Detection of Aphids on Sticky Plates using YOLOv5 with Image Tiling

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Abstract

The health of seed potato crops is being threatened by viruses like the Potato Virus Y (PVY). Early detection of aphids creates the opportunity to instantly use pesticides. This study considers single-stage object detection and classification of aphids with YOLOv5[3] in combination with image tiling. The YOLOv5l-model with positive tiling is the best performing model with an F1-score of 0.525.

Introduction

- The health of seed potato crops is being threatened by viruses like the Potato Virus Y (PVY). [1]
- In the last five years, more than 15% of harvested seed potatoes and sugar beans were infected with the PVY virus [2]. There is a linear relationship between the number of aphids and number of infected plants.
- Early detection of aphids creates the opportunity to instantly use pesticides.
- Currently, manually counting aphids is very time-consuming and the use of Convolutional Neural Networks (CNNs) to detect aphids and instantly display the necessity of applying pesticides, could be an alternative.
- YOLO, A single-stage object detection and qualification model is considered to robustly find aphids on yellow sticky plates.

Materials and Methods

Datasets:

- A dataset is collected containing both aphids and other insects on yellow sticky plates: four months, every two weeks the yellow sticky traps were placed at ten Frisian farms, resulting in 80 yellow sticky plates.
- High resolution images (4000x4000 pixels) of the yellow sticky traps were taken with a SONY a7 MARK II SLR-camera.
- From the images combined with their annotations, the 'Aphids dataset' has been established. The data is divided as shown in Table 1.

Network:

- Single-stage object detection with different YOLOv5-models[3] in combination with image tiling. YOLOv5s, YOLOv5m, YOLOv5l and YOLOv5x are considered.
- Images with a high resolution are being used, therefore, tiles are selected from images which are then processed by the model.

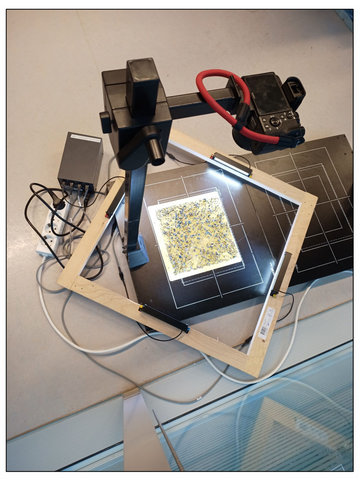

Figure 1. Camera-setup for data acquisition of the 'Aphid & Other Insects Dataset'.

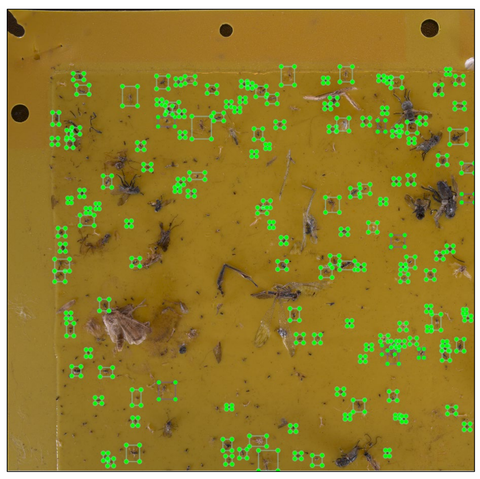

Figure 2. Image with annotations made with LabelImg annotation software[4].

Model	Images	Non-Aphids	Aphids
Training	102	3302	402
Validation	47	1427	181
Testing	22	1200	136
End-Validation	4	369	50
Improved Testing	4	369	50

Table 1. Distribution of the 'Aphids & Other Insects dataset'.

Experiments and Results

- Experiments have been executed on the influence of different options and parameters of the end-to-end tiled YOLOv5 Tiled Object Detection model on the 'Aphids Dataset'.
- Multiple YOLOv5-models are compared, various hyperparameters are modified and the influence of tile size, tiling, augmentations and class probabilities has been studied.
- After going through the model, images with bounding boxes of the ground truth and the predictions are reconstructed. Figure 4 shows an image during validation. Figure 5 shows an image during testing.

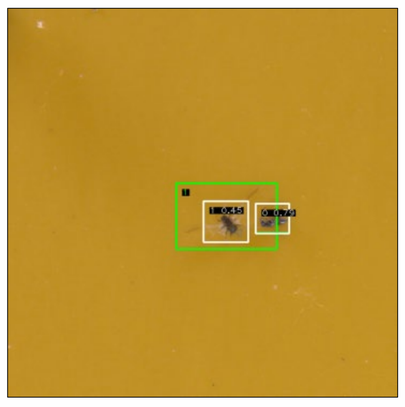

Figure 4. Object detection during validation. Green = Ground truth, White = Predictions

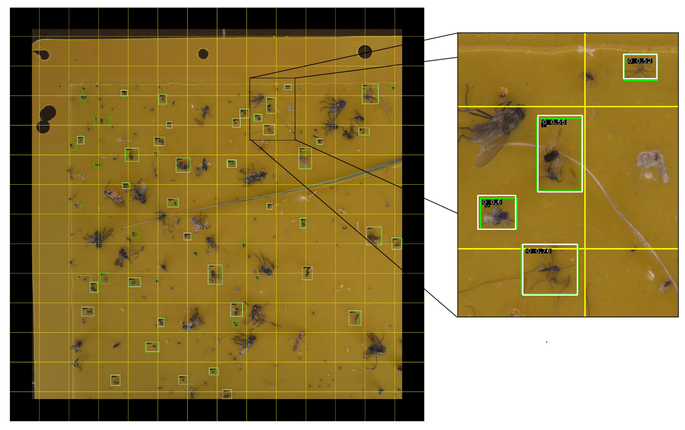

Figure 5. Object detection during Testing. Green =Ground truth, White = Predictions

Discussion

- Larger YOLOv5-models outperform the smaller ones, in Table 2.
- Due to limitations in computational power, only smaller batch size can be used for larger models.

Model	Batch	Epochs	Pre_A	Rec_A	F1_A
YOLOv5s	2	400	0.382	0.559	0.454
	4	400	0.449	0.419	0.433
	8	400	0.430	0.418	0.424
YOLOv5m	4	400	0.431	0.520	0.471
YOLOv5l	2	400	0.455	0.549	0.485

Table 2. YOLOv5-models of different size, with various batch size and learning rate.

- Results in Table 3 show that there is no significant difference between different class probabilities. However, faster training towards a class is accomplished with higher probabilities for this class.
- Tiles with a size of 640x640 pixels seem to be preferable above tiles with a size of 320x320 pixels, as shown in Table 4.
- The best results are achieved with the YOLOv5l-model in combination with positive image tiling. The model has been trained for 400 epochs with a batch size of 2, number of tiles of 2, tile size of 640x640pixels, learning rate of 0.001 and no augmentations. A F1-score on aphids of 0.525 is achieved (Table 4).

Model	Epochs	Probability	Prec-A	Rec-A	F1-A
YOLOv5s	100	50/50	0.356	0.451	0.398
	100	100/0	0.358	0.495	0.415
	400	50/50	0.430	0.418	0.424
	400	100/0	0.333	0.574	0.421

Table 3. Relevant results regarding class probabilities

Model	Batch	Tile	Aug	$Prec_A$	Rec_A	$F1_A$
m	2	640	No	0.488	0.463	0.475
		640	Yes	0.576	0.390	0.465
	4	640	No	0.492	0.456	0.473
		640	Yes	0.389	0.478	0.429
		320	No	0.416	0.507	0.457
l	2	640	No	0.473	0.588	0.525
	2	640	Yes	0.593	0.397	0.476

Table 4. Summary of the best overall results.

Conclusions

- An end-to-end method to find aphids on yellow sticky plates has been established. Multiple experiments with YOLOv5-model in combination with image tiling, alternating various hyperparameters has been executed.
- A higher probability towards a class has proven not to increase results for this class. The higher probability does result in faster training for the specific class.
- The YOLOv5l-model with positive tiling is best performing with an f1-score of 0.525.

Acknowledgements

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Europees Landbouwfonds voor Plattelandsontwikkeling: Europa investeert in zijn platteland

References

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- [2] Westerman, P. (2022, January 1). Virus- en vectorbeheersing in pootaardappelen. WUR. https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksprojecten-LNV/Expertisegebieden/kennisonline/Virus-en-vectorbeheersing-in-pootaardappelen.htm
- [3] Jocher, G. (2020, August 21). ultralytics/yolov5. GitHub.
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