 64)	1,792
block1_conv2 (Conv2D)	(None, 75, 75, 64)	36,928
block1_pool (MaxPooling2D)	(None, 37, 37, 64)	0
block2_conv1 (Conv2D)	(None, 37, 37, 128)	73,856
block2_conv2 (Conv2D)	(None, 37, 37, 128)	147,584
block2_pool (MaxPooling2D)	(None, 18, 18, 128)	0
block3_conv1 (Conv2D)	(None, 18, 18, 256)	295,168
block3_conv2 (Conv2D)	(None, 18, 18, 256)	590,080
block3_conv3 (Conv2D)	(None, 18, 18, 256)	590,080
block3_pool (MaxPooling2D)	(None, 9, 9, 256)	0

Figure 2-A: Model architecture

block4_conv1 (Conv2D)	(None, 9, 9, 512)	1,180,160
block4_conv2 (Conv2D)	(None, 9, 9, 512)	2,359,808
block4_conv3 (Conv2D)	(None, 9, 9, 512)	2,359,808
block4_pool (MaxPooling2D)	(None, 4, 4, 512)	0
block5_conv1 (Conv2D)	(None, 4, 4, 512)	2,359,808
block5_conv2 (Conv2D)	(None, 4, 4, 512)	2,359,808
block5_conv3 (Conv2D)	(None, 4, 4, 512)	2,359,808
block5_pool (MaxPooling2D)	(None, 2, 2, 512)	0
global_average_pooling2d (GlobalAveragePooling2D)	(None, 512)	0
dense (Dense)	(None, 512)	262,656

Figure 2-B: Model architecture

batch_normalization (BatchNormalization)	(None, 512)	2,048
dropout (Dropout)	(None, 512)	0
dense_1 (Dense)	(None, 9)	4,617

Total params: 14,984,009 (57.16 MB)  
 Trainable params: 268,297 (1.02 MB)  
 Non-trainable params: 14,715,712 (56.14 MB)

Figure 2-C: Model architecture

### Results and Discussion

The proposed model demonstrated stable learning behavior throughout training.

#### Training Performance

- Final training accuracy: **64.26%**
- Training loss: **1.0514**

#### Validation Performance

- Validation accuracy: **69.27%**
- Validation F-score: **69.35%**
- Validation loss: **0.8929**

The learning curves indicate consistent improvement in accuracy and reduction in loss values[63-65]. No severe overfitting was observed, as validation performance remained stable and comparable to training performance.

Class-wise evaluation revealed higher accuracy for certain varieties such as **Ajwa**, while lower performance was observed for visually similar varieties such as **Meneffi, Sokari, and Sugaey**. This behavior is primarily due to similarities in color and texture among these classes.

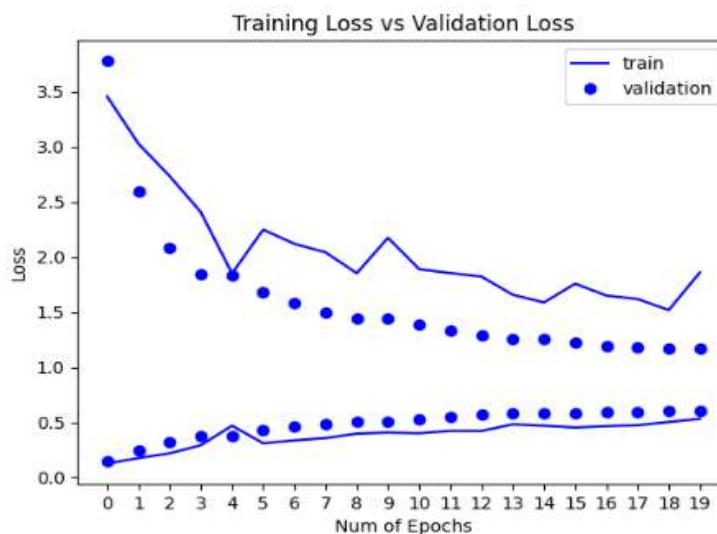


Figure 3: Training Loss vs Validation Loss

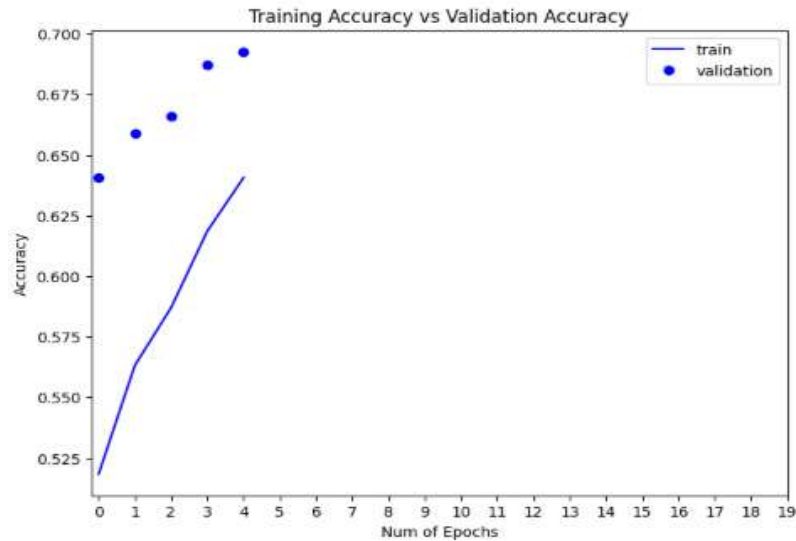


Figure 4: Training vs Validation Accuracy

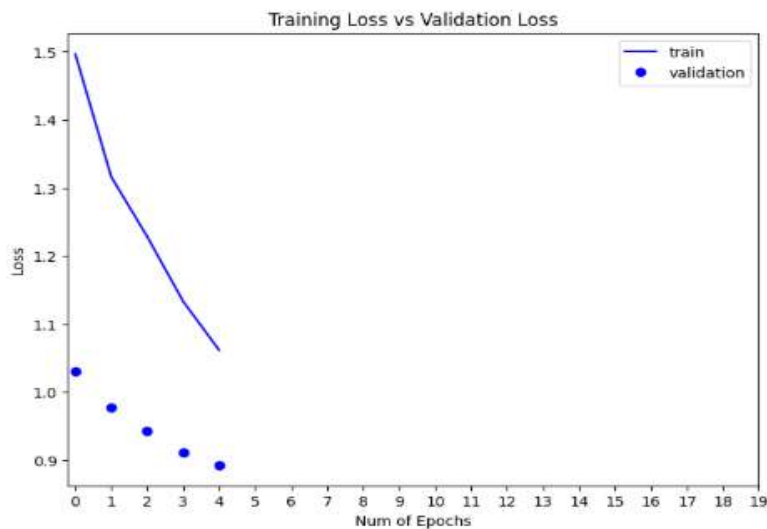


Figure 5: Training vs Validation loss

## Conclusion

This study demonstrates the effectiveness of using transfer learning and convolutional neural networks for the classification of nine date fruit varieties. The VGG16-based model achieved reliable classification performance and exhibited stable generalization behavior.

The results confirm that deep learning techniques can significantly support automated date classification systems, reducing dependence on manual inspection. Future work may focus on increasing image resolution, fine-tuning deeper layers, and integrating attention mechanisms to further improve classification accuracy.

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