First results of the development of Intelligent Non-invasive Phenotyping of Raspberries using Machine Learning and 3D Imaging

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Introduction

- **The efficiency of breeding for raspberry traits** must rely on intelligent, **non-invasive phenotyping methods using AI**.
- The use of **non-invasive imaging techniques** and data analysis during the evaluation process will increases the quality and yield of raspberries.
- The development of a model for **raspberry phenotyping based on RBG and 3D imaging and the ML approach will** enable more accurate, faster and more productive evaluation of raspberries.

Objectives

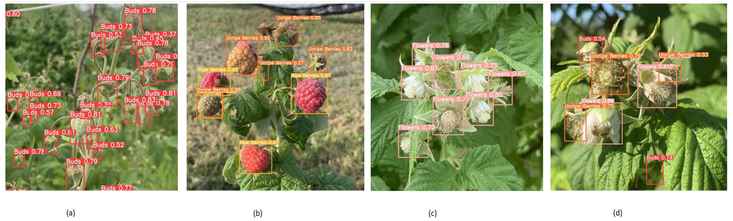
To develop of a non-invasive ML-based raspberry phenotyping model using RGB and 3D imaging to process yield components and understanding environmental interactions.

Materials and Methods

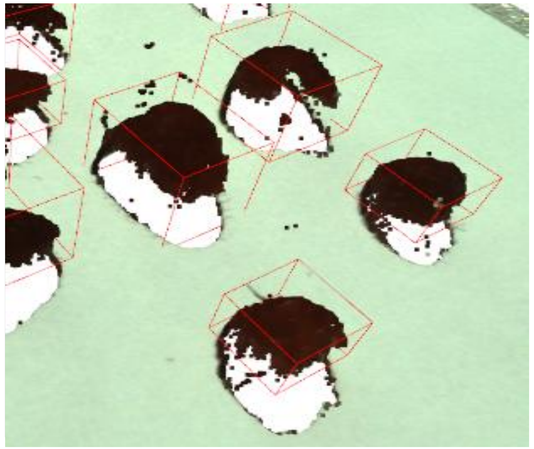
- **Location**: orchard of LatHort in Dobele, the southern part of Latvia (GPS: 56.6323154; 23.3425648).
- **Phenotypic characterization** was performed on a representative part (Rubus genotypes) of LatHort collection.
- **RBG** image acquisition using the iPhone XS cell phone.
- **3D image acquisition** using Zivid One + 3D camera.
- **Development of a non-invasive ML-based raspberry phenotyping model** using RGB and 3D imaging to process yield components.

Results 1. RBG Raspberry dataset and detection

- Raspberry RBG image acquisition.
- Manual annotating of raspberries using Labelmg 1.8.6 software.
- Original RasperrySet dataset 2039 images (1773x1773 px) consisting of five classes: `bud`, `flower`, `unripe berry`, `ripe burry`, `damaged buds`.
- Raspberry (object) detector with trained DNN YOLOv5 architecture.



Detection results obtained with the trained YOLOv5 detector on random images from the test set of the RaspberrySet dataset.



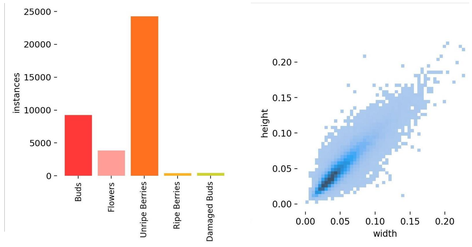
Raspberry localization with 3D bounding boxes

Results 2. Parametric characterization of raspberry using 3D imaging

- Development of 3D point cloud detection algorithms KNN (k nearest neighbours), “imaginary square” and object projection.
- The algorithms detect and localize raspberries as a 3D object.
- 3D raspberry dataset
- The tool for locating raspberries with 3D bounding boxes on 3D images.
- The Raspberry Grooved Index.
- The software for 3D raspberry detection and localization with 3D bounding boxes.

Statistics of floricane raspberry fruits, 2021

Cultivars	Fruit laterals per cane, count	Berries per fruit lateral, count	Average weight of berry, g	Yield, g per cane
S2-6-13	21.5	11.7	2	503.1
S2-6-8	18.2	14.4	1.8	471.7
S11-25a-4	15.1	12.4	2.5	468.1
Patricija	15.6	8.7	2.3	312.2
Labetovskaja	13.2	10.1	2.1	280.0
Lina	11.7	8.5	2.7	268.5
S1-12-13	15.4	9.1	1.8	252.3
Ruvi	18.3	9.8	1.4	251.1
Kapriz Bogov	13.9	7.8	2.1	227.7
Bozhestvennaja	10.5	7.2	2.7	204.1
Sulamifa	18.6	7.8	1.3	188.6
Octavia	8.7	8.8	2.2	168.4
Shahrizada	9.7	6	2.3	133.9
Glen Ample	6.9	7.3	2.2	110.8
p values between genotypes <5.7E-29				



(left) Parameters of RaspberrySet dataset. (right) Average proportion of high and width of the instances.

Conclusions and perspectives

- The DNN YOLOv5 model has been developed for the detection and localization of raspberries in RGB images.
- The model has been trained for raspberry yield estimation and achieves an average accuracy (mAP) > 70%.
- The 3D model can distinguish raspberries based on their height, width and depth in a 3D point cloud.
- The phonological parameter - Raspberry Grooved Index has been created.

- Future research will focus on **extraction and evaluation of multiparameters for phenotyping from 3D raspberry images.**
- **Analysis of raspberry texture and statistical analysis** (SPSS) for non-invasive categorization of phenotypes.
- Development of a **3D image-based methodology for phenotyping.**
- Integration of the developed methods into a **ML-based system prototype and its validation.**
- **Demonstration of a non-invasive phenotyping prototype** for raspberry yield estimation and raspberry trait breeding.

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