Coffee Bean Classification Using Deep Learning

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***Abstract*—Coffee bean classification, an integral process in the coffee industry, has traditionally relied on manual methods.This study uses deep learning and computer vision techniques to classify coffee beans in a novel way. The model makes use of transfer learning and a ResNet50-based architecture that has been adjusted for the differentiation of coffee beans according to their visual characteristics.Approach is equipped with data augmentation and re scaling, contributing to improved generalization and model robustness.**

The study includes the creation and assessment of a strong classification model capable of identifying the different characteristics of post-roasted coffee beans, attaining a remarkable accuracy rate of 97% . Extensive testing shows how well the model recognizes the visual properties of coffee beans.

Keywords — C***offee Bean Grading***, ***Image Processing, ResNet50, Transfer Learning, Dataset, Training.***

I. INTRODUCTION

The complex procedure of roasting coffee beans is closely related to the coffee business, an important worldwide economic power and the producer of one of the most cherished beverages in the world. The degree of roasting, a crucial factor influenced by the artful process of roasting, plays a fundamental role in determining the flavor and quality of brewed coffee. Traditionally, manual methods and human judgment have been employed to assess the attributes of coffee beans.

The coffee business is on the verge of transformation in today's age of technological advancement, where automation offers precision and efficiency. ResNet model-based deep learning and computer vision techniques present a compelling way to improve coffee bean classification and quality management.

Before roasting, green coffee beans exhibit a soft texture and emit a 'grassy' aroma. Roasting initiates chemical transformations at high temperatures. Once green coffee beans reach their maximum temperature, they undergo a cooling process to halt roasting [1]. Roasting leads to weight reduction, introduces new aromas, and prepares the beans for brewing [2]. The color of roasted coffee beans serves as a key descriptor [3]. Lightly roasted beans are noted for their high acidity and caffeine content, medium roasted is darker brown.

In this study, the objective is to classify roasted coffee beans based on their roast levels using the ResNet model, a powerful deep learning architecture celebrated for its excellence in image classification. The application of ResNet enables precise and automated categorization of coffee beans according to their roast characteristics, promising significant advancements in quality control within the coffee industry.

II. LITERATURE REVIEW

Coffee bean classification has traditionally relied on manual inspection, a labor-intensive process. Recent advancements in deep learning have opened up opportunities for automating this task, improving both efficiency and accuracy. Here are some few significant investigations into the classification of coffee beans using deep learning:

A study by Micaraseth et al. (2022) ,deep learning was employed to develop an automated coffee bean inspection machine. The system accurately classifies coffee beans, which can save significant working time. While this study didn't focus on multiple bean classes, it's indicative of the broader trend in the field towards automation and accuracy [4].

Chang et al. applied deep learning to detect coffee bean defects according to standards defined by the Specialty Coffee Association (SCA). Their deep learning model demonstrates the capability to identify various defect types, contributing to the quality control of coffee beans [5].

A review of image-based coffee bean quality classification has highlighted various machine learning approaches used for classifying coffee beans based on their quality. This survey offers insights into the different methodologies employed in this context [6].

In a recent study, Deep learning and image processing techniques have also been utilized to recognize the roast levels of coffee beans. A method proposed by Nasution et al. achieved an impressive accuracy of 97.5% in identifying roasted coffee bean levels [7].

In a study by MA Alrasyid (2023), ResNet-50 pre-trained Convolutional Neural Networks (CNNs) were used to categorize three types of Indonesian Arabica coffee beans, demonstrating the application of deep learning in coffee bean classification [8].
A research paper titled "Review On Image-based Coffee Bean Quality Classification" by SP Pragathi (2022) provides an overview of various machine learning approaches used in classifying coffee beans based on their quality [9]

In conclusion, the use of deep learning and machine learning has significantly advanced the field of coffee bean inspection. The references highlighted throughout this survey serve as a testament to the remarkable capabilities of these technologies in significantly enhancing the accuracy and efficiency of coffee bean inspection processes.

This paper extends these insights by introducing an innovative approach that incorporates ResNet50 for coffee bean classification, contributing to the ever-evolving field of agricultural technology.

III. METHODOLOGY

The methodology for coffee bean classification using the ResNet algorithm involves the following steps:

A. Data Collection

To start the research, gather a diverse and comprehensive dataset of coffee bean images. This dataset should encompass a variety of coffee bean types, including different species (e.g., Arabica, Robusta), quality levels, and roast types (light, medium, dark, green). The images can be collected from various sources, such as coffee farms, online databases, or coffee industry partners.

B. Data Preprocessing

Preprocess the collected images to a uniform size, often set at 224x224 pixels. Standardizing image dimensions is crucial for compatibilty with deep learning models.Normalize pixel values to a consistent scale, typically within the range of [0, 1]. Normalization enhances training efficiency and mitigates issues stemming from variations in pixel intensity. In figure you can see the result of preprocessed image.

Fig. 1

C. Transfer Learning

Use transfer learning to fine-tune a pre-trained ResNet50V2 model on the preprocessed images.Transfer learning is taking a model that has already been trained and updating the final layers to match the new data in order to adapt it to a new task. This process reduces training time and increases the model's precision.

D. Model Training

The entire model, including the pre-trained ResNet50 V2 layers and the custom classification layers, will be trained using the coffee bean dataset. This process allows the model to fine-tune its parameters to the coffee bean images.

E. **Model Evaluation**

Use a validation dataset different from the training dataset to assess the performance of the trained ResNet50 model.The assessment of the model's performance involves measuring several metrics like accuracy, precision, recall, and F1 score.

Overall, this methodology provides a well-structured framework for building and assessing a deep learning model for coffee bean image classification. The results from the model evaluation will shed light on the model's performance, highlighting its strengths and potential areas for further improvement or research.

IV. BUILD MODEL

The effective grading of coffee beans using image processing techniques depends on the development of a trustworthy and precise machine learning model. In this seminar article, provide a ResNet-based approach for coffee bean grading that makes use of an advanced convolutional neural network's capabilities.

1. Importing Libraries

Pandas, Numpy, and other machine learning libraries are described as an interface of a set of rules created in a specific language to carry out repetitive tasks like arithmetic calculations, interpreting images, and so forth.

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import tensorflow as tf
from sklearn.model_selection import train_test_split
from sklearn.metrics import classification_report, confusion_matrix
from tensorflow.keras.applications import ResNet50V2
```

2. Load the Model

In this seminar work, we demonstrate a reliable deep learning-based technique for classifying coffee beans. Use a pre-trained ResNet-50V2 model, which is well-known for its powerful feature extraction skills, as a key part of our strategy. We considerably improve our model's capacity to correctly classify various coffee bean varieties by optimizing it for our particular goal of coffee bean classification.

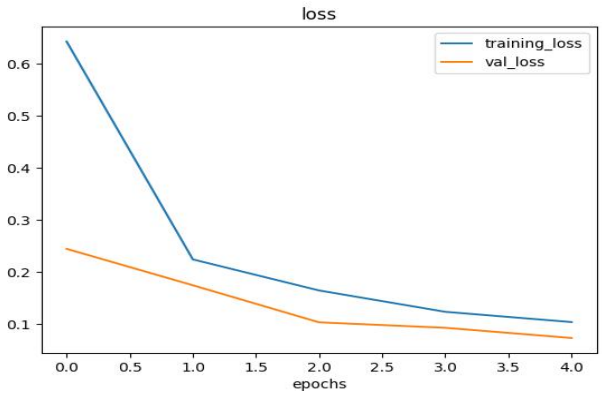
```
x = GlobalAveragePooling2D()(base_model.output)
x = Dense(512, activation='relu')(x)
x = Dense(256, activation='relu')(x)
output = Dense(4, activation='softmax')(x)

model = Model(inputs=base_model.input, outputs=output)
model.load_weights("Coffee.h5")
```

V. RESULT

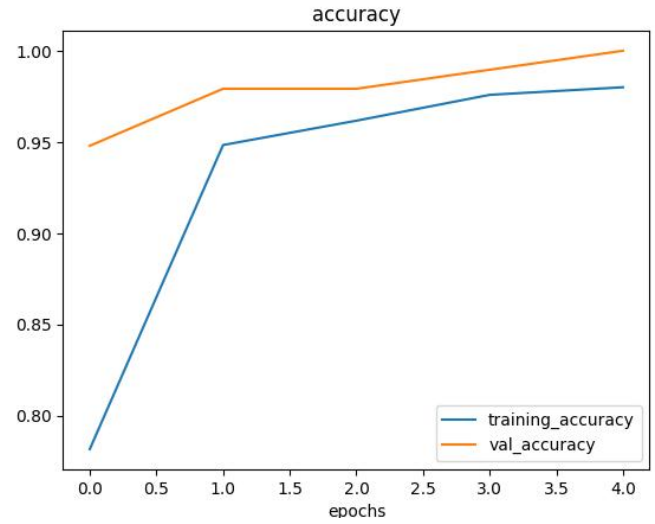
The algoritham used in this system is ResNet that provides greater accuracy.

```
loss: 0.1157 - accuracy: 0.9767
```

The performance of the model is evaluated based on accuracy. The model achieved an accuracy of 97% on the test dataset, demonstrating its effectiveness in grading coffee beans.



The graph illustrates the loss over epochs. The model exhibits a consistent decrease in loss as the training progresses, indicating successful learning.



This graph showcases the model's accuracy improvements over epochs. It shows a steady increase in accuracy during training, reflecting the model's ability to better grading of coffee beans over time.
In the course of this research, I have constructed a web-based implementation of the outcomes.

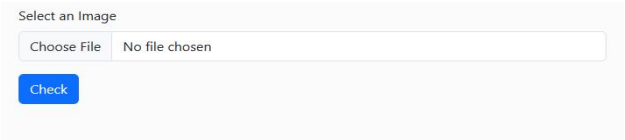


Fig .2 Uploading coffee bean image

The output of the prediction is :

Fig. 3 predict the roast level

VI. CONCLUSION

Coffee bean grading methods based on ResNet have a lot of potential and can be a helpful method for deep learning and image processing algorithms.

This method provides a practical and affordable alternative for precisely classifying roast levels of coffee beans, which is in high demand. It has been demonstrated that preprocessing methods, such as scaling pictures to 224*224 pixels and normalizing, increase the ResNet-50 model's accuracy.

To summarise, the ResNet-based strategy for coffee bean grading is an exciting field of study that may advance the development of future techniques for grading coffee beans that are more precise and effective.

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