# DESIGN AND IMPLEMENTATION OF A PORTABLE IoT DEVICE FOR ASSESSING QUALITY OF GREEN COFFEE BEANS USING DEEP LEARNING

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## Content

## Project Background

- **Economic Value:** Coffee is a vital export for Uganda, earning foreign exchange and supporting over 1.7 million households [1].
- **Bean Quality**: Critical for trade; quality beans define economic health.
- **Quality Checks:**Possible inconsistencies arise from UCDA's manual evaluations.

Figure 1: Green coffee beans

# Project Background continued

| Method | Advantages | Disadvantages |
|---|---|---|
| Manual sorting | Accurate for obvious defects | 1.Inconsistent results due to human fatigue and variability<br><br>2.Slow process |
| Visual inspection | Simple and cost effective | 1. Subjective and inconsistent results due to human error<br>2. Time-consuming and labor-intensive<br>3. Limited ability to detect subtle defects |
| Cupping(Sensory Evaluation) | Recognized standard in the coffee industry | 1. Highly subjective and dependent on cuppers' experience and skill<br>2. Time-consuming and requires trained personnel<br>3. Happens too far down the value chain |

Figure 2: Method analysis table

# Previous Works

- Automated Defect Classification.
- Continuous Sample Processing.
- Screening: Discards defective beans [2].

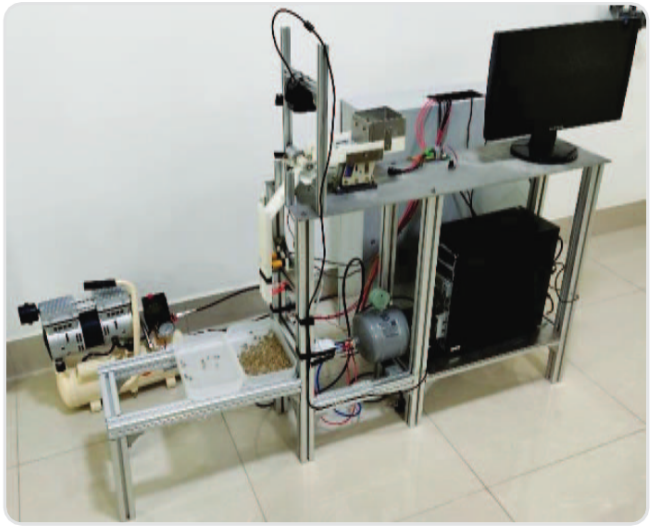

Figure 3: Coffee beans screening system[2].

## Problem Statement

The current system of quality assessment of green coffee beans is impeded by manual methods that are prone to subjective judgment and delays which prolongs the certification time for exporters and introduces variability in quality determination, affecting the trade flow as well as the credibility and consistency of the coffee beans destined for international markets.

## Justification

- Improve reliability of the quality assessment process.
- Ensure consistent quality assessment of the green coffee beans.
- Support economic growth through enhanced trade efficiency.

Figure 4: Manual sorting of green coffee beans sample at UCDA lab

## Project Objectives

### Main Objective

To design and implement a portable Internet of Things device that assesses the quality of green coffee beans using deep learning.


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## Specific Objectives

1. To identify the key parameters that influence green coffee beans quality and select the appropriate sensors for measuring them.
2. To design the software components of the device, including the schematic designs.
3. To develop deep learning models for image analysis of green coffee beans.
4. To implement the hardware design and deploy the deep learning model.
5. To integrate the software and hardware components and test the performance of the device.

## Scope

- Limited to export-ready green coffee beans.
- Limited to Robusta coffee beans.


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# Methodology

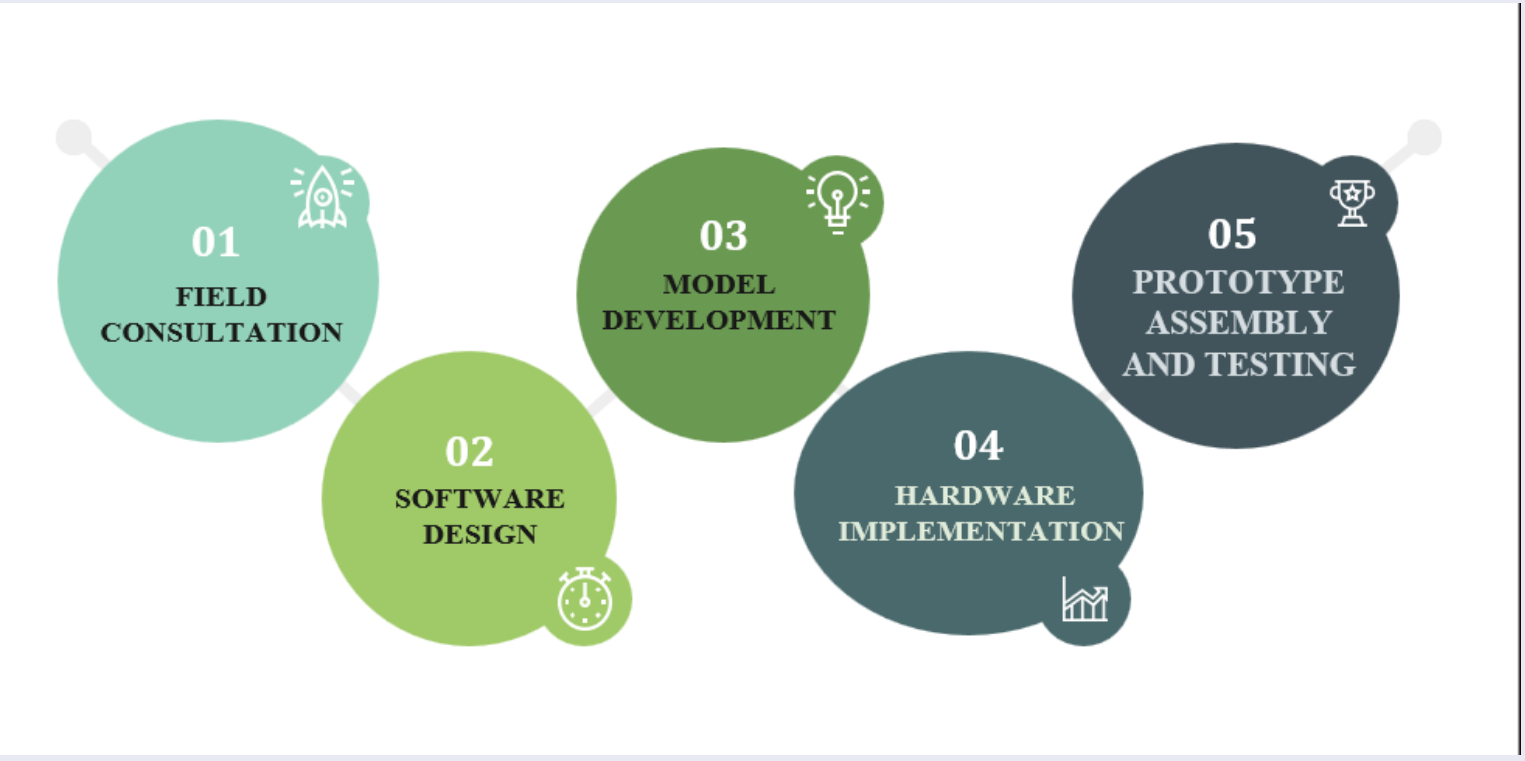



Figure 5: Methodology

## Field Consultation

- **Key Quality Parameters:** Temperature, humidity and defect count, as advised by UCDA experts.
- **Sensor Selection:** Selected the dht11 sensor that measures temperature and humidity

Figure 6: Green coffee beans assessment setup

# Software Design

- Python, EAGLE, OpenCV

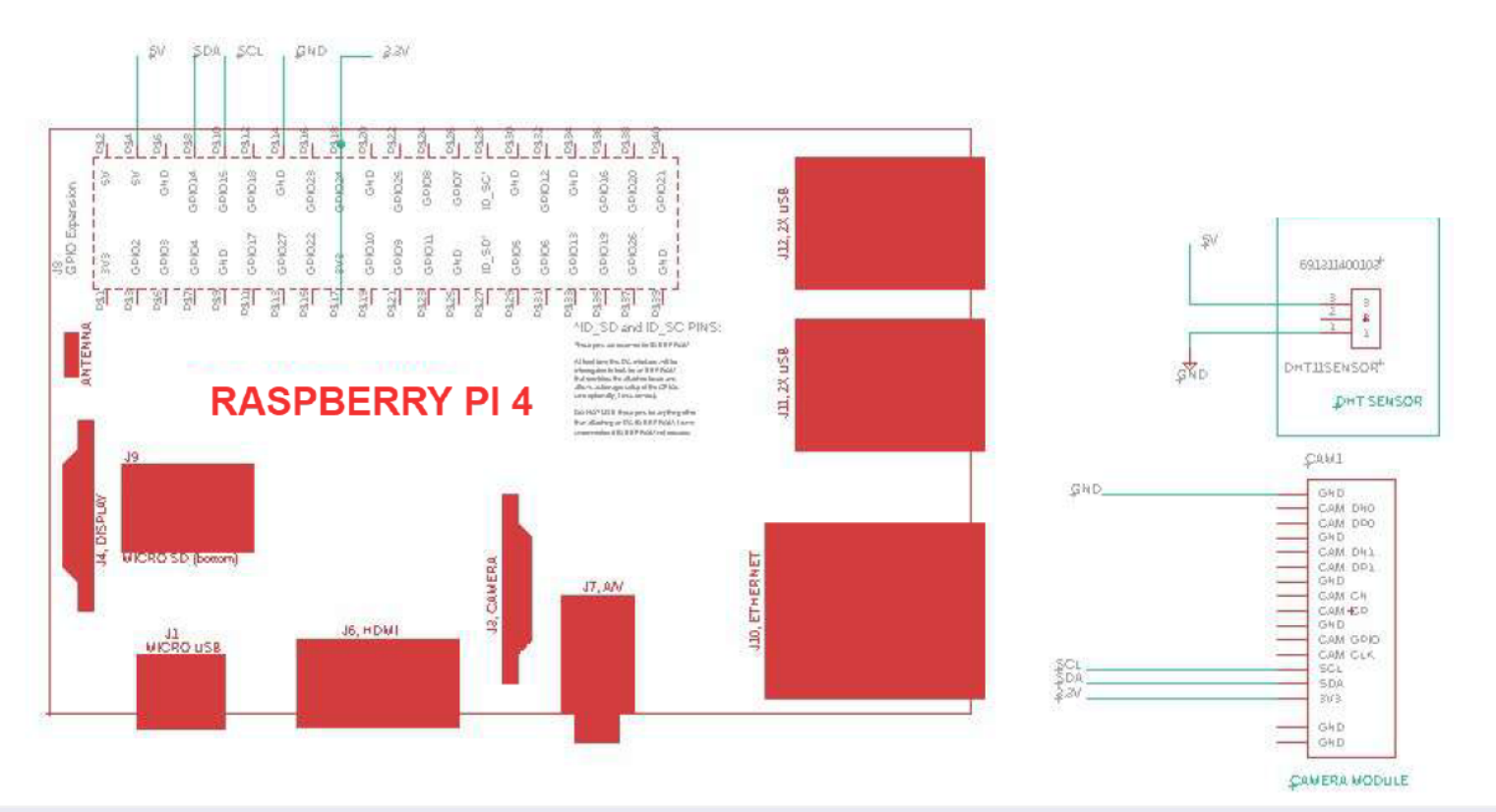



Figure 7: Prototype schematic design

## Data Collection and Pre-processing

- Sourced a dataset from Roboflow universe of 4,265 images.
- Collected samples from UCDA to capture local data
- Dataset totalled up to 7,020 images with four classes.

| **Pre-processing step** | **Action taken** |
|---|---|
| Orientation | auto-orient |
| Resizing | 416 x 416 |
| Augmentation | Flip horizontal, vertical |
| Splitting | Split into train, validation and test (70%, 15%, 15%) |

Table 1: Data pre-processing steps

# Data collection and Pre-processing cont.

Figure 8: Sample training image

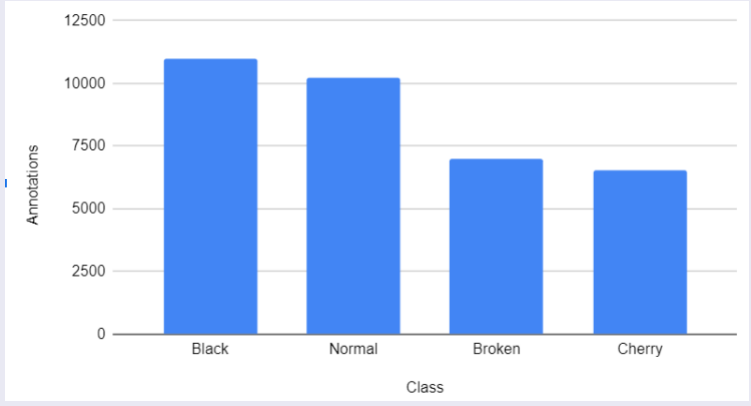



Figure 9: Class distribution

## Model Training and Evaluation

- Considered two object detection model architectures: YOLO and SSD-MOBILENET.
- Trained the models using Google Colaboratory.

| **Model** | **mAP@0.5** | **mAP@0.5:0.95** |
|---|---|---|
| SSD-MOBILENET-V2 | 0.68 | 0.677 |
| YOLOv5 | 0.94 | 0.85 |
| YOLOv7 | 0.962 | 0.867 |
| YOLOv8 | 0.99 | 0.879 |

Table 2: Model comparisons

# YOLOv8 Model Results- Training and Loss curves

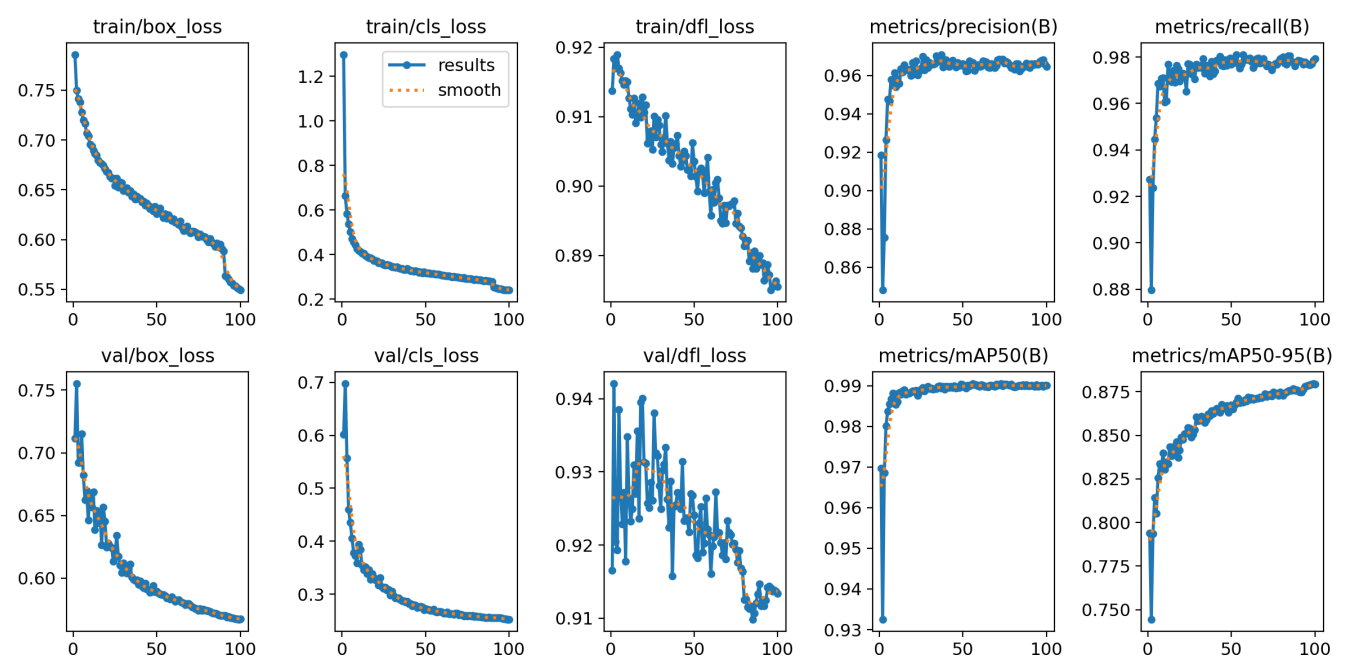



Figure 10: Model training results

# Confusion Matrix For YOLOv8 Model

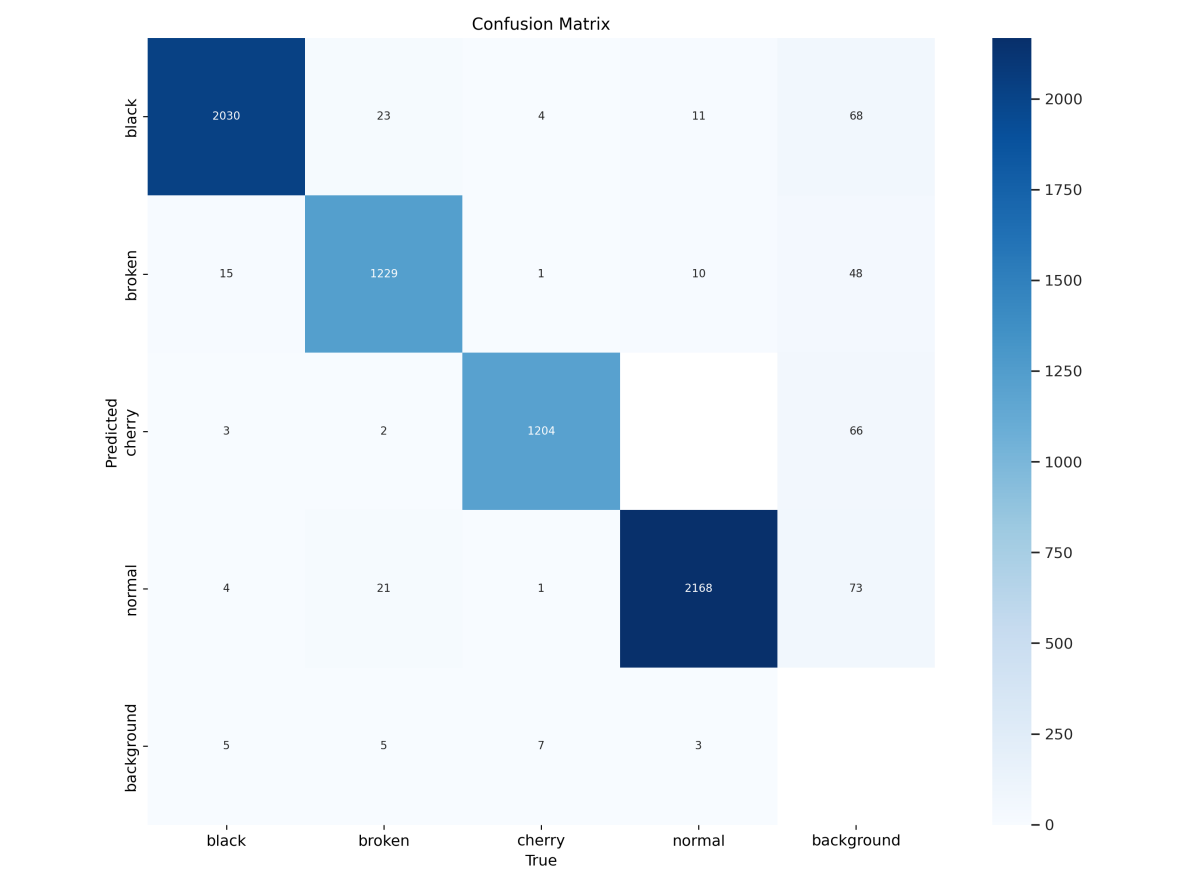



Figure 11: Confusion matrix

## Quality Assessment Metrics

- UCDA methods of quality assessment are based on a strict count of defects.
- **Quality grades** are:
  - **Good quality** - less than 7% defects in sample
  - **Medium quality**- between 7% and 10% defects in sample
  - **Poor quality**- greater than 10% defects in the sample
- Desired relative humidity: 35-75%
- Desired temperature : $22.0^{\circ}C(+-6^{\circ}C)$

# System Flow

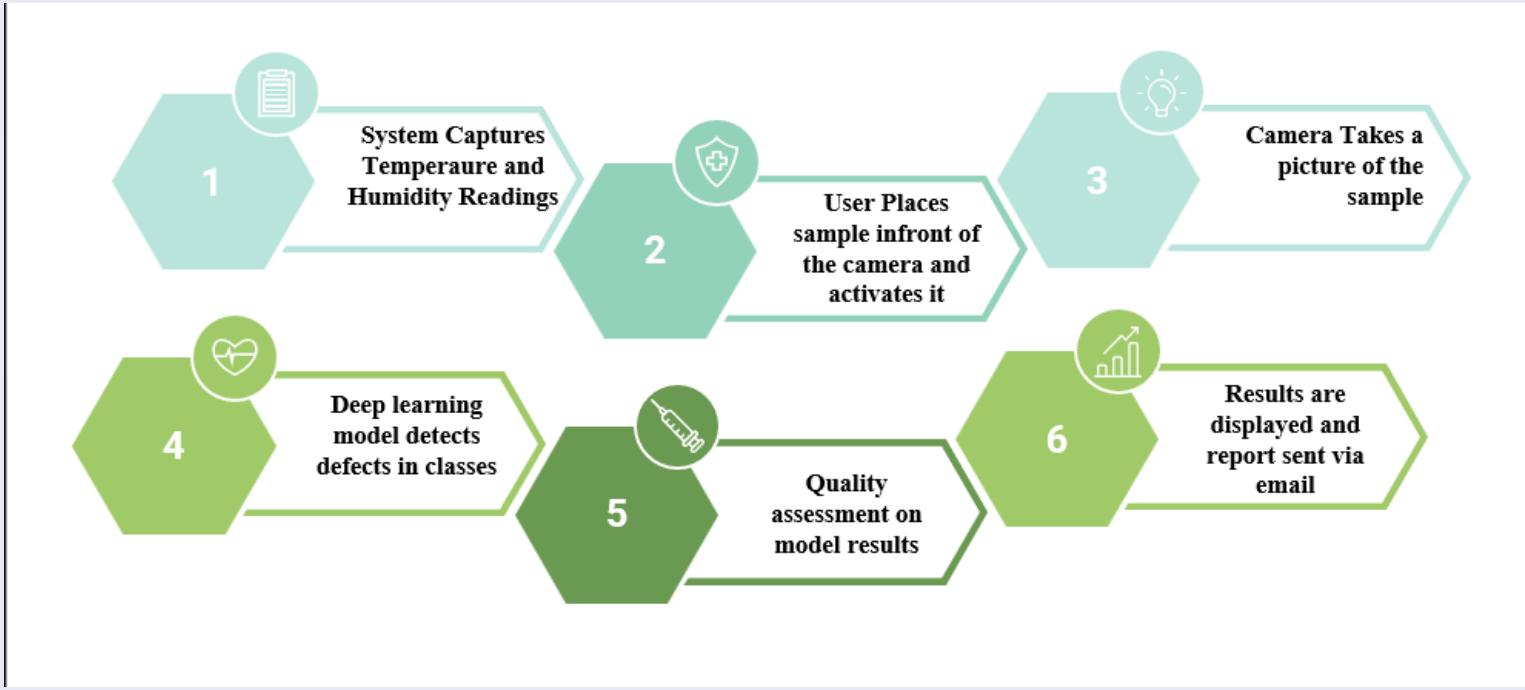



Figure 12: System flow

## Hardware Implementation and Model Deployment

- Raspberry Pi 4, dht11, picamera module.
- Made a 3D design for the casing using Solid Works, printed it and assembled the components together.
- Deployed the model file to the Raspberry Pi's storage.

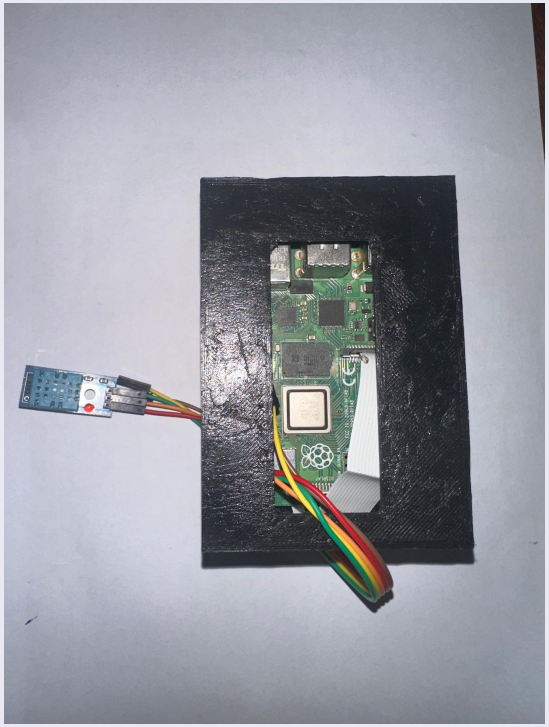


Figure 13: Hardware implementation

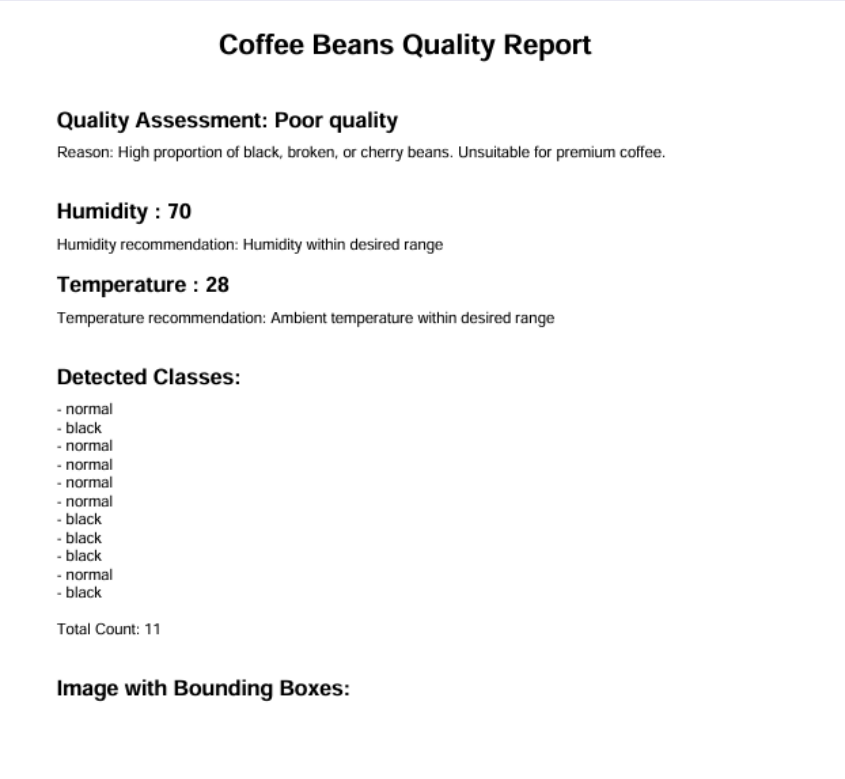
# Prototype Testing

- We tested the device with coffee samples from UCDA.


Figure 14: Results

# Results

- A functional prototype that assesses green coffee bean quality and sends quality reports to clients' emails.



**Coffee Beans Quality Report**

**Quality Assessment: Poor quality**

Reason: High proportion of black, broken, or cherry beans. Unsuitable for premium coffee.

**Humidity : 70**

Humidity recommendation: Humidity within desired range

**Temperature : 28**

Temperature recommendation: Ambient temperature within desired range

**Detected Classes:**

- normal
- black
- normal
- normal
- normal
- normal
- black
- black
- black
- normal
- black

Total Count: 11

**Image with Bounding Boxes:**

Figure 15: Quality report

## Comment Resolution Matrix

| Comment | Resolution |
| --- | --- |
| Portability not addressed | Hardware was implemented using lightweight components and enclosed in durable casing |
| Provide an analysis of the current methods for assessing quality of green coffee bean | Analysis table is provided |

Figure 16: Comment resolution matrix

## Conclusion

- A portable device for green coffee bean quality assessment was implemented, which detects the beans in their classes and outputs a quality grade accordingly.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## Future Work and Recommendations

- Adapt the device for use in earlier stages of the coffee value chain.
- Adapt the device for quality assessment of other agricultural products.
- We recommend that the device is connected to a cloud platform for secure storage.

## References


[1] R. World, Coffee, "Ugandan coffee exports," https://worldcoffeeresearch.org/focus-countries/uganda., accessed: 2023-10-26..

[2] L. T. University, "Coffee beans screening using deep-learning," Google, [Online]. Available: https://research.leedstrinity.ac.uk/en/publications/deep-learning-based-coffee-beans-quality-screening. [Accessed 20 April 2024].


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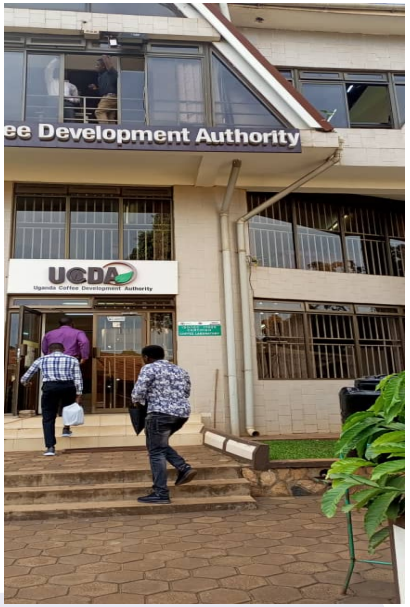
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UCDA

# THANK YOU!


Uganda Coffee Development Authority
UCDA