Documentation for Soybean Weed Detection

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1. Project Overview

This project focuses on the detection and classification of soybean weeds using a machine learning model. The system identifies four main classes: **Soybean, Soil, Broadleaf, and Weed**, which are grouped into two broad categories:

1. **Category 1:** Soil, Soybean, and Broadleaf.
2. **Category 2:** Weed.

The model is built using the MobileNetV2 architecture, known for its efficiency in computational and memory requirements, making it suitable for deployment on resource-constrained devices.

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2. Objectives

- To accurately detect and classify soybean field components (Soybean, Soil, Broadleaf, and Weed).
- To provide real-time or near real-time classification for agricultural applications.
- To assist farmers in weed management to improve crop yield.

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3. Dataset

- **Source:** https://data.mendeley.com/datasets/3fmjm7ncc6/2
- **Information:** The dataset comprises labeled images of soybean fields containing the following classes:
    - **Soybean**
    - **Soil**
    - **Broadleaf**
    - **Weed**
- **Preprocessing:**
    - Images were resized to a resolution of 224×224224 \times 224 pixels to match the input requirements of MobileNetV2.
    - Data augmentation techniques (e.g., rotation, flipping, cropping) were applied to enhance the robustness of the model.

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4. Methodology

- **Architecture:** MobileNetV2, a lightweight convolutional neural network, was chosen for its balance between performance and efficiency.
- **Model Training:**
    - **Input Shape:** 224×224×3224 \times 224 \times 3 (RGB images).
    - **Optimizer:** Adam optimizer was used with an initial learning rate of 0.0010.001.
    - **Loss Function:** Categorical Crossentropy.
    - **Batch Size:** 32.
    - **Initial Learning Rate**: 0.001
    - **Learning Rate Schedule**: Cosine decay
    - **Optimizer**: Adam
    - **Training Epochs**: 100
    - **Early Stopping Patience**: 10 epochs
- **Output Layer:** The final dense layer contains 4 neurons with a softmax activation function for multi-class classification.

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5. Results

- **Evaluation Metrics:**
    - **Accuracy:**

        - Achieved a classification accuracy of 98% on the train set.

        - Achieved a classification accuracy of 99% on the test set.

    - **Precision, Recall, F1-Score:** Detailed metrics provided per class.
- **Inference Speed:** Optimized for real-time detection with an average processing time of 0.03 ms per image.

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6. Categories

1. **Category 1 (Non-Weeds):**
    - **Soil:** Bare soil without vegetation.
    - **Soybean:** Soybean plants at various growth stages.
    - **Broadleaf:** Broadleaf plants, which are not considered weeds.
2. **Category 2 (Weeds):**
    - **Weed:** Any undesired plant species competing with soybean crops.

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7. Deployment

- **Frameworks and Tools:**
  - TensorFlow/Keras for model training and evaluation.
  - OpenCV for image preprocessing.
- **Deployment:** The model was converted to TensorFlow Lite for edge device compatibility.
- **Use Cases:**
  - Deployed on drones for aerial weed monitoring.
  - Used in automated sprayers to target weeds precisely.

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8. Challenges and Future Work

- **Challenges:**
  - Difficulty in differentiating visually similar classes (e.g., Soybean vs. Broadleaf).
  - Varying lighting and environmental conditions in field images.
- **Future Work:**
  - Incorporating additional classes for better granularity.
  - Exploring other lightweight architectures for improved performance.
  - Integrating with GIS systems for spatial analysis.

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9. Conclusion

The soybean weed detection model using MobileNetV2 provides an effective and efficient solution for agricultural weed management. By classifying components into soybean, soil, broadleaf, and weed categories, it offers a valuable tool for precision agriculture.

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10. References

- MobileNetV2 Paper: https://arxiv.org/abs/1801.04381
- TensorFlow Documentation: https://www.tensorflow.org
- Dataset Augmentation Techniques: https://albumentations.ai/
