Comparative Evaluation of CNN and ViT Architectures For Citrus Disease Detection in Field Conditions

Rohan Dash[1]
[1]Pine View School, Osprey, FL 34229, United States of America
Contact: rohankdash@gmail.com

INTRODUCTION & BACKGROUND

Citrus diseases pose a major threat to citrus industry that is spread across 140+ countries around the world.

90% decrease in citrus production ('15-'23)

62% decrease in citrus growers ('02-'17)

44% incidence of HLB in the Brazil Citrus Belt

Given the extent of damage caused, we need to address this problem through early detection of diseases. However, most early detection methods have limitations. Manual hand inspection can be inaccurate. Lab investigations are laborious and time intensive. Spectrometers are too expensive for usage. Automated detection methods, **particularly Computer Vision models have shown promise**.

Introduction to Citrus Diseases

Greening, aka Huanglongbing is the most devastating disease for citrus plants.

- Leads to tree death, misshapen fruits, and significant yield loss

Citrus canker is a disease caused by the bacterium, Xanthomonas citri.

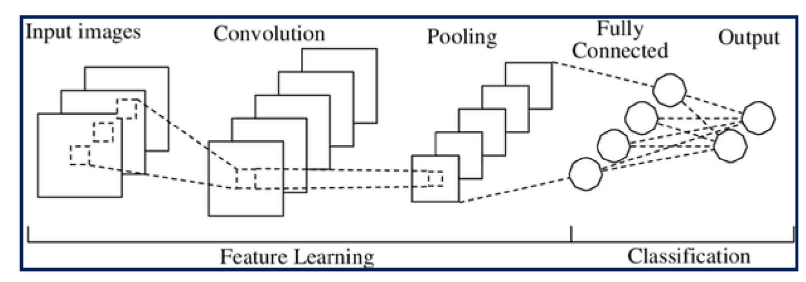
- Lesions on fruit, premature fruit drop and low marketability of the crop.

Citrus Black spot is caused by the fungal pathogen Phyllosticta citricarpa.

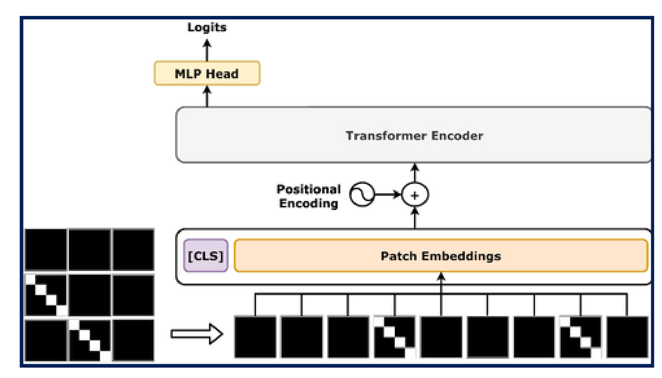
- Reduces fruit quality and can lead to significant economic losses.

Images provided by https://www.flickr.com/photos/usdagov/

Introduction to Computer Vision



Convolutional Neural Networks (CNN) are a type of deep learning algorithm that can process and analyze image data. They have been the dominant CV model.



Vision Transformers (ViT) on the other hand, instead of scanning the image, treat the image like a quilt and split it into small patches, learning at a local level. They are known for their transformer encoders. ViTs have risen in popularity recently.

Research Goal: Design two computer vision models (YOLOv8, a CNN, and RT-DETR, a ViT) and train them on a standardized dataset before evaluating them in their detection abilities. Implement the better performing model in a real-world scenario.

METHODS & PROCEDURE

Dataset Creation: Curate a high quality dataset utilizing public data and images from Citrus farms. Label the data using annotation tools, augment images for simulated complexity.

```
from ultralytics import YOLO

model = YOLO('yolov8m.pt')
model.train(
    data='/content/cdbench.yam
    epochs=50,
    imgsz=640,
    batch=16,
    name='yolov8m'
)
```

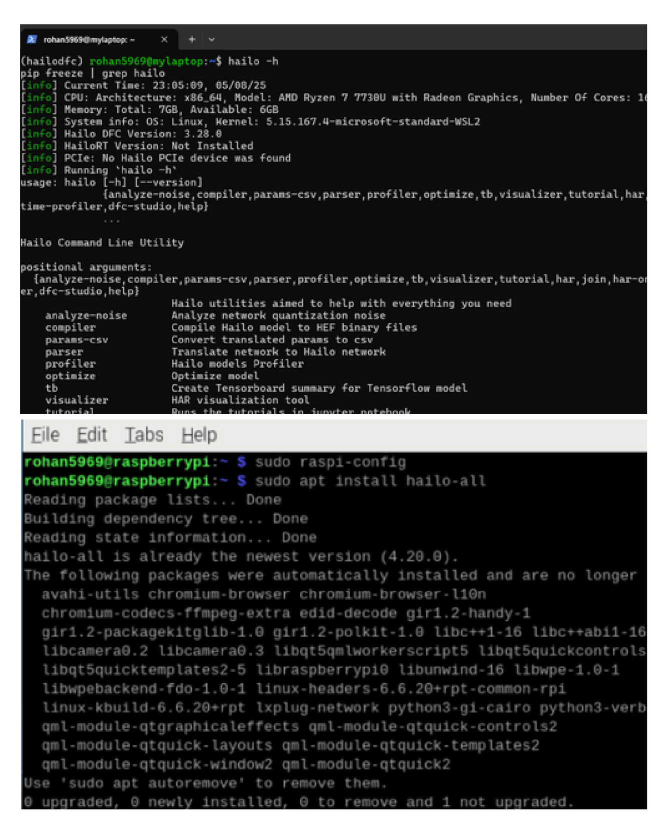
```
training_args = TrainingArguments(
    output_dir=f"{dataset.name.replace
    num_train_epochs=50,
    img_sz=640,
    per_device_train_batch_size=16,
    metric_for_best_model="eval_map",
    greater_is_better=True,
    load_best_model_at_end=True,
    eval_strategy="epoch",
    save_strategy="epoch",
    save_total_limit=2,
    remove_unused_columns=False,
    eval_do_concat_batches=False,
)
```

Environment and Model Setup: Utilize Google Colab for all work. Download models from Github Repositories. Import libraries to train models. Set hyperparameters and transfer dataset.

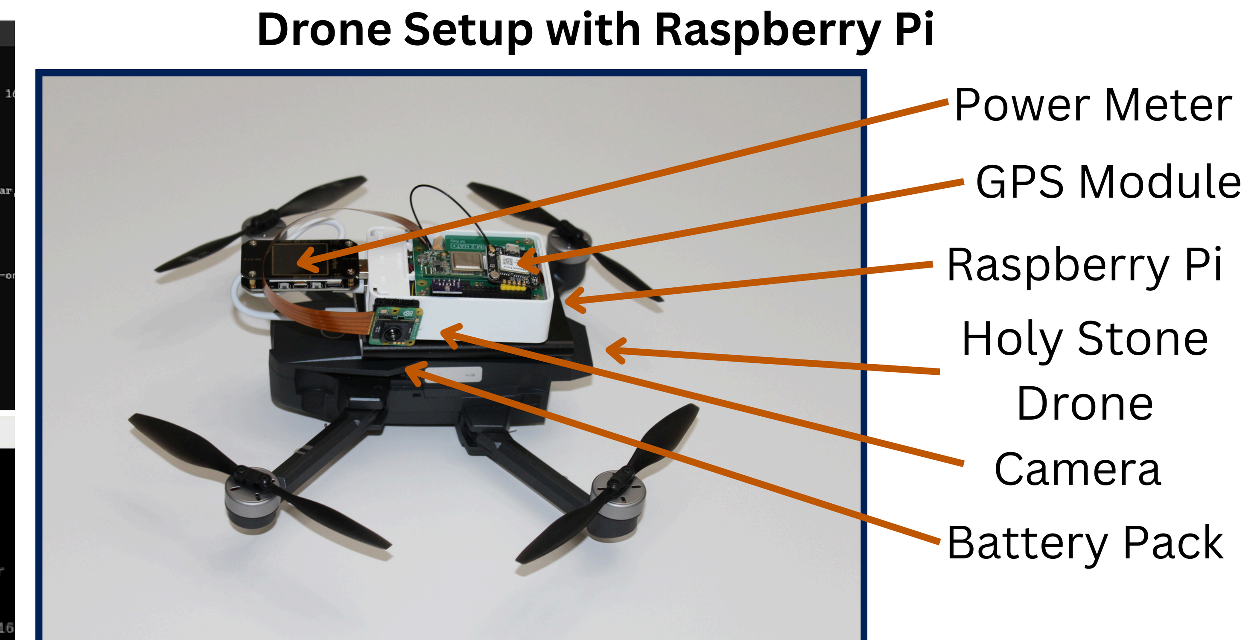
Model Training and Optimization: Train YOLOv8 and RT-DETR on cross-folded data, and use Bayesian Optimization to improve learning rates after the first set of standard epochs.

Deployment and Post Flight Analysis: Deploy both models at a citrus farm, and analyze the model's detections with video footage, Grad-CAM and Raspberry Pi sensors.

HARDWARE IMPLEMENTATION



Drone Setup with Raspberry Pi



Models were downloaded using Linux and uploaded to the Raspberry Pi, which connected to the camera.

FIELD VALDATION & ANALYSIS

The drone setup was brought to a citrus farm to test its performance in detecting citrus diseases in real time. Detections were captured via RealVNC viewer and uploaded for analysis.

$$\text{Precision} = \frac{TP}{TP+FP} \qquad \text{mAP@95} = \frac{1}{10N}\sum_{t=0.5}^{0.95}\sum_{i=1}^{N}\text{AP}_i^{\text{IoU}=t}$$

$$\text{Recall} = \frac{TP}{TP+FN} \qquad \text{mAP@50} = \frac{1}{N}\sum_{i=1}^{N}\text{AP}_i^{\text{IoU}=0.5}$$

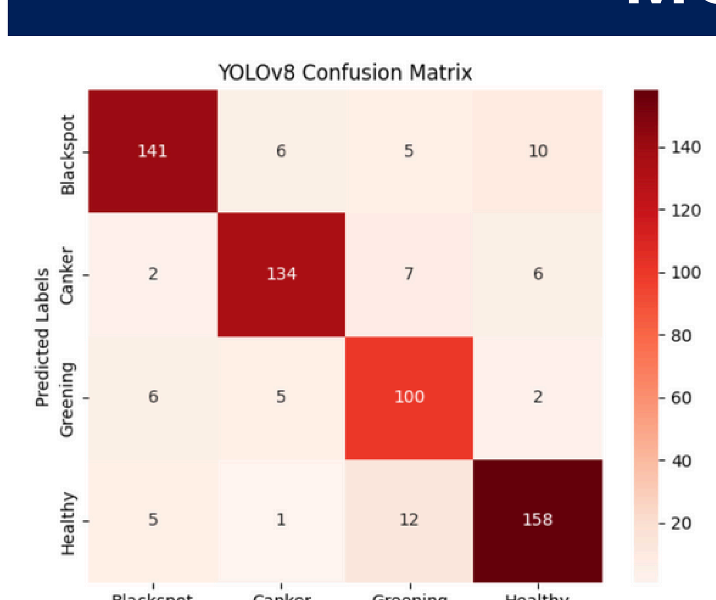
$$\mathcal{L}_{\text{cls}} = -\sum_{c=1}^{C}\left[\hat{p}_c \log(p_c) + (1-\hat{p}_c)\log(1-p_c)\right]$$

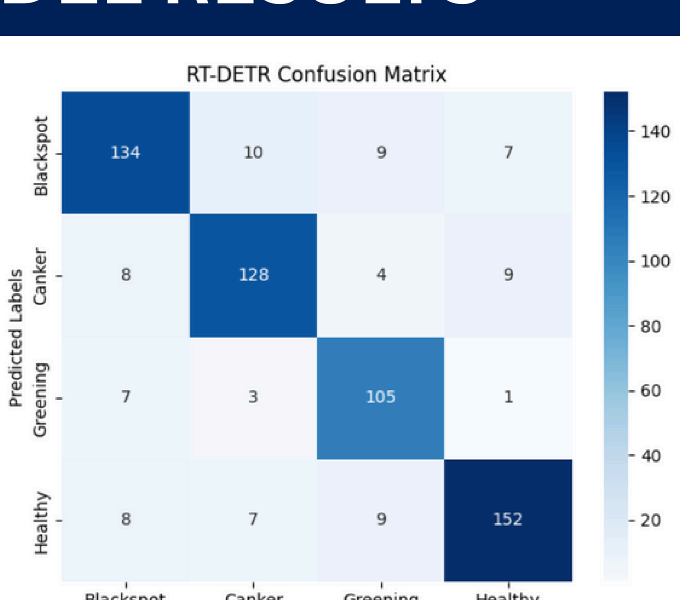
$$\mathcal{L}_{\text{box}} = 1 - \left(\text{IoU} - \frac{\rho^2(\mathbf{b},\hat{\mathbf{b}})}{c^2} - \alpha v\right)$$

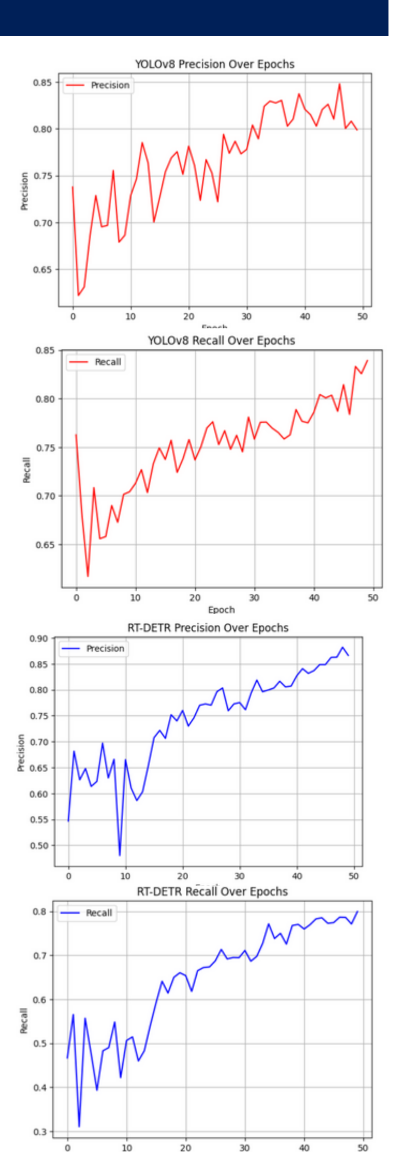
$$\mathcal{L}_{\text{DFL}} = -\sum_{i=1}^{4}\sum_{j=1}^{K}\hat{q}_{i,j}\cdot(1-q_{i,j})^{\gamma}\cdot\log(q_{i,j})$$

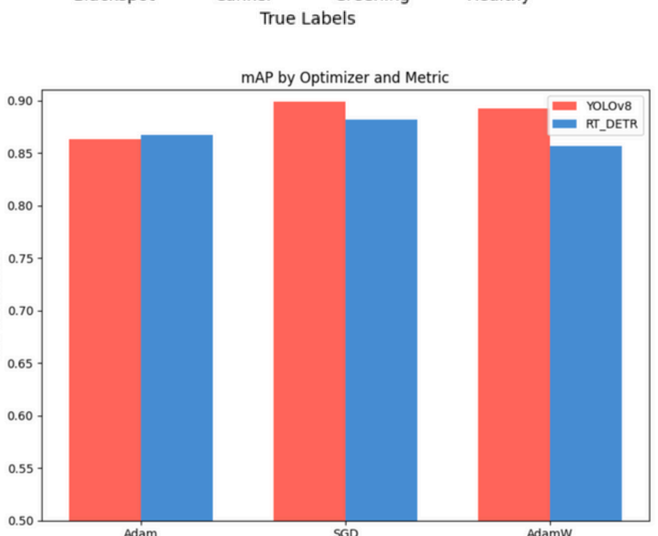
Overall, YOLOv8 **demonstrated a higher performance** than RT-DETR in its ability to detect citrus diseases, however, RT-DETR had a **slightly higher precision** that showed its ability to avoid false positives. For farmers - this is a valuable insight that shows that **both models are necessary in deployment**, for validation of each other as well as **higher confidence.**

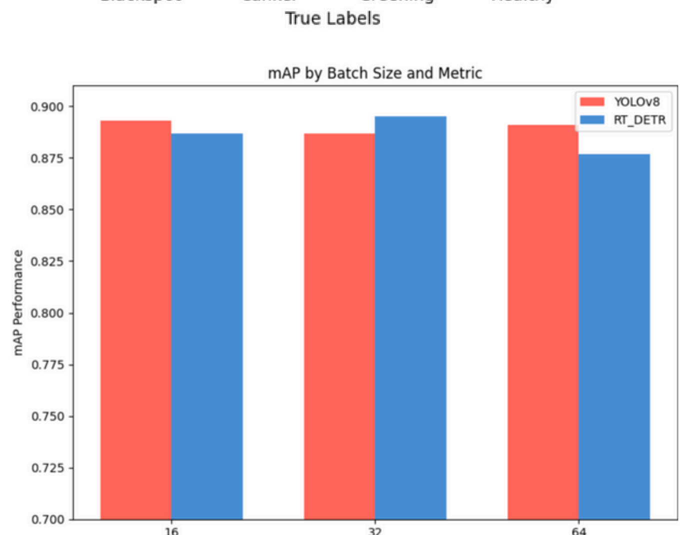
MODEL RESULTS











CONCLUSIONS

YOLOv8 is a **slightly better real-time detection model** than RT-DETR on a custom image dataset of citrus diseases. The substitution of training with specific hyperparameters **boosted both models over 10%**. After several in-field tests, performance showed that both models were capable of doing real time detection on a farm. Grad-CAM and failure case analysis allowed for a **better interpretation of both models.** **Future work** could include improved tracking of citrus diseases using GPS mapping, autonomous drone flying, reducing manual work and orthomosaics to map and geo-locate diseased vs non diseased plants in the entire orchard.

Sources: (1) Thomas H. Spreen, Robert E. Barber, Jr., Mark G. Brown, Alan W. Hodges, Jordan C. Malugen, W. David Mulkey/, Ronald P. Muraro/, Robert P. Norberg, Mohammad Rahmani, Fritz M. Roka, Robert E. Rouse, "An Economic Assessment of the Future Prospects for the Florida Citrus Industry", March 2006. (2)Mayalekshmi K M, Abhishek Ranjan, Rajendra Machavaram, "In-field Chilli Crop Disease Detection Using YOLOv5 Deep Learning Technique", IEEE, April 2023, doi: 10.1109/I2CT57861.2023.1012646816 (3) Shahi, T. B., Xu, C., Neupane, A., & Guo, W. (2023). Recent advances in crop disease detection using UAV and deep learning techniques. Remote Sensing, 15(9), 2450. https://doi.org/10.3390/rs15092450 (4) E and C. Vijayakumaran, "A Comprehensive Analysis of the Developments and Applications of Deep Learning in Citrus Plant Disease Detection," 2023 Second International Conference on Augmented Intelligence and Sustainable Systems (ICAISS), Trichy, India, 2023, pp. 699-703, doi: 10.1109/ICAISS58487.2023.10250579 (5) U.S. citrus production – an uphill battle to survive. (n.d.). American Farm Bureau Federation. https://www.fb.org/market-intel/u-s-citrus-production-an-uphill-battle-to-survive (6) Cooper, D. (n.d.). Hurricane Milton Citrus Losses Could Reach $55 Million - Citrus Industry Magazine. Citrus Industry Magazine. https://citrusindustry.net/2024/12/26/hurricane-milton-citrus-losses-reach-55-million/#:~:text=The%20University%20of%20Florida%20Institute,to%20%2455.2%20million%20in%20Florida. (7)Callies, T. (2021, April 20). What to do about Citrus Black Spot - Citrus Industry Magazine. Citrus Industry Magazine. https://citrusindustry.net/2021/03/23/what-to-do-about-citrus-black-spot/