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Capstone Report

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Coffee Land

From Leaves to Roast, AI Knows Coffee Best

Abstract

This project addresses the pressing challenges faced by coffee farmers in Saudi Arabia, focusing on the harmful impact of coffee leaf diseases, delayed harvesting, and the escalating threat of pests. With a vision aligned with Saudi Arabia's ambitious goals outlined in Vision 2030, our AI-driven solution aims to help coffee farms not to lose crop as much as possible. The primary objectives include early detection of diseases, optimization of harvest schedules, and precise guidance for achieving the ideal coffee bean roast. Through advanced machine learning algorithms, the proposed solution not only safeguards the income of coffee farmers but also contributes to the creation of a distinctive Saudi coffee identity. By integrating innovative technologies, this project aspires to foster a prosperous economy, elevate Saudi Arabia's position in the global coffee market, and promote sustainable practices in line with Vision 2030's principles.

Introduction

This section lays the groundwork for our project, driven by a compelling motivation to tackle crucial challenges in coffee farming. It aligns seamlessly with Saudi Vision 2030. Our focus centers on the pressing issues of coffee leaf diseases, delayed harvesting, and the harm brought by pests, recognizing these hurdles as substantial barriers to economic growth and sustainable agriculture. By establishing a direct link to the goals and tactics outlined in Saudi Vision 2030., our project aspires to play a key role in achieving the nation's aims of economic diversification, innovation, and ecological sustainability. This introduction offers background information, explaining the significance of our project and how it actively contributes to transforming the coffee farming scenario. We propose an AI solution to address the identified issues, aligning with the visionary aspirations of Saudi Vision 2030.

Literature Review:

Coffee farming faces several challenges, including diseases, inefficient harvesting, pests, and roasting errors. Research highlights the need for solutions.
Studies emphasize efficient strategies to deal with diseases, focusing on prevention and early detection. Understanding evolving strains is key for sustainable solutions.

Literature explores modern technologies to improve traditional harvesting methods. Timely and optimized harvesting is crucial for overall crop health.

Adding to that, farmers recognize the impact of changing environmental conditions on pests. Research investigates climate influence, pest-resistant crops, and integrated pest management.

Moreover, the final coffee quality depends on roasting. Studies delve into common roasting errors, flavor impacts, and advancements in technology for better outcomes.

In summary, existing literature guides our understanding of these challenges, paving the way for innovative solutions in coffee farming.

Data Description and Structure :

Our models' dataset primarily originated from Kaggle, reflecting our precise approach to data collection. The acquisition process involved downloading and inspecting a collection of images pertinent to our study. Preprocessing was a Varied effort, Involving the merging of separate text files with their corresponding images to create comprehensive class labels. Furthermore, our preprocessing efforts extended to a thorough comprehension of the dataset, strategically planning its optimal utilization. This meticulous approach ensured that our models were equipped with a well-organized and insightful dataset, laying a robust foundation for subsequent analyses and conclusions.

Methodology

In this project, we developed four models, each employing an algorithm targeted to its specific goal.

Firstly, to address coffee leaf diseases, we constructed a classification model using computer vision. This model takes a coffee leaf image as input and classifies its diseases if present.

Initially, we created a base model with seven layers and four classes. After training, the accuracy hovered around 50%. Subsequently, we implemented transfer learning by leveraging a pre-trained model **EfficientNet**. This step significantly improved the accuracy, achieving a rate of 70%.
To further enhance accuracy and precision, we explored the use of another pre-trained model, InceptionV3, known for its efficacy in image classification. Additionally, we applied augmentation techniques to the training dataset, exposing the model to a more diverse environment. Lastly, we have also needed to weigh the classes since they were not balanced. These combined efforts resulted in an impressive accuracy of 90%.

Secondly, to address the issue of pests damaging coffee leaves, we implemented the YOLOv8 object detection pre-trained model. Unlike conventional classification models, most of the code modifications were made in the YAML file for this model. Challenges arose with the dataset, making the model more intricate. Although attempts were made to apply augmentation to the training dataset, difficulties were encountered. Given more time, we could have addressed these issues and potentially increased both accuracy and performance metrics.

Thirdly, to tackle the issue of untimely harvesting and crop losses due to coffee fruit maturity, we developed another object detection model, YOLOv8. The transfer learning model incorporated augmentation in the YAML file, and it required approximately 100 epochs to achieve the desired results.

Lastly, the issue of coffee bean roast is delicate, especially for those not well-versed in roasting levels. To address this, we constructed a classification model to assist in determining the exact desired roast. We promptly employed transfer learning, as our previous experience with CNN models indicated it to be the most effective approach for achieving high accuracy and precision. The chosen pre-trained model was InceptionV3, consisting of three layers. Additionally, we ensured the data underwent augmentation to introduce complexity to the training process. Ultimately, we achieved an accuracy of 95%.

Discussion and Results:

1. Coffee Leaf Disease Classification:

- The base model started at 50% accuracy but improved to 90% with InceptionV3, and data augmentation.

- Success in disease identification supports Saudi Vision 2030's goal of sustainable agriculture.

2. Pests Detection using YOLOv8:

- YOLOv8 effectively detected pests, but dataset challenges and code modifications added complexity.

- Demonstrates potential for integrated pest management on coffee farms.

3. Coffee Fruit Maturity Detection using YOLOv8:

- Repurposed YOLOv8 identified coffee fruit maturity, showing versatility.

- Successful convergence in approximately 100 epochs highlights adaptability.

4. Coffee Bean Roast Classification using InceptionV3:

- InceptionV3's three-layer model effectively classified roast levels with 95% accuracy.

- Transfer learning and data augmentation contributed to accurate roast determination.

Discussion on Implications and Challenges:

- Dealing with imbalanced data classes.

- Challenges like limited datasets and augmentation difficulties highlight the need for ongoing refinement.

- Short amount of time from model building to deployment.

Conclusion:

These models represent a significant step toward modernizing and optimizing coffee farming.

AI-driven solutions have the potential to revolutionize traditional practices, supporting sustainability and technological advancement.

Conclusion and Future Work

In conclusion, our project introduces a smart solution using AI to help coffee farmers avoid losing their crops, especially considering it takes about three years for coffee plants to grow. Our analysis shows that our system looks after the entire life of coffee plants, ensuring they stay healthy from the leaves to the quality of the coffee bean. Aligned with the goals of Saudi Vision 2030 for a better economy, our model aims to support local coffee farms, helping them produce more coffee for increased sales.

We envision our model being like a helpful guardian on farms, making things easier for farmers. It not only makes operations more efficient but also saves money by reducing the need for constant monitoring by workers.

Despite our success, we faced a challenge with a limited dataset, which made training the model more complicated. Looking ahead, we plan to improve accuracy by collecting a bigger and better dataset. This project marks a step toward more sustainable and tech-savvy coffee farming, in line with the ambitious goals of Saudi Vision 2030.

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