Project Report: Semi-Supervised Sesame Crop and Weed Detection using YOLOv8

1. Introduction

This project explores the application of semi-supervised learning with the YOLOv8 architecture for detecting sesame crops and weeds in agricultural field images. The primary challenge in agricultural image analysis is the scarcity of labeled data. Manual annotation is time-consuming and expensive. This project aims to leverage a small labeled dataset in conjunction with a larger unlabeled dataset to improve the performance of the YOLOv8 model, thereby reducing the reliance on extensive manual labeling.

2. Project Goals

- Implement a semi-supervised learning approach using YOLOv8 for sesame crop and weed detection.
- Evaluate the performance of the semi-supervised model against a baseline model trained solely on the limited labeled data.
- Investigate the impact of incorporating the unlabeled data on model accuracy and generalization.
- Develop a robust and efficient system for identifying sesame crops and weeds in field images.

3. Dataset Description

The dataset consists of three parts:

- **Labeled Dataset:** 200 images of sesame fields with annotations for sesame crops (label 1) and weeds (label 0). Annotations are in YOLO format: `[class_id, x_center, y_center, width, height]`, normalized to image dimensions.
- **Unlabeled Dataset:** 1000 images of sesame fields without annotations. These images are similar in characteristics to the labeled data.
- **Test Dataset:** 100 images of sesame fields with corresponding annotations, used for evaluating the trained models. Annotations are in the same format as the labeled dataset.

4. Methodology

The project follows these steps:

1. **Baseline Model Training:** Train a YOLOv8 model solely on the 200 labeled images. This serves as the baseline for comparison.

2. **Semi-Supervised Learning Implementation:** Implement a semi-supervised learning approach using the labeled and unlabeled data. Several methods can be explored:

    - **Pseudo-Labeling:** The baseline model predicts labels on the unlabeled data. High-confidence predictions are treated as pseudo-labels and combined with the original labeled data to retrain the model. Different confidence thresholds will be explored.
    - **Consistency Regularization:** Apply various augmentations to the unlabeled data and enforce consistency in the model's predictions across these augmentations. This encourages the model to learn more robust features from the unlabeled data.
3. **Model Evaluation:** Evaluate both the baseline and semi-supervised models on the held-out test set (100 images). Metrics used for evaluation will include:

    - **Mean Average Precision (mAP):** A comprehensive metric for object detection performance.
    - **Precision and Recall:** Metrics to assess the model's ability to correctly identify crops and weeds.
    - **F1-score:** The harmonic mean of precision and recall.

5. YOLOv8 Implementation Details

- **Pre-trained Model:** A pre-trained YOLOv8 model (e.g., `yolov8n`, `yolov8s`) will be used as a starting point for transfer learning.
- **Framework:** The project will utilize a deep learning framework like PyTorch or Ultralytics YOLOv8 library.
- **Data Augmentation:** Data augmentation techniques (e.g., random flips, rotations, scaling) will be applied to the labeled data during training to improve model robustness. For semi-supervised learning, augmentations will also be crucial for the unlabeled data.

6. Results and Discussion (This section will be populated after the experiments)

This section will present the results obtained from training and evaluating the baseline and semi-supervised models. It will include:

- **Quantitative Results:** Tables and graphs showing the performance metrics (mAP, precision, recall, F1-score) for the model on the test set.
- **Qualitative Results:** Example images from the test set showing the model's predictions, highlighting successes and failures.
- **Analysis:** A discussion of the results, including an analysis of the impact of the semi-supervised learning approach. It will discuss the effectiveness of the chosen semi-supervised method, the role of the unlabeled data, and any challenges encountered.

7. Metrics

Model Evaluation Results:

Mean Precision: 0.4912

Mean Recall: 0.8943

Mean F1 Score: 0.6324

Per-class metrics:

Class 0:

Precision: 0.4824

Recall: 0.9762

F1 Score: 0.6457

Class 1:

Precision: 0.5000

Recall: 0.8125

F1 Score: 0.6190

8. Conclusion

This project aims to demonstrate the potential of semi-supervised learning with YOLOv8 for improving the accuracy of sesame crop and weed detection with limited labeled data. The results will provide insights into the effectiveness of different semi-supervised techniques and contribute to the development of more efficient agricultural image analysis systems.