HBC.2022.0062

VLAIO TETRA

Machine Vision for Quality Control

(MV4QC)

Tussentijdse vergadering III

Met de steun van VLAIO

Agenda

- Status project
- Toelichting cases fase 1
- Toelichting cases fase 2
- Toelichting demonstratoren

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Status project - werkpakketten

WP1

- Rapport WP1 geschreven – laatste versie op de website
- Bedrijfsbezoeken afgerond

WP2

- Rapport WP2 geschreven – laatste versie op de website
- Masterclass op 23-24 oktober

WP3

- Rapport WP3 geschreven – laatste versie op de website
- Seminarie georganiseerd op 15 februari 2023

WP4

- Alle zes de cases in een eerste fase afgewerkt – laaste versie op de website
- Eerste demonstrator afgewerkt – tweede demonstrator in ontwikkeling

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Status project - leverbaarheden

- ✓ L1.1 Startvergadering (12/10/2022)
- ✓ L1.2 Rapport die de aanwezige kennis, noden, mogelijke toepassingen, en vijf geselecteerde cases beschrijft (Rapport WP1)
- ✓ L2.1 Rapport die de bestaande technieken bundelt (Rapport WP2)
- ❑ L2.2 Seminarie over de gebundelde technieken (Masterclass op 23-24 oktober)
- ✓ L3.1 Rapport die de praktische kennis bundelt (Rapport WP3)
- ✓ L3.2 Seminarie over de praktische kennis (15/02/2023)
- ❑ L4.1 Vijf uitgewerkte use-cases
- ✓ L4.2 Inschakelen van studenten voor het uitwerken van de use-cases en demonstratoren
- ✓ L4.3 Rapport over de vijf uitgewerkte use-cases
- ❑ L4.4 Twee ontwikkelde demonstratoren (1/2 afgerond)
- ❑ L4.5 Workshop rond de demonstratoren
- ❑ L5.1 Economische evaluatie en haalbaarheidsstudie
- ❑ L5.2 Rapport over de economische evaluatie en haalbaarheidsstudie
- ✓ L6.1 Cursusmateriaal dat zal ingezet worden binnen het vak ‘Machinevisie’ en Manama ‘AI for Business and Industry’
- ❑ L6.2 Finale begeleidingsgroep vergadering
- ❑ L6.3 Webinar voor doelgroep
- ✓ L6.4 Website

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Toelichting cases

Fase 1

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Machine Vision for Quality Control (MV4QC)

Case 1

Detection of surface damage on flat sheets

Decospan

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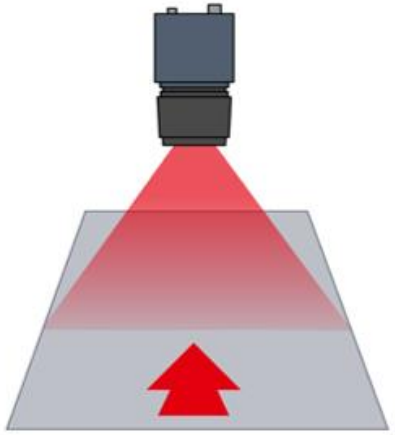
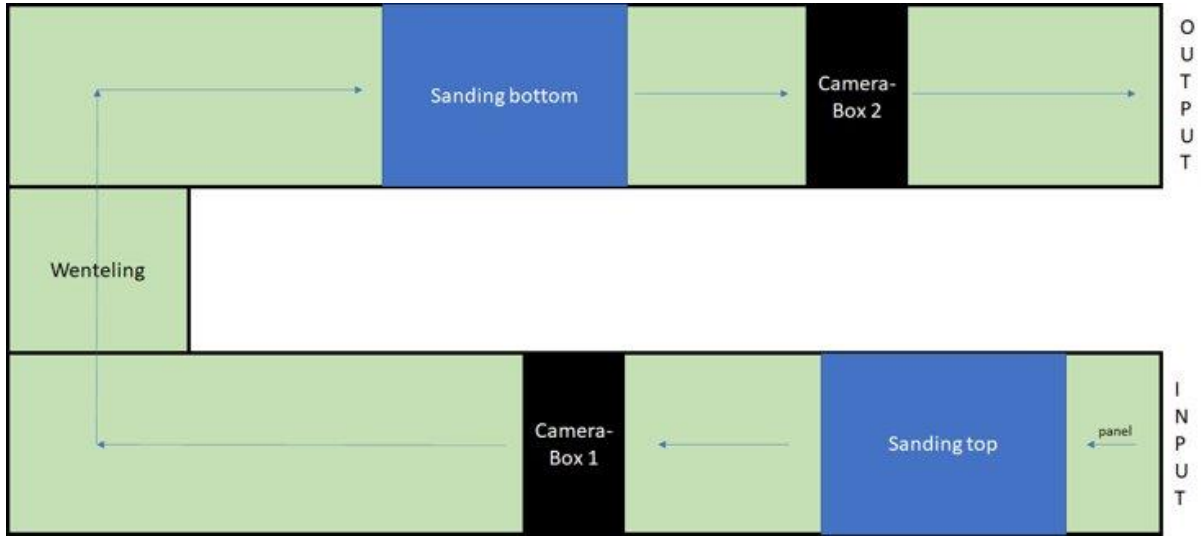
Case 1 – Quality control setup

- 2 camera boxes (both sides)
- Line scan camera





Case 1 – Data

- Annotated images with bounding boxes for defects:
  - Dents
  - Sawing errors
  - Cuts
  - …
- Images with different types of wood
  - Colour variation
  - Non-defects

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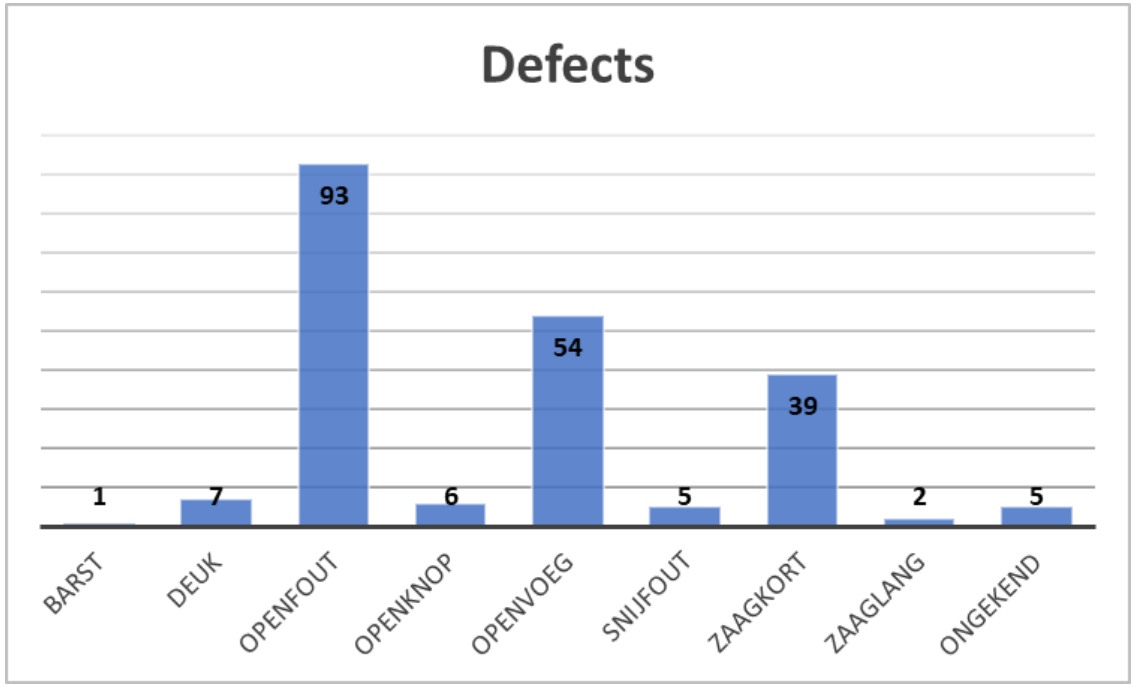
Case 1 – Data

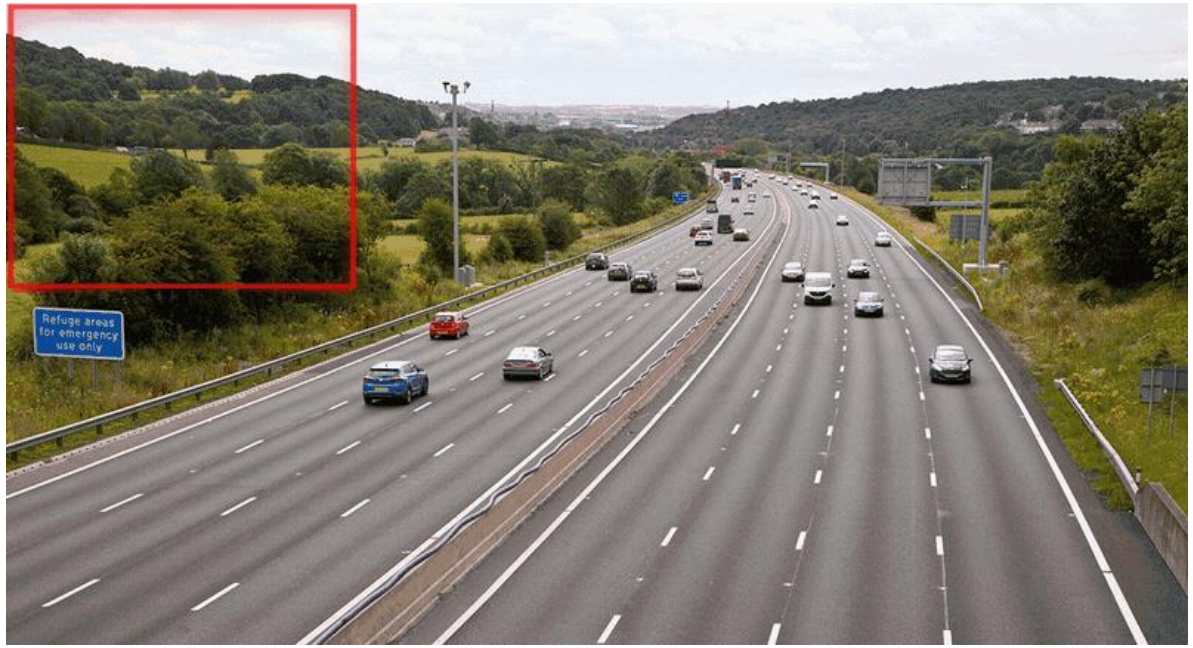
- Large pixel sizes
- Irregular sizes
- Limited, imbalanced dataset
  - 130 images
  - 212 defects



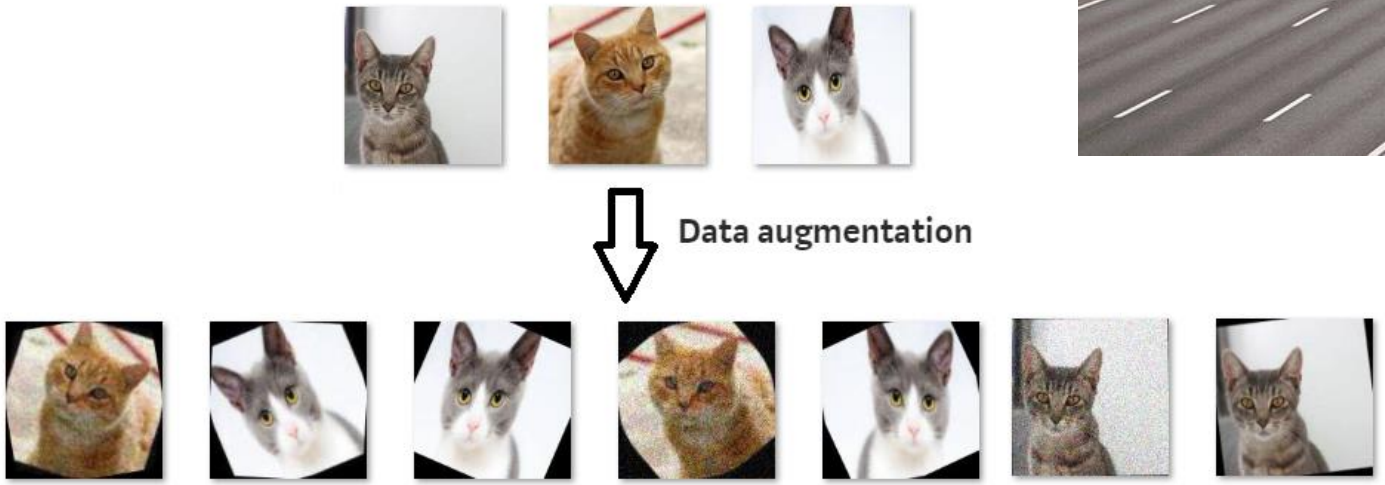
Met de steun van VLAIO

Case 1 – Data pre-processing

- Patching/slicing
  - Smaller, regularised sizes



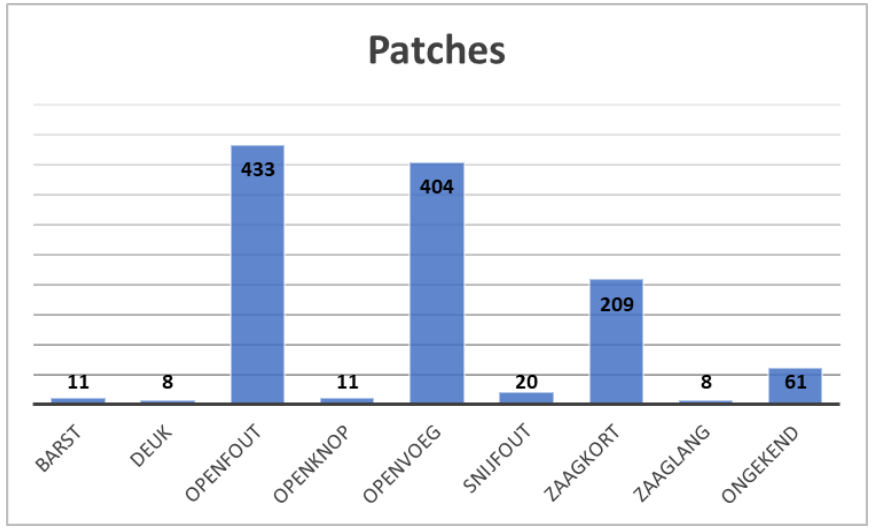
- Augmentation

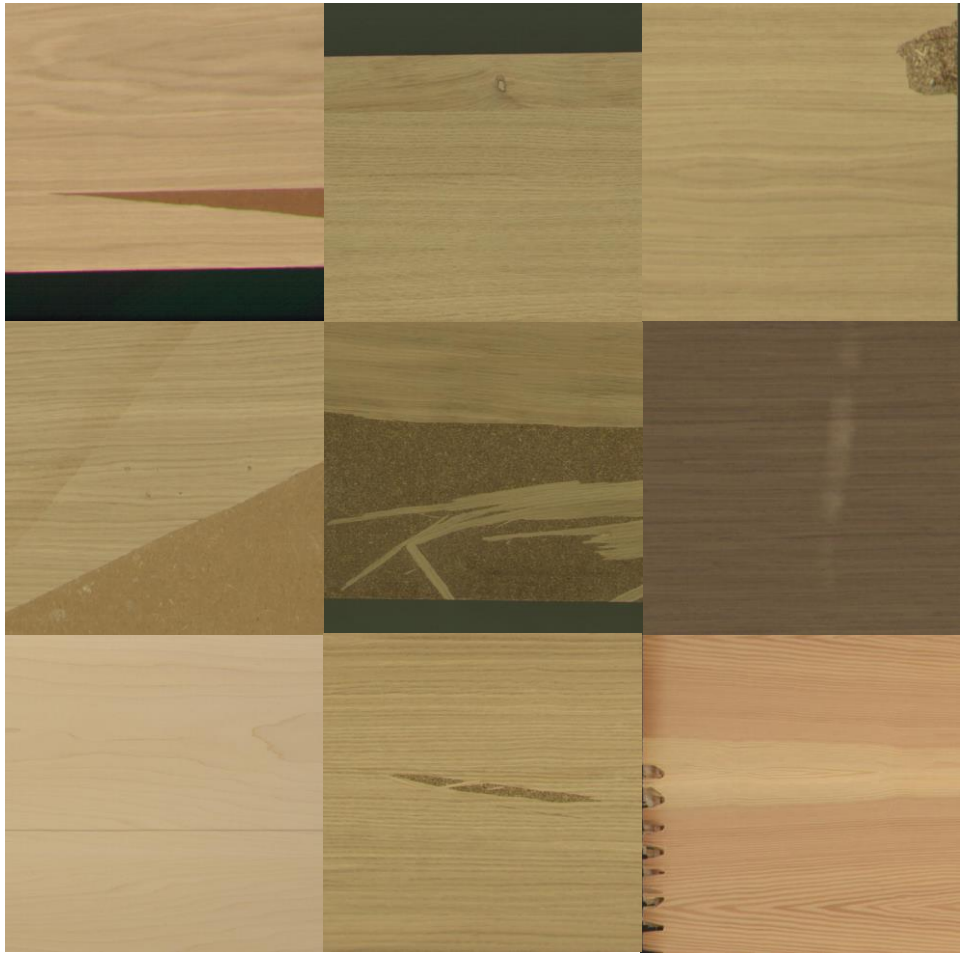


Met de steun van VLAIO

Case 1 – Data pre-processing

- Patching/slicing:
  - Patches of 1024x1024 pixels
  - 256 (25%) pixels overlap
  - 1114 patches with 1165 defects





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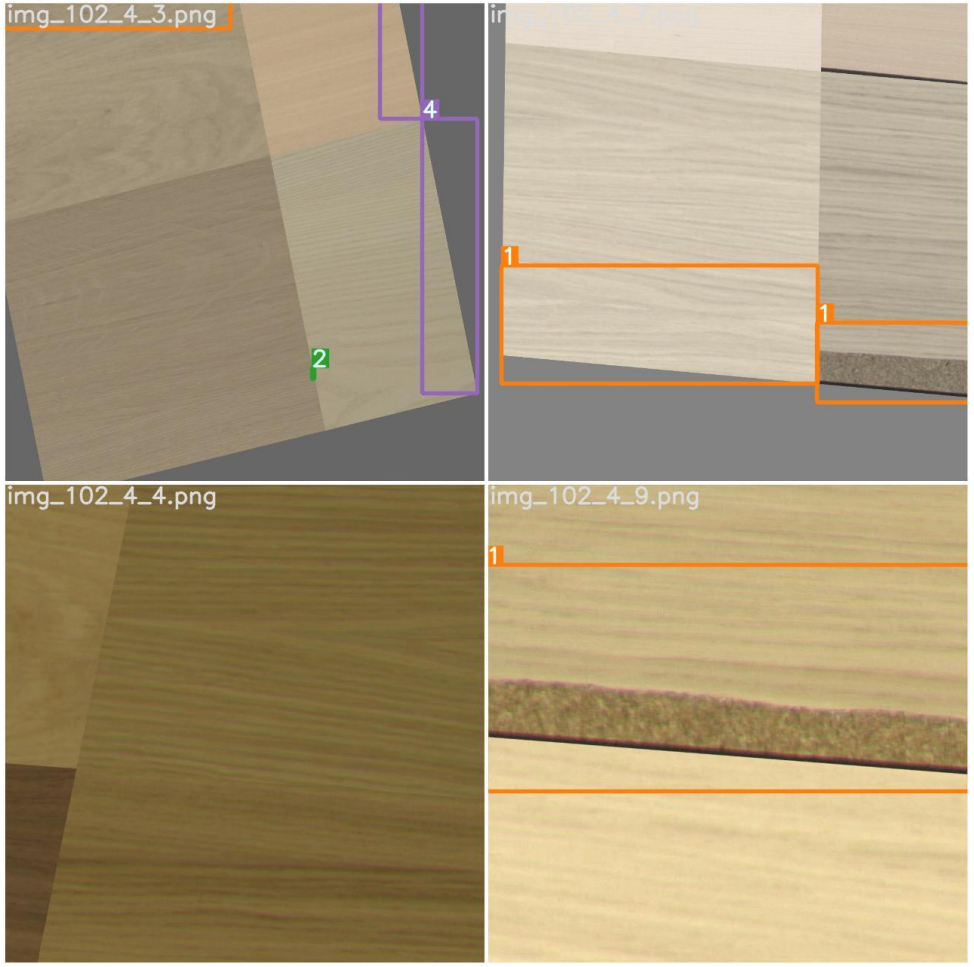
Case 1 – Data pre-processing

- Data augmentation:
  - HSV
  - Rotation (10°)
  - Scaling
  - Shear
  - Flip
  - Mosaic



Case 1 – Data pre-processing

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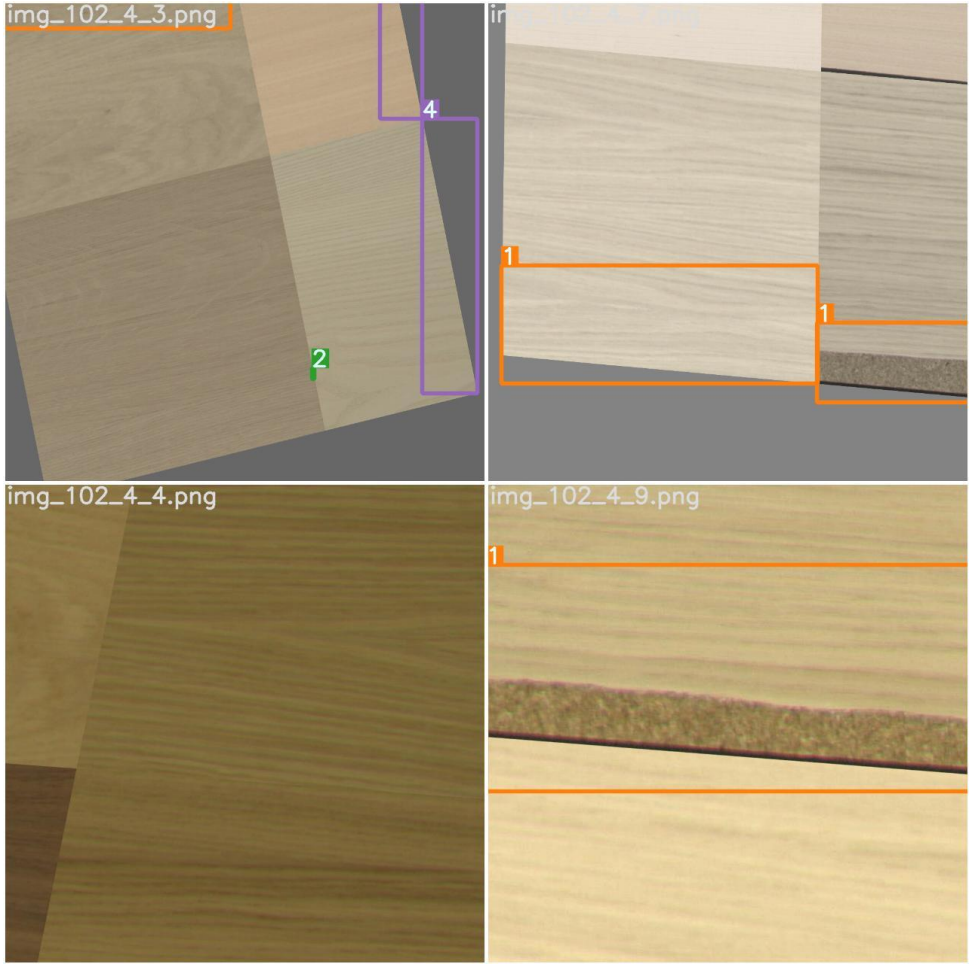
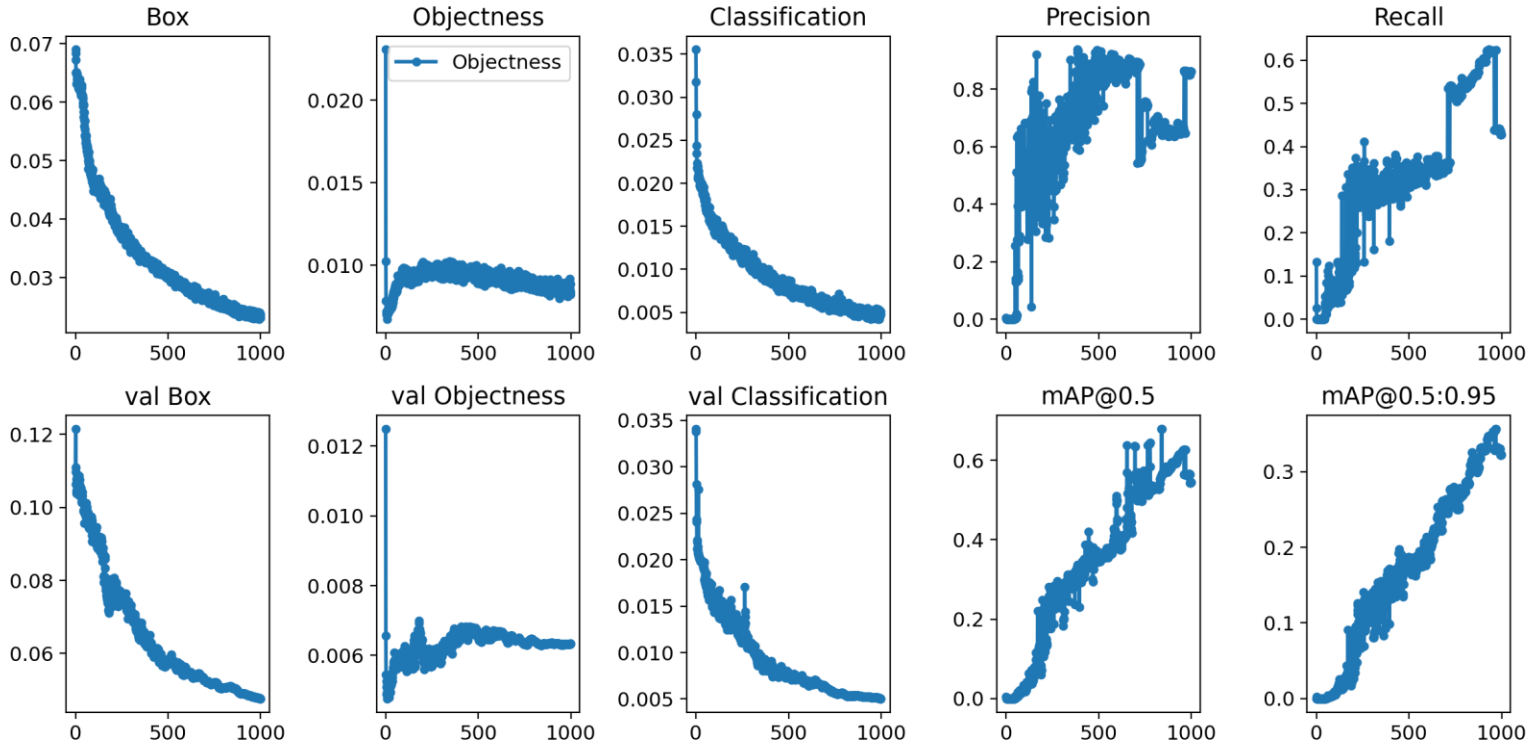


Case 1 - Training

- Dataset split 80/10/10
- 1000 epochs
- Metrics
  - Precision
  - Recall
  - mAP



Met de steun van VLAIO

Case 1 – Evaluation

- Metrics on test set:

Klasse	Labels	Precision	Recall	mAP@0.5
deuk	1	1	0	0
openfout	46	0.757	0.609	0.673
openvoeg	36	0.839	0.724	0.79
snijfout	2	1	0	0.128
zaagkort	19	0.667	0.632	0.648
zaaglang	1	1	0	0.995
barst	1	0.561	1	0.995
ongekend	5	1	0.555	0.698
totaal	111	0.853	0.44	0.616

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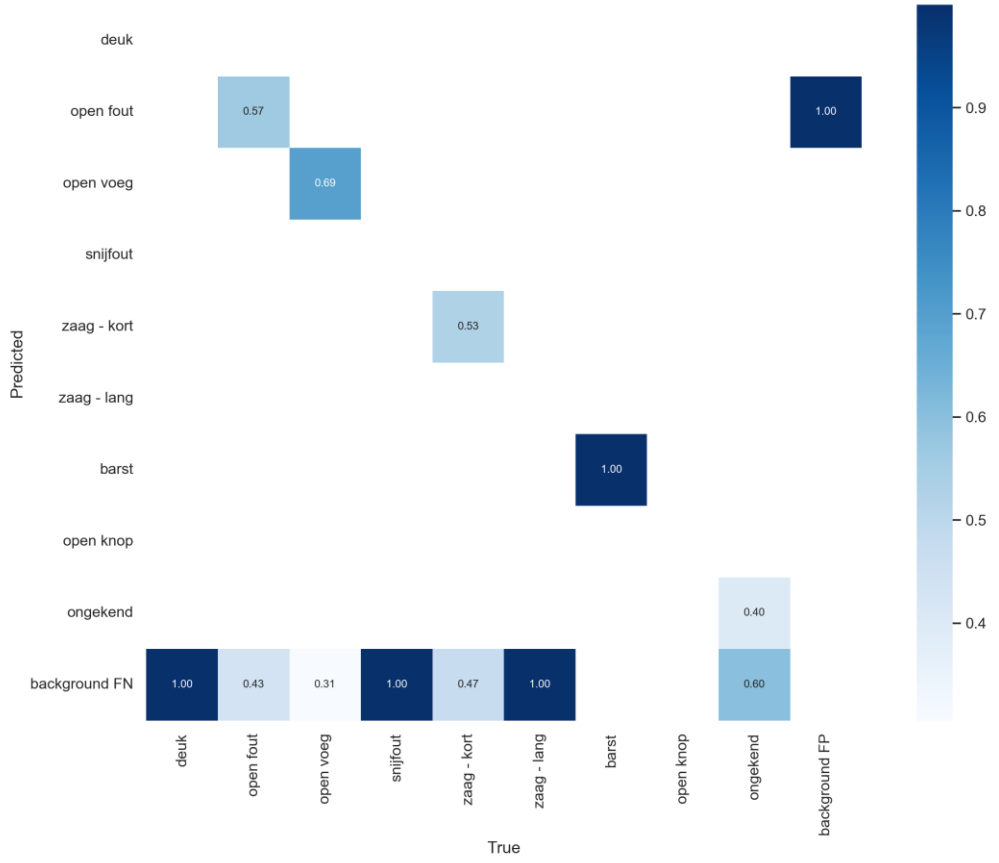
Case 1 – Evaluation

- Confusion matrix on test set:



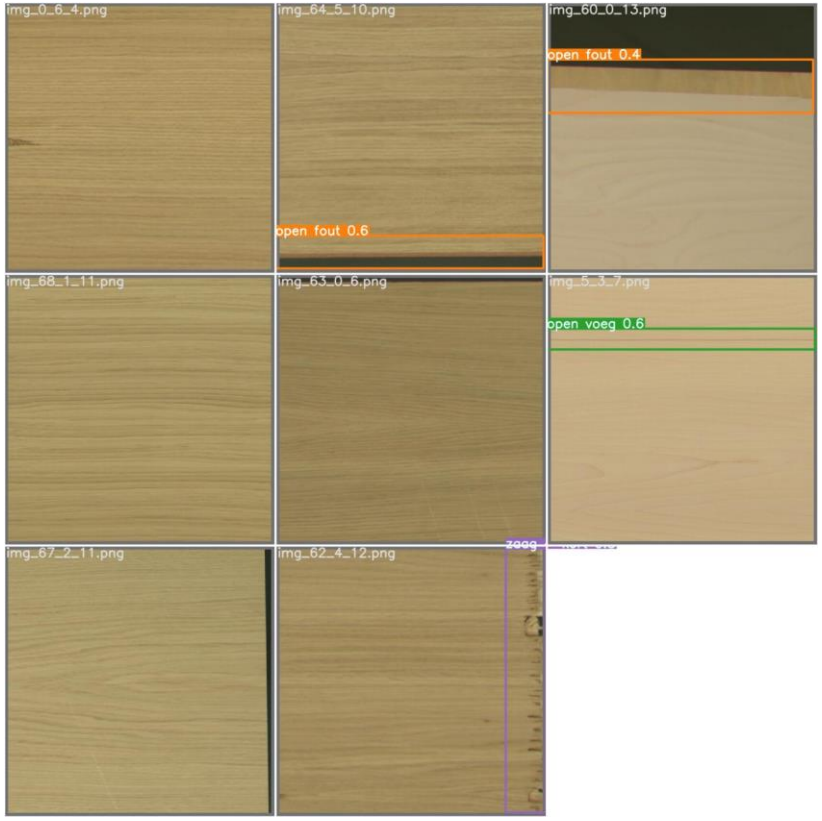
Met de steun van VLAIO

Case 1 – Evaluation

- Inference on test set:

Actual

Predicted



Met de steun van VLAIO

Case 1 – Conclusion

- New dataset due to patching
- YOLO
  - Precision okay, low recall
  - Can improve with more training
- Other architectures available

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Case 1 – Further work

- Literature study
- Clean and analyse the dataset
- Imbalanced dataset causes problems: use of class weights
- Other networks: faster R-CNN with ResNet 50 or MobileNet v3 backbone, RetinaNet, …

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Machine Vision for Quality Control (MV4QC)

Case 1

Detection of surface damage on flat sheets

MCAM

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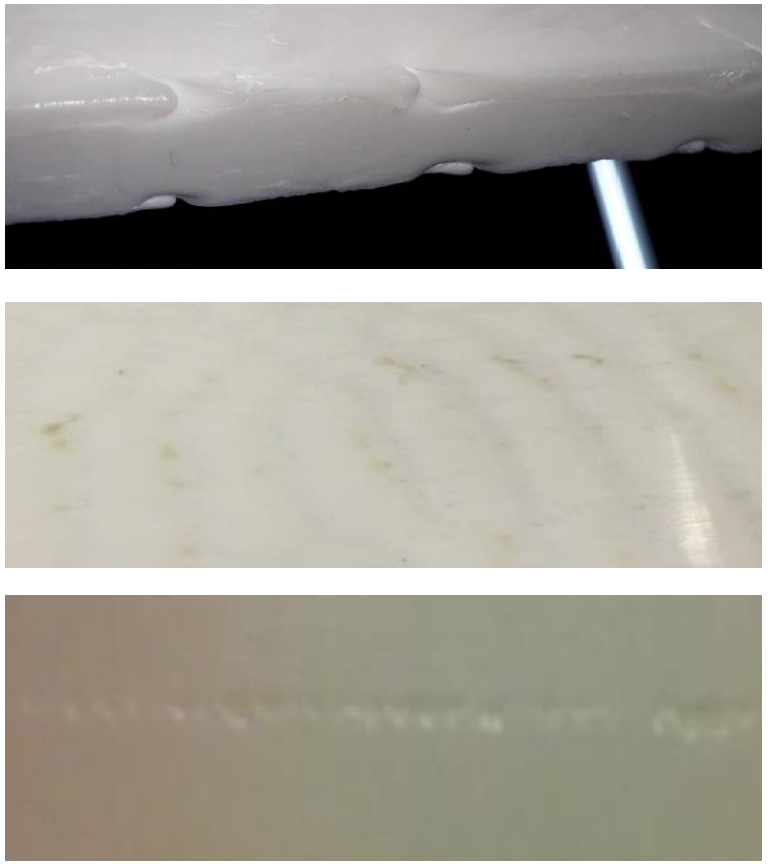
Case 1 - Detection of surface damage on flat sheets

Several defects occur when extruding polymer sheets

- Stick defects
- Damage on the sides
- Color deviations

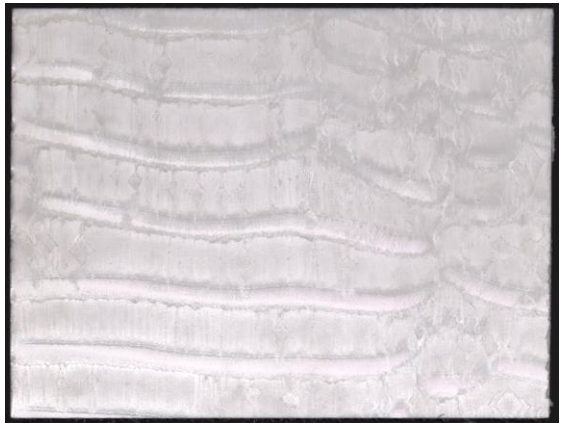


Met de steun van VLAIO

Case 1 - Detection of surface damage on flat sheets

Tests were done by Covicon. Some pictures of sample sheets were taken and some machine vision techniques were used.

Images were taken with a 4k line camera (RGB) and a lens of 25mm. Resolution is 0.2mm/px and a metaphase line light was used with white collimated light.

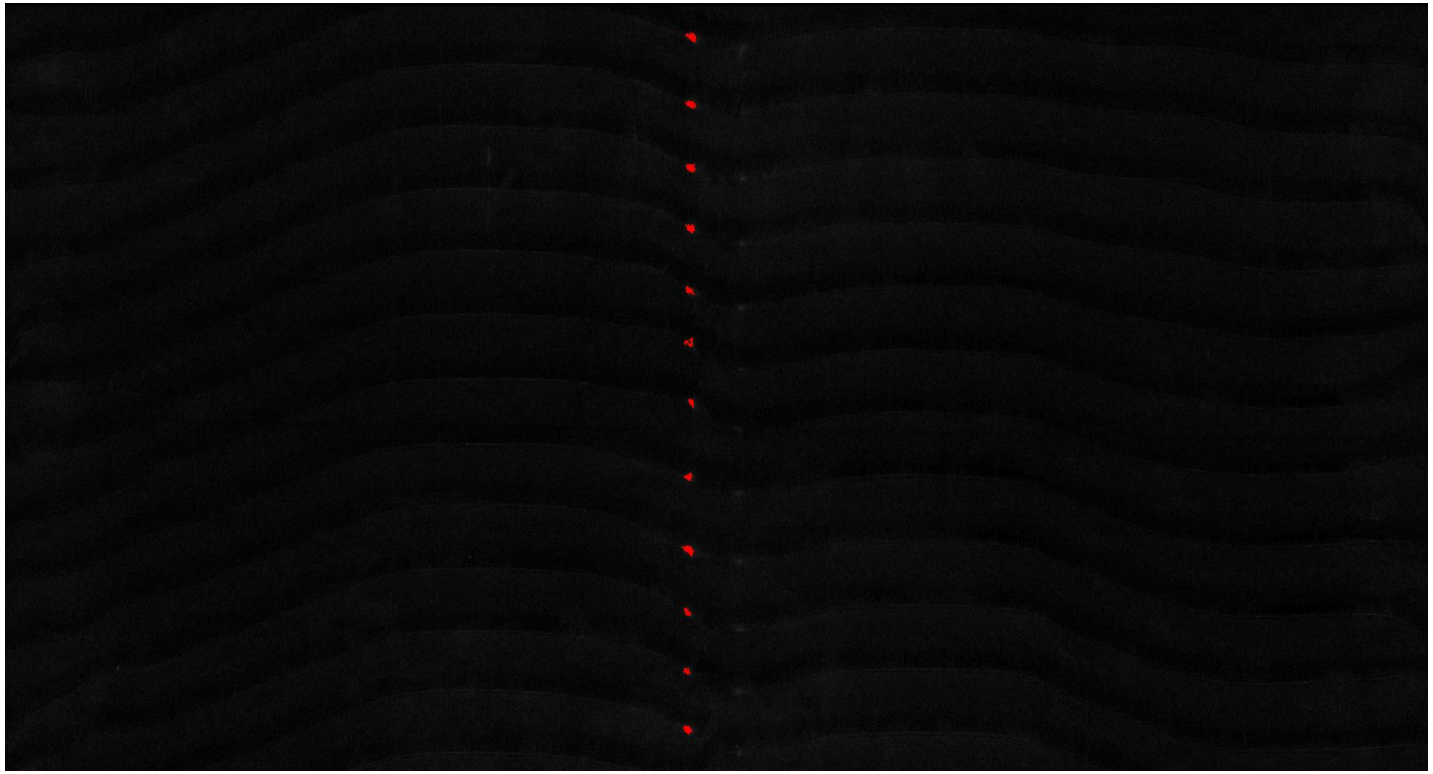


Met de steun van VLAIO

Case 1 - Detection of surface damage on flat sheets

Detection of burned spots

- Possible without AI
- Thresholding

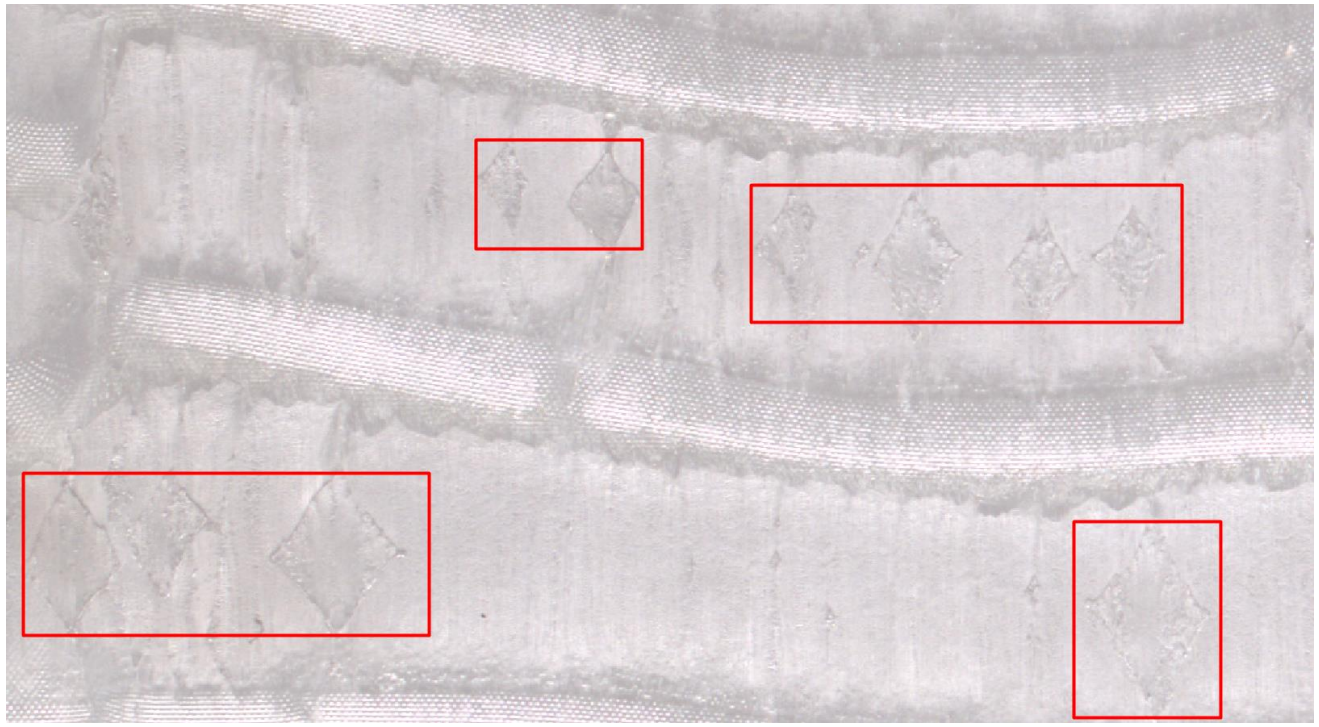


Met de steun van VLAIO

Case 1 - Detection of surface damage on flat sheets

Stick defects:

- Challenging problem

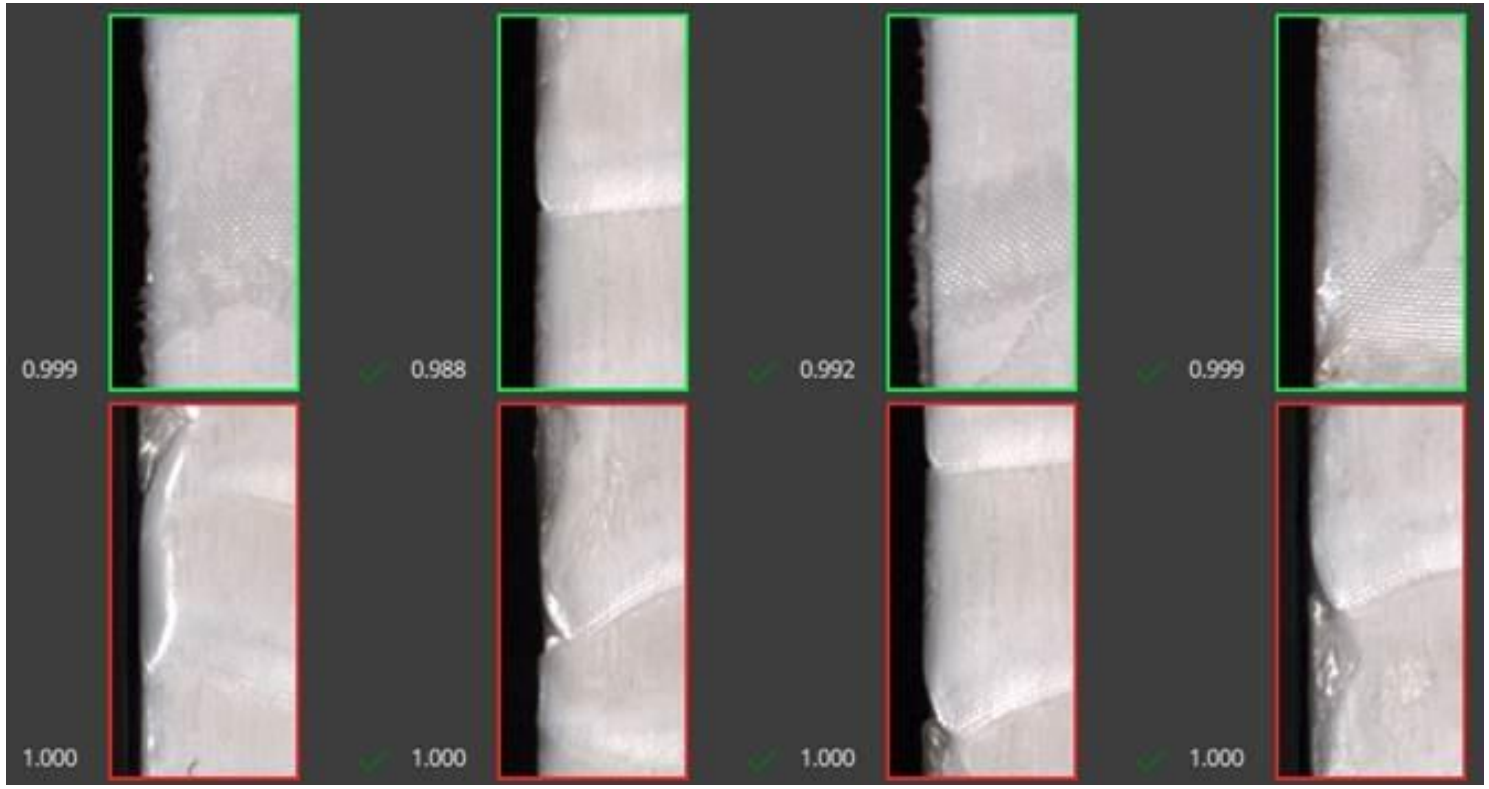


Met de steun van VLAIO

Case 1 - Detection of surface damage on flat sheets

Defects on the side

- Detection using AI
- Resnet18 was used



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Machine Vision for Quality Control (MV4QC)

Case 2

Detectie van optimale snijlijn van witloof

Inagro

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Objectives

- Inagro
- Objectives
  - Detection chicory
  - Detection cutting line
  - Classification good/bad

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Hardware setup

- Camera: RealSense D415
  - USB3.0
  - 1280 x 720 (1MP)
- Illumination: from environment

Met de steun van VLAIO

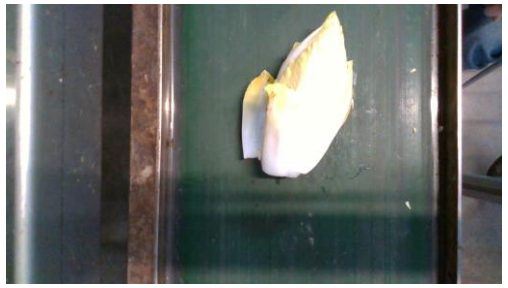
Dataset

Dataset containing:

- 1463 images
- Different lighting conditions

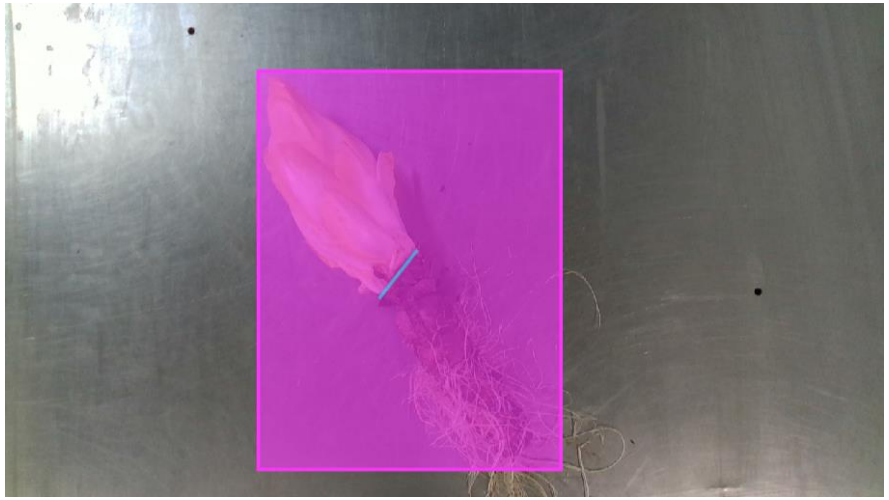
Foto klasse:	met de volledige wortel	te weinig gesneden	te veel gesneden	ideaal gesneden	schuin gesneden
Aantal afbeeldingen:	218	418	282	421	123



LabelBox render:

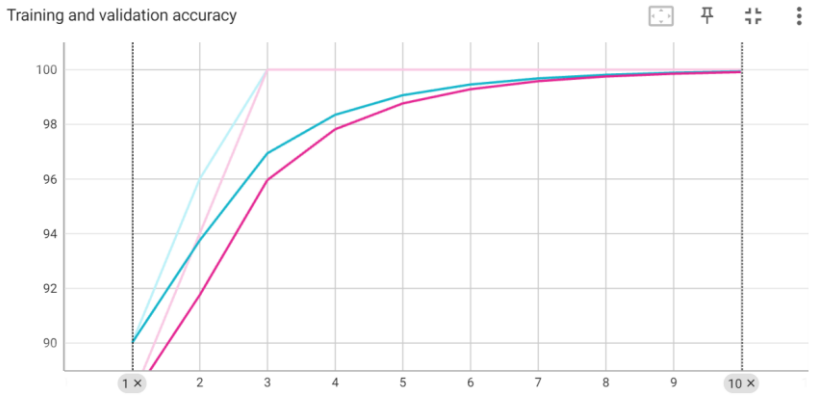
- Image url
- Bounding box [left, top, width, height]
- Line [x1, y1, x2, y2]

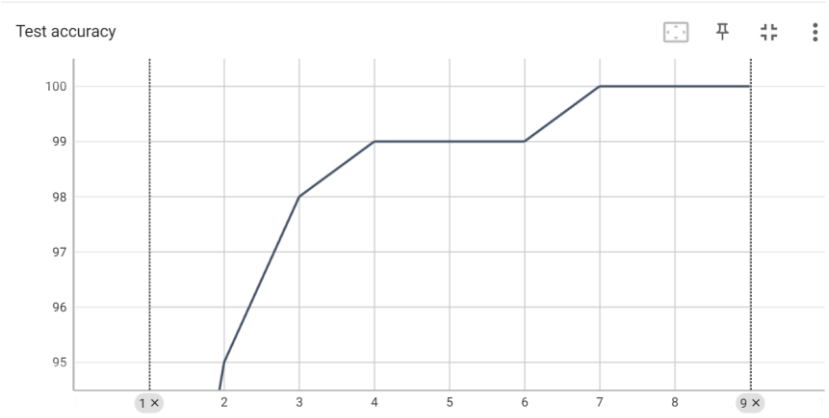


Met de steun van VLAIO

Classification

- Needs more cutting / does not need cutting
- ResNet18
- 681 training, 146 validation, 147 test
- Epochs: 10
- Learning rate: 0.001
- Batch size: 64
- Loss: Cross Entropy
- Accuracy: 99,72%



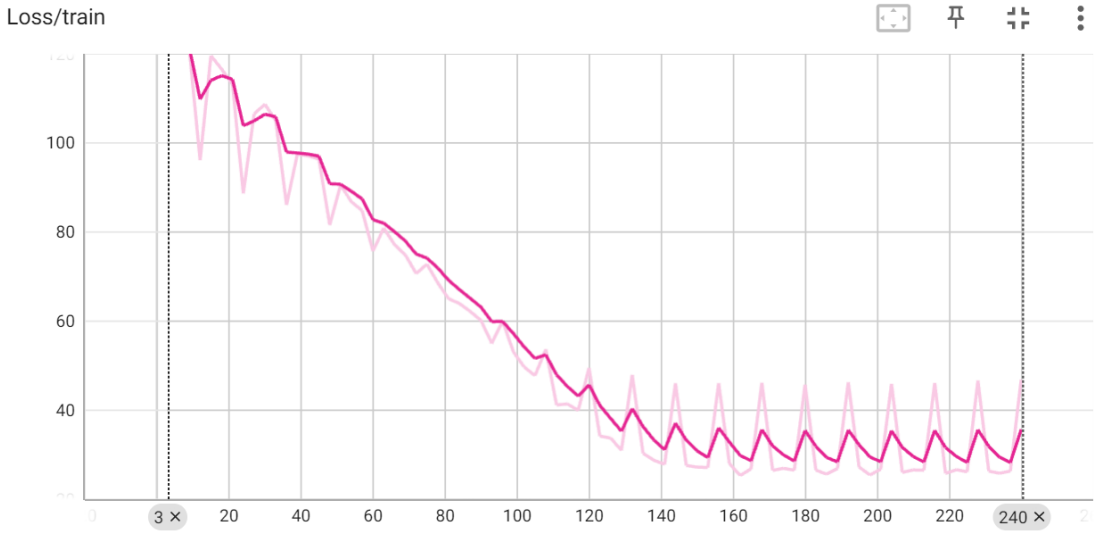


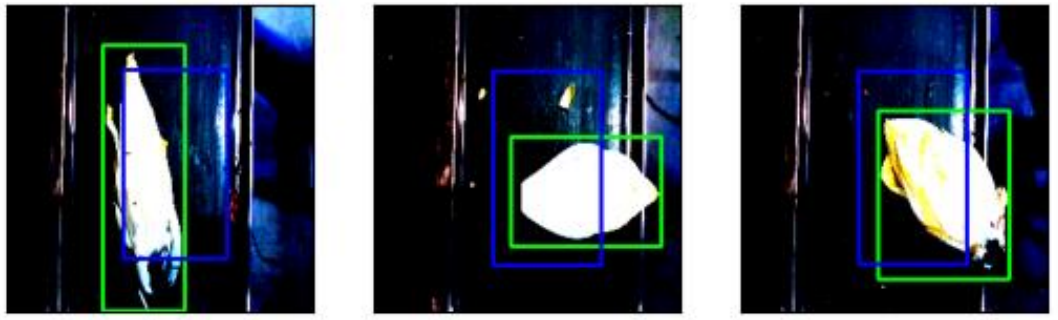
	Root	No Root
Root	50 (98%)	0 (0%)
No Root	1 (2%)	96 (100%)

Met de steun van VLAIO

Detection of bounding box

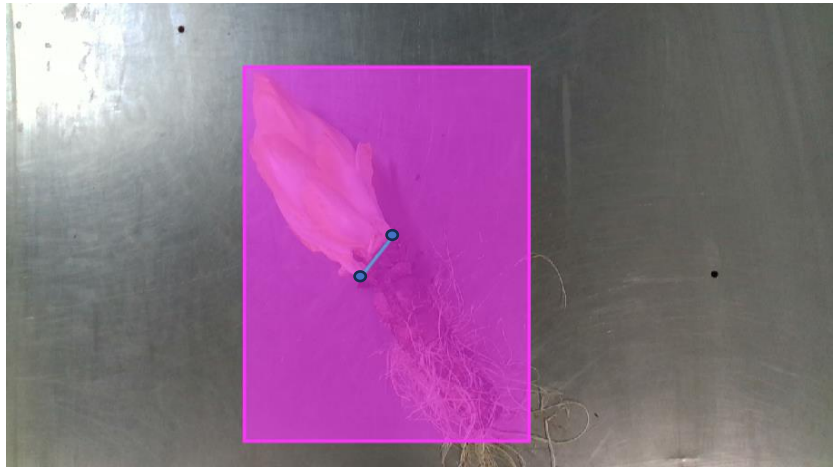
- ResNet18
- 681 training, 146 validation, 147 test
- Epochs: 10
- Learning rate: 0.001
- Batch size: 64
- Loss: L1 loss

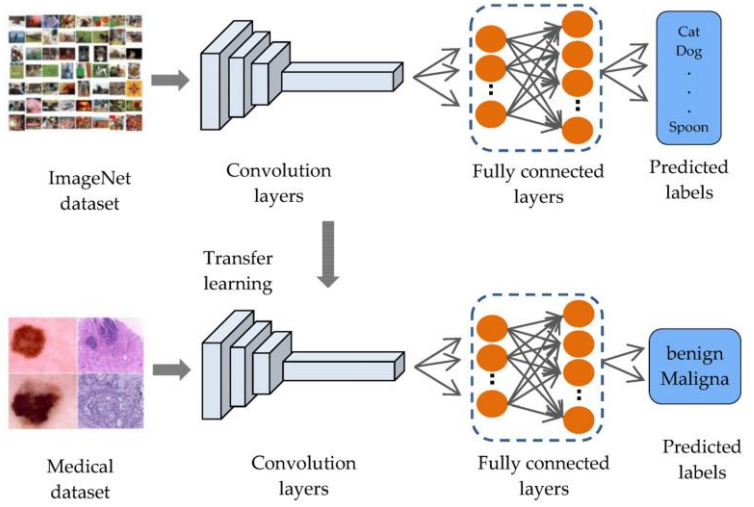




Detection of cutting line

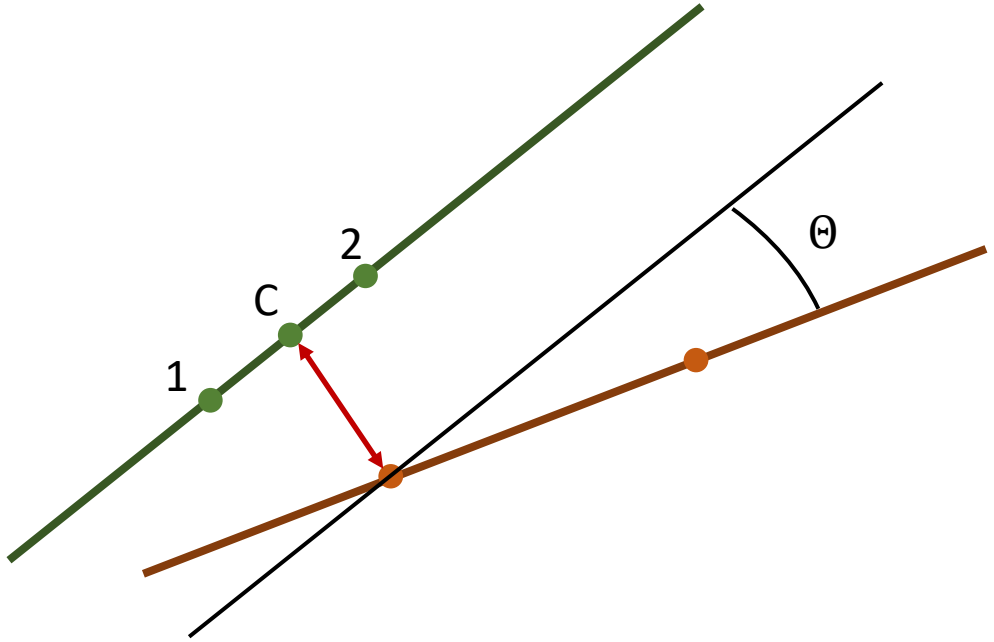
- Using line labels [x1, y1, x2, y2]
- Using ResNet18
- Using transfer learning





Met de steun van VLAIO

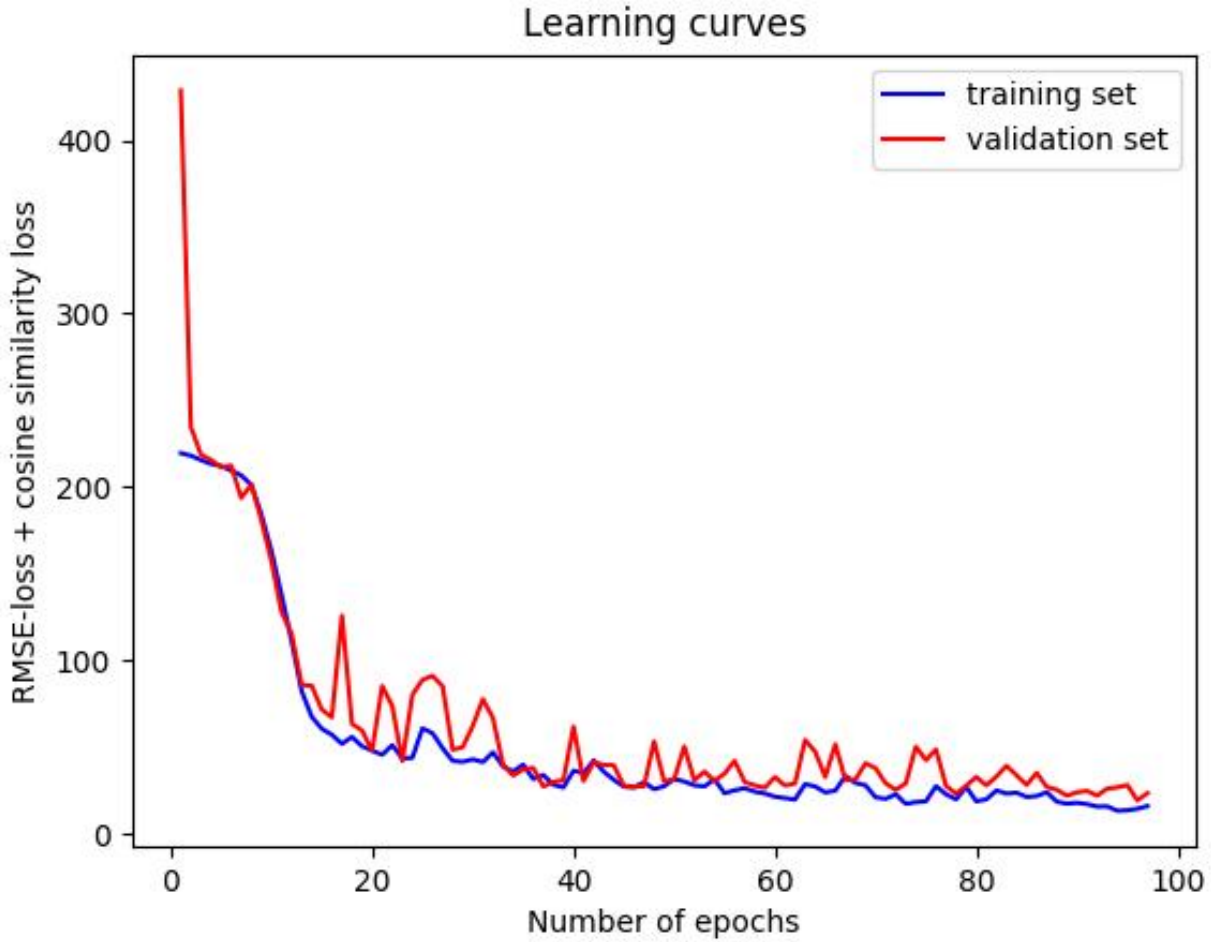
Detection of cutting line – Loss computation



Met de steun van VLAIO

Detection of cutting line – Model training

- Dataset: 216 images
  - Train: 151
  - Validation: 32
  - Test: 33
- Hyperparameters:
  - Epochs: 100
  - Learning rate: 0.01
  - Batch size: 16
- Results on validation set
  - RMSE-loss: 8.6 pixels
  - Angle loss: 10.6 degrees
  - Total loss: 19.3

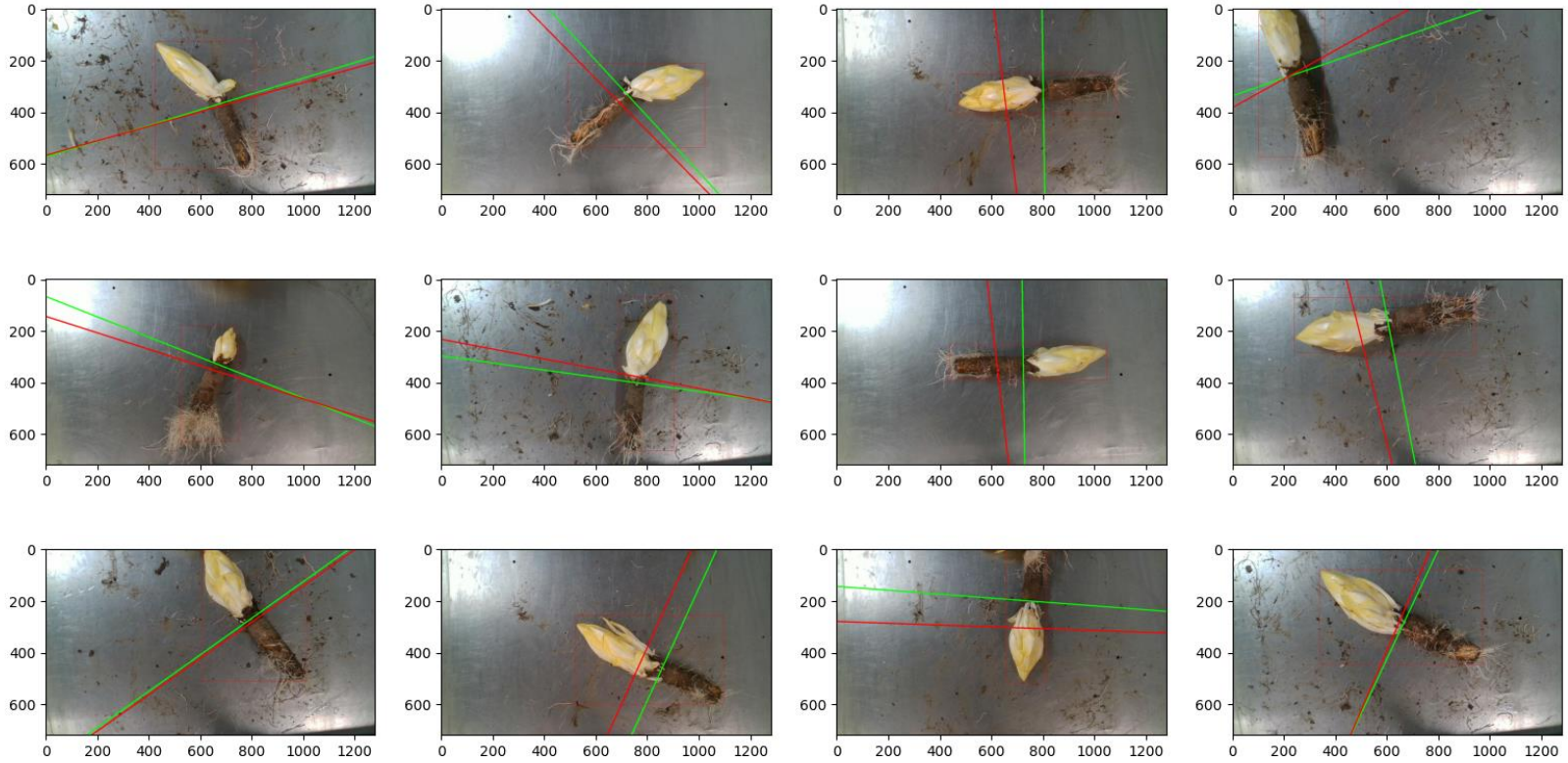


Met de steun van VLAIO

Detection of cutting line – model validation

Training set

- RMSE: 7.9 pixels
- Cosine: 6 degrees
- Total: 13.9

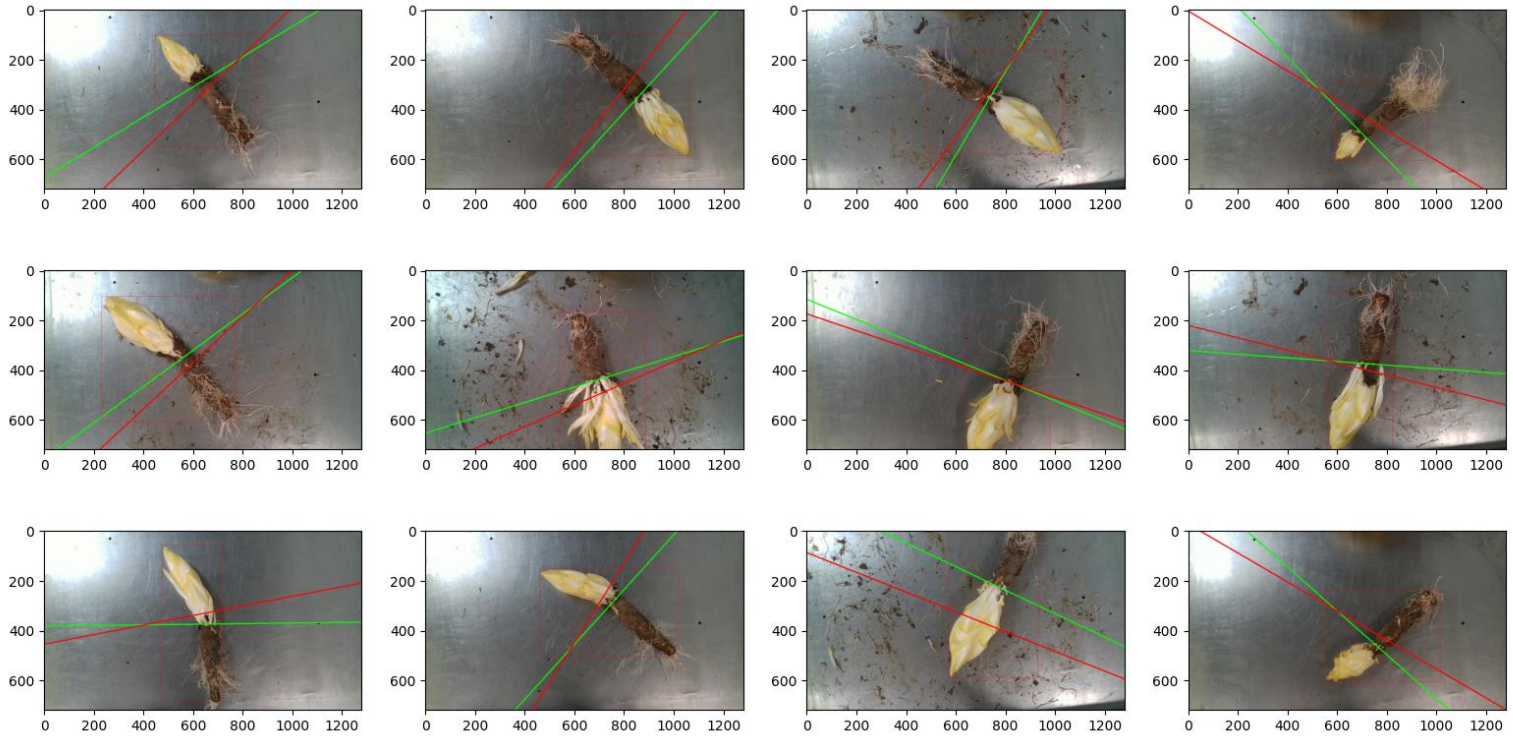


Met de steun van VLAIO

Detection of cutting line – model validation

Test set

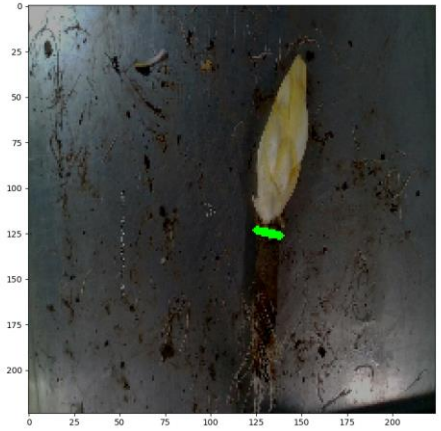
- RMSE: 11.1 pixels
- Cosine: 22.8 degrees
- Total: 33.9

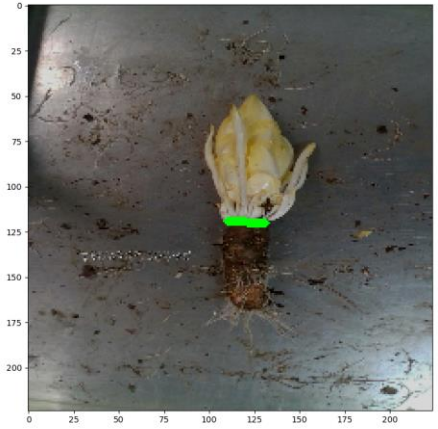


Met de steun van VLAIO

Detection of cutting line – Data augmentation

- Resizing
- Normalization
- Rotation
- Horizontal flip
- Brightness





Met de steun van VLAIO

Conclusions

- Good classification results
- Bounding box detection using Yolo
- Cutting line detection using more data and data augmentation

Met de steun van VLAIO

VLAIO TETRA

Machine Vision for Quality Control

(MV4QC)

Case 3

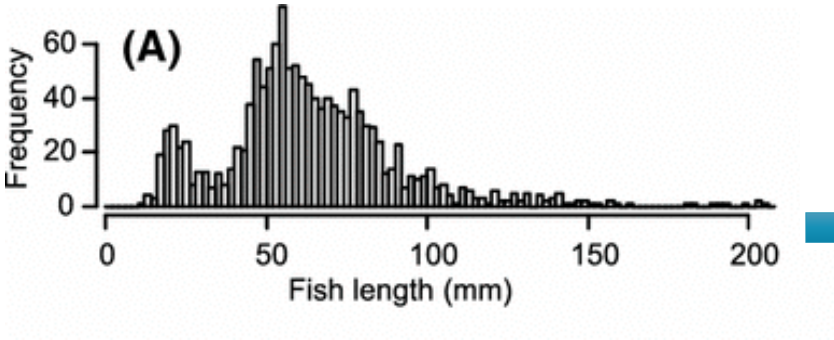
Inline determination of the length distribution of fish by category

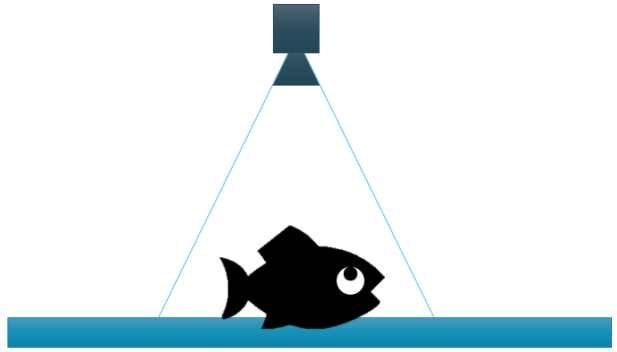
ILVO

Met de steun van VLAIO

Objectives

- Instituut voor Landbouw-, Visserij- en Voedingsonderzoek
- Ecological project
- Objectives
  - Detection
  - Classification
  - Length determination

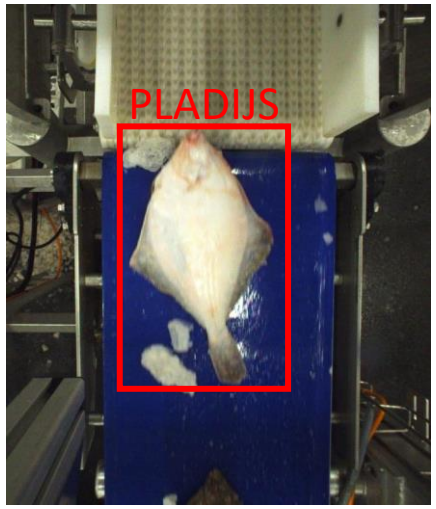


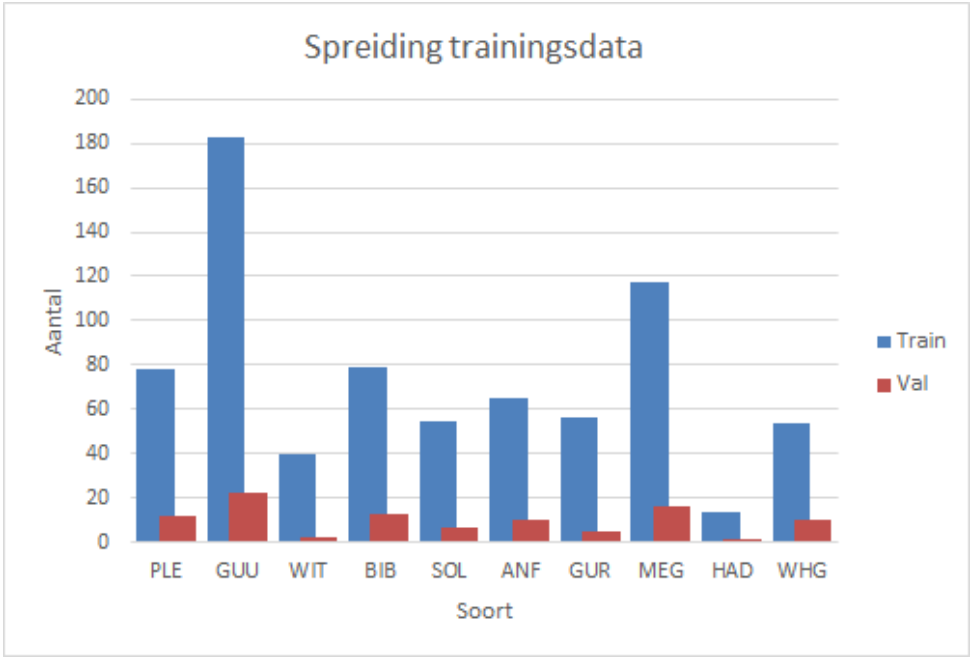


Dataset

Dataset containing:

- 18 videos
- 5-10 min
- 10 species





LabelBox render:

- Image url
- Bounding box [left, top, width, height]
- Class [PLE,GUU,WIT,BIB,SOL,ANF,GUR,MEG,HAD,WHG]

Met de steun van VLAIO

Hardware setup

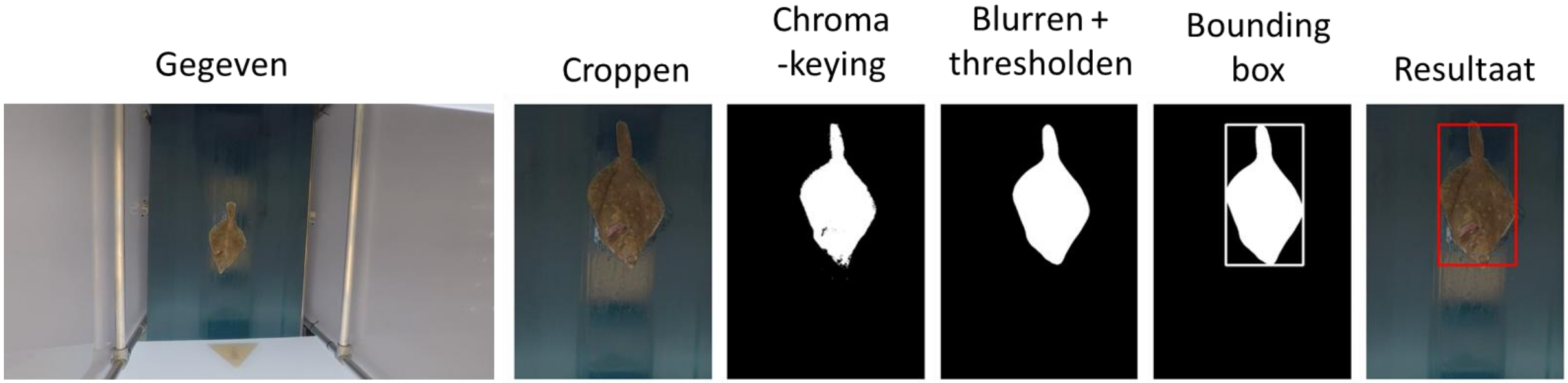
- Camera: MER2-302-56U3C
  - USB3.0
  - C-mount
  - 2048x1536 (3MP)

- Lens: LCM-5MP-04MM-F2.0-1.8-ND1
  - Focal distance 4mm → wide angle
  - Aperture F2.0

- Illumination: TL-illumination from environment

Met de steun van VLAIO

Image processing



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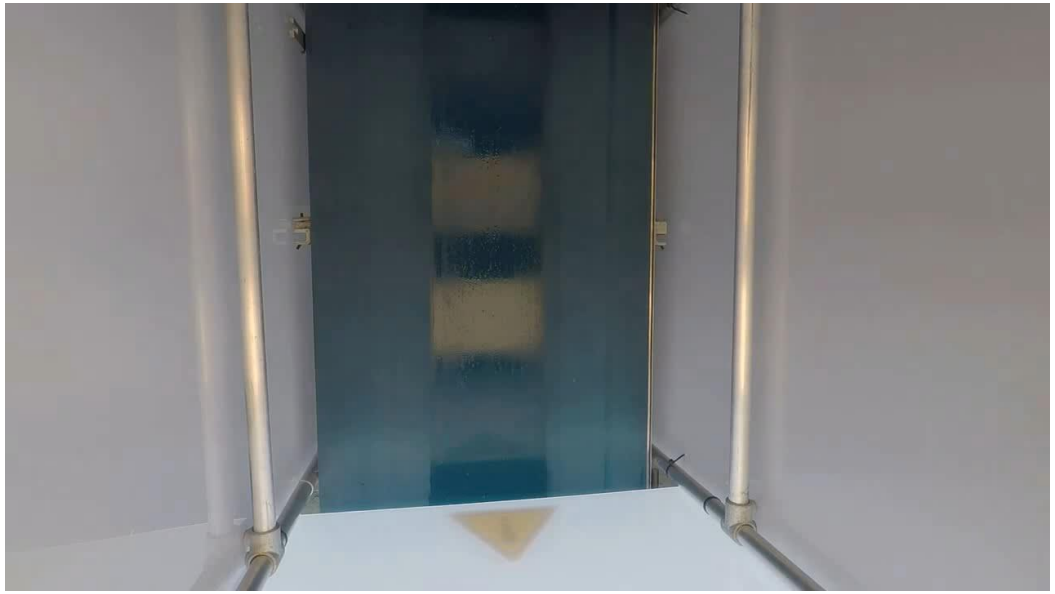
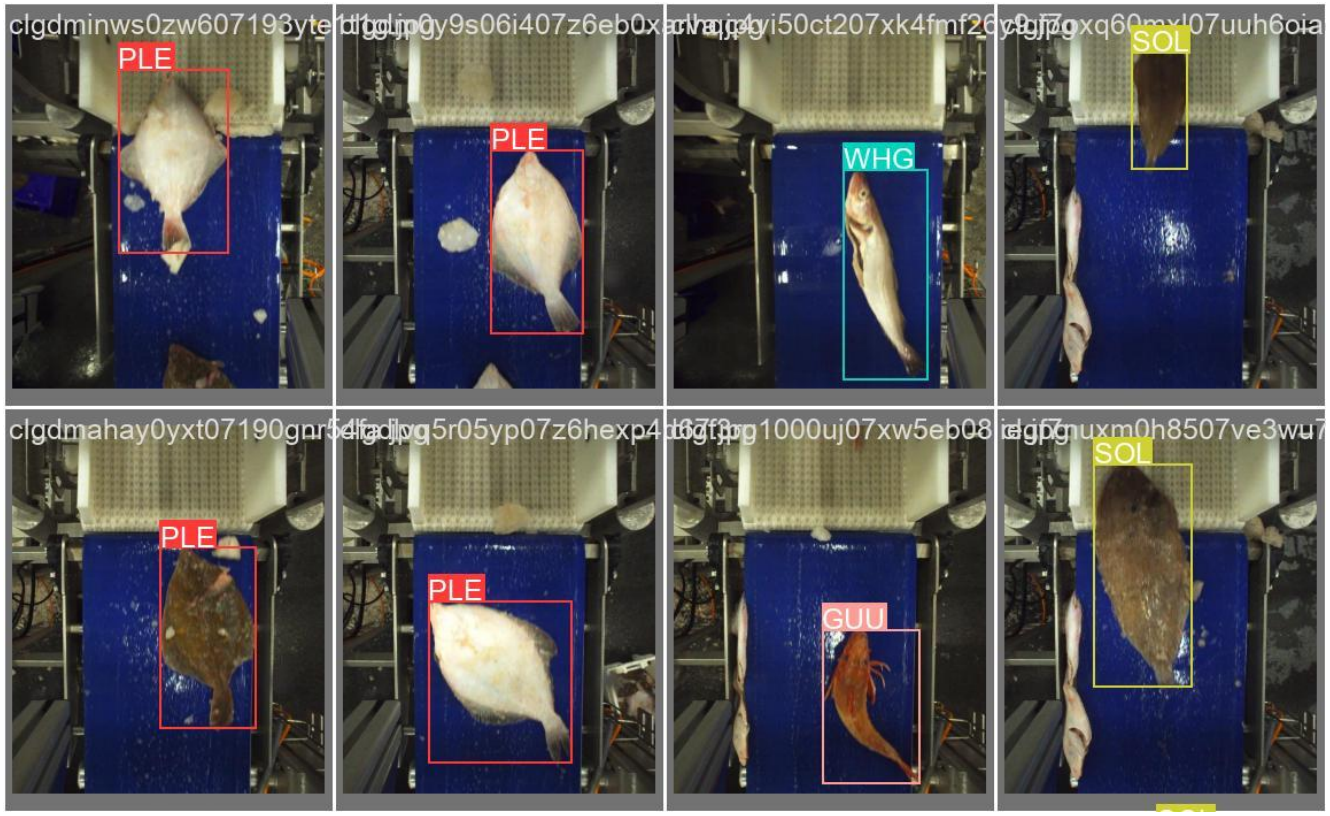
Object detection and classification - YOLO





Met de steun van VLAIO

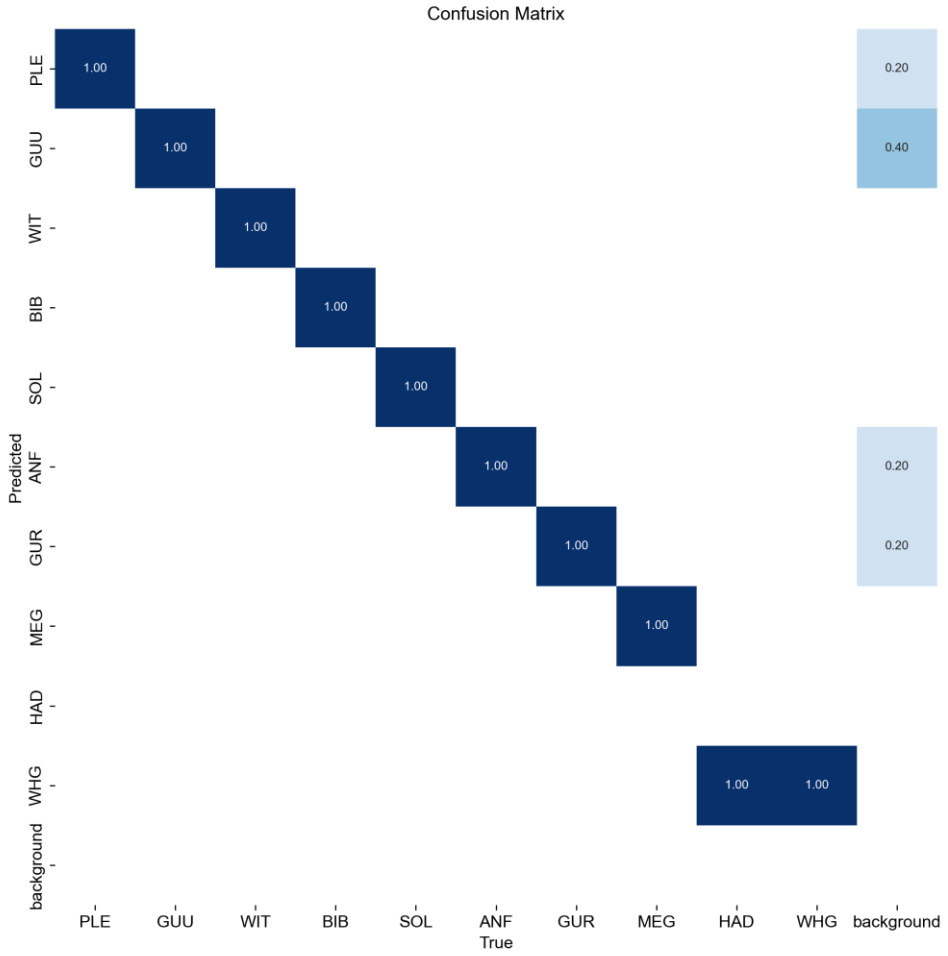
Object detection and classification - YOLO

- HAD systematically detected as WHG

  → Very few images of HAD

  → HAD and WHG are similar

- Background not correctly classified

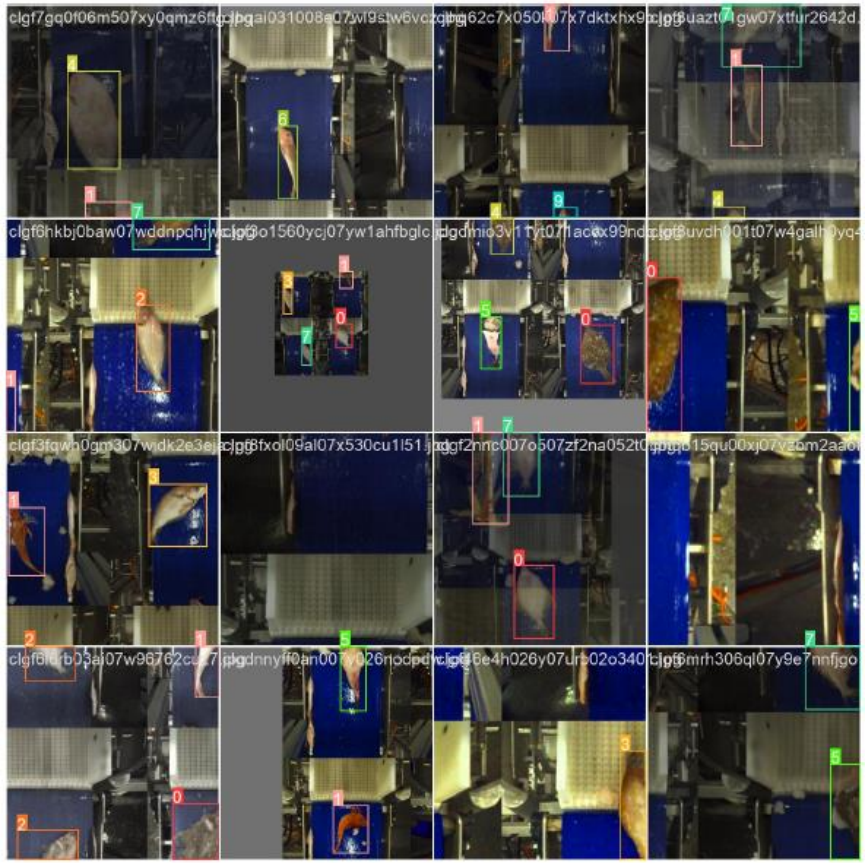


Met de steun van VLAIO

Object detection and classification - YOLO

Improvements:

- Imbalanced dataset techniques
  - Oversampling
  - Weighting error
- Data augmentation
  - Brightness, scale, rotation, etc.



Met de steun van VLAIO

Object detection and classification - Resnet

Model validation

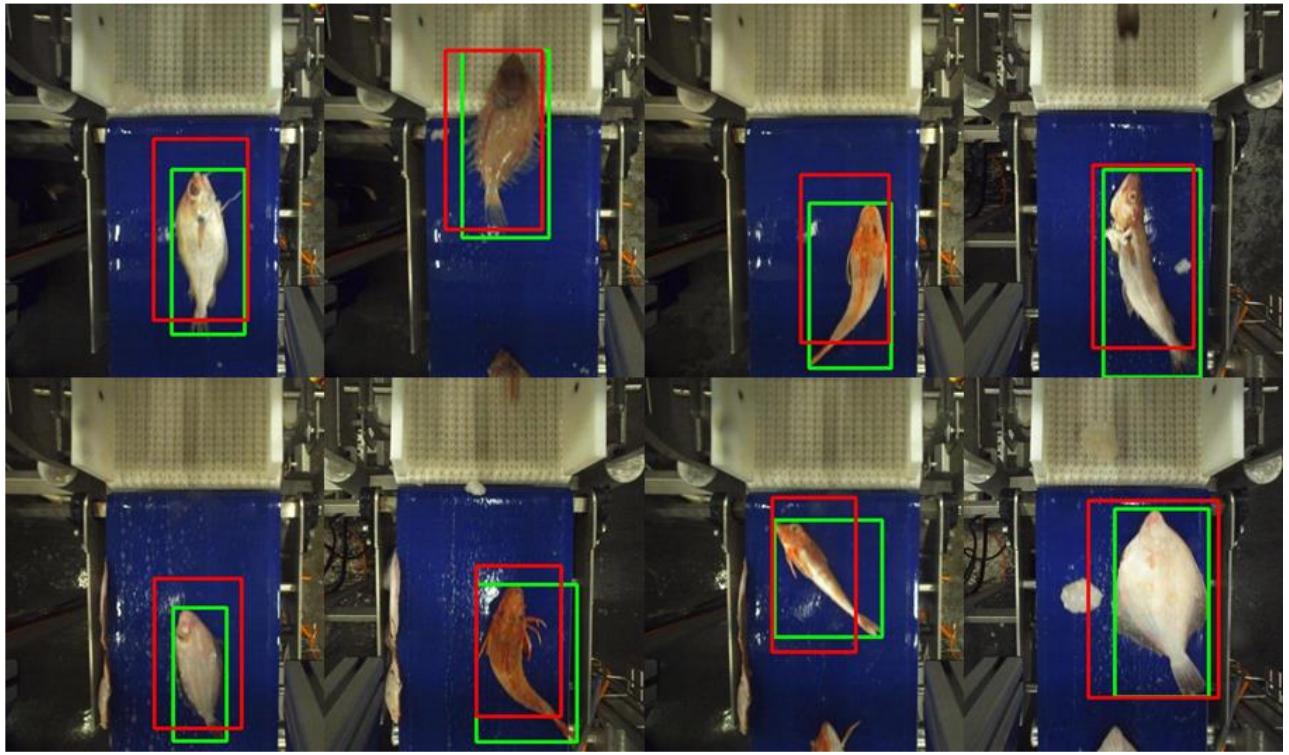
- Model: ResNet18 pretrained
- Input:
  - 500x500 pixels
  - Normalized
- Hyperparameters:
  - Epochs: 100
  - Learning rate: 0.0005
  - Batch size: 16

		BestHD1									
		Werkelijke soort									
		PLE	GUU	WIT	BIB	SOL	ANF	GUR	MEG	HAD	WHG
Voorspelde soort	PLE	12	0	0	0	0	0	0	0	0	0
	GUU	0	22	0	0	0	0	0	0	0	0
	WIT	0	0	2	0	0	0	0	0	0	0
	BIB	0	0	0	13	0	0	0	0	0	0
	SOL	0	0	0	0	7	0	0	0	0	0
	ANF	0	0	0	0	0	10	0	0	0	0
	GUR	0	0	0	0	0	0	5	0	0	0
	MEG	0	0	0	0	0	0	0	16	0	0
	HAD	0	0	0	0	0	0	0	0	1	0
	WHG	0	0	0	0	0	0	0	0	0	10

Met de steun van VLAIO

Object detection and classification - Resnet

- Tail sometimes not detected properly



Met de steun van VLAIO

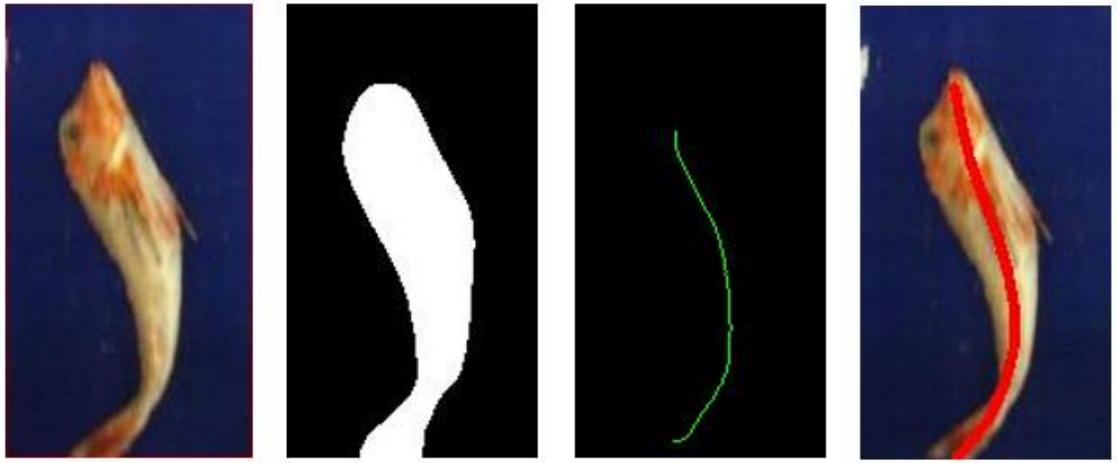
Length determination

1. Cropping using bounding box

2. Segment fish using
   Segment anything model (SAM)

3. Skeletonisation

4. Number of pixels → real length

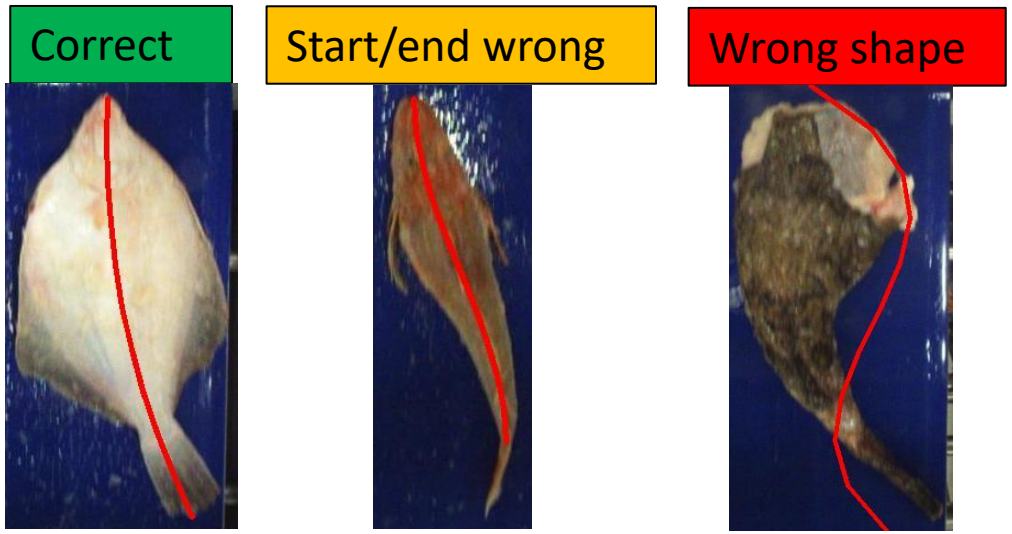


Met de steun van VLAIO

Length validation

- Visually (no length data)
- 11% due to SAM
- 9% fish not in middle
- 5% wrong mask

74%	Correct
11%	Start/end wrong
9%	Wrong shape
5%	Error

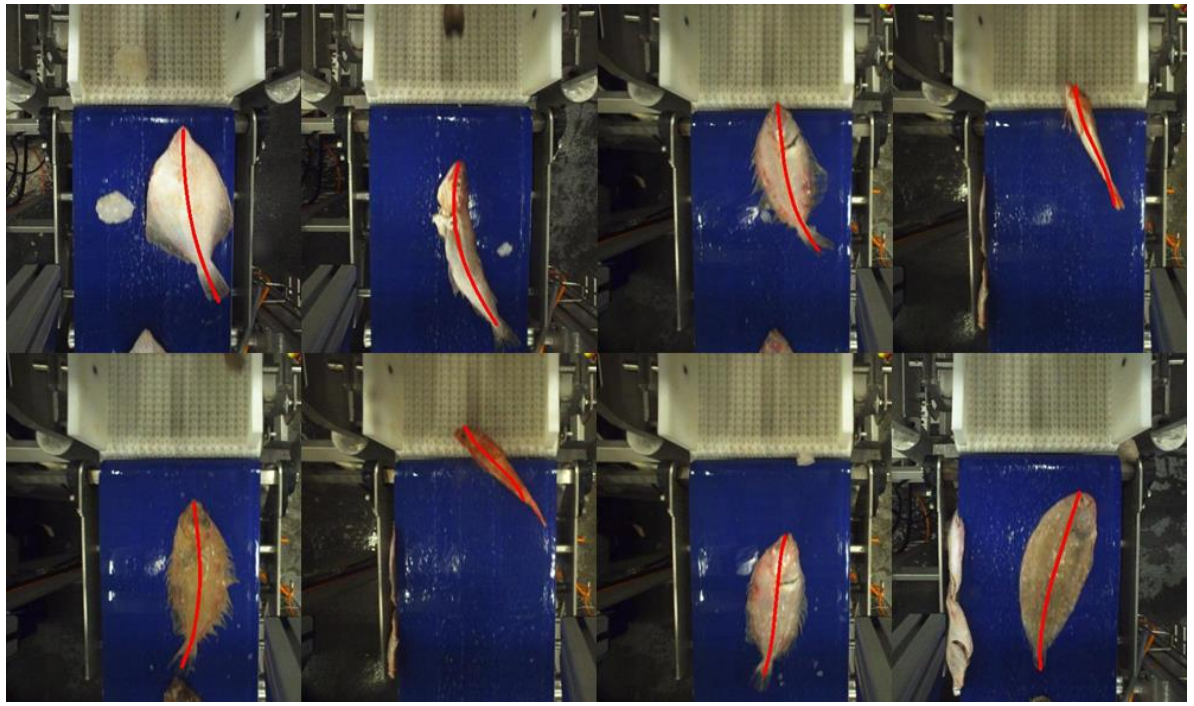


Met de steun van VLAIO

Totaal system validation

- 74% rating was based on images with correct bounding boxes
- 86% of the bounding boxes are correct
- 64% is the total succes rate of the system

64%	Correct
20%	Start/end wrong
14%	Wrong shape
1%	Error



Met de steun van VLAIO

Conclusions

- Larger and more balanced dataset → better results
- Larger image size → better results
- YOLO had difficulties in predicting HAD
- Tail is difficult for Resnet but no problem for YOLO
- YOLO provides an easier framework for performant model development
- SAM is time consuming and causes the largest errors

Met de steun van VLAIO

VLAIO TETRA

Machine Vision for Quality Control

(MV4QC)

Case 4

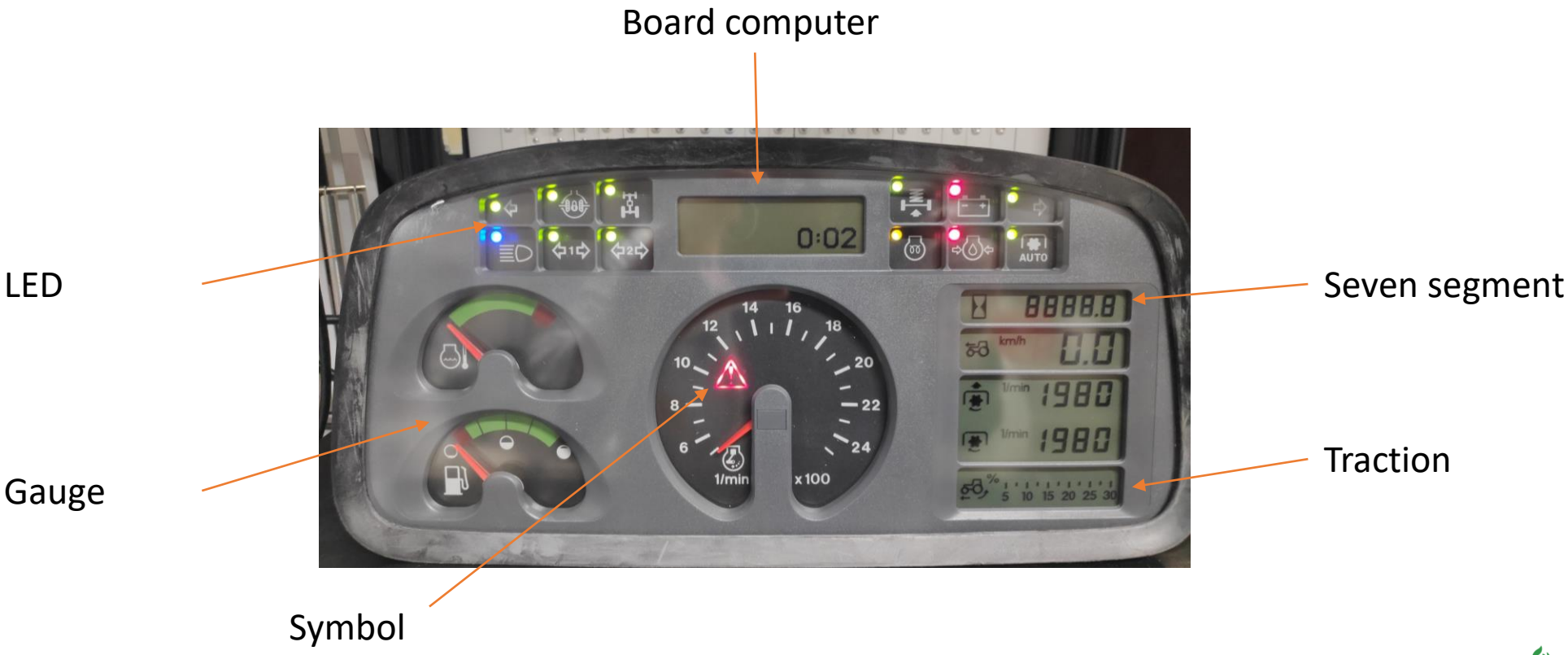
Determination of the proper functioning of a LED display

TVH

Met de steun van VLAIO

Case 4: Objective

Evaluating the correct working of a Forklift Display



Case 4: Results

Detection of LED

HSV filter

Detected LED

Detection of Warning symbol

Binarized warning

Warning detected

Detection of active Backlight

Backlight effect location

Amount of orange detected

Met de steun van VLAIO

Case 4: Results

Gauge

Targeted gauge

Pointer filter out

Lines drawn based on pointer

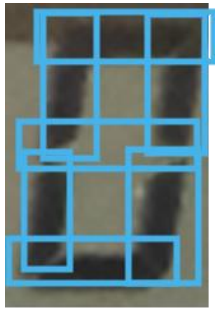
- Multiple techniques
- Different ranges
- Translation angle value
- Margin of error

Met de steun van VLAIO

Case 4: Results

Seven segment

Target



Seven individual segments

```
DIGITS_LOOKUP = {
    (1, 1, 1, 1, 1, 1, 0): 0,
    (0, 1, 1, 0, 0, 0, 0): 1,
    (1, 0, 0, 0, 1, 1, 1): 1,
    (1, 1, 0, 1, 1, 0, 1): 2,
    (1, 1, 1, 1, 0, 0, 1): 3,
    (0, 1, 1, 0, 0, 1, 1): 4,
    (1, 0, 1, 1, 0, 1, 1): 5,
    (1, 0, 1, 1, 1, 1, 1): 6,
    (1, 1, 1, 0, 0, 0, 0): 7,
    (1, 1, 1, 1, 1, 1, 1): 8,
    (1, 1, 1, 1, 0, 1, 1): 9
}
```

Digit lookup table

```
(1, 1, 1, 1, 1, 1, 0): 0,
```

Result for the target

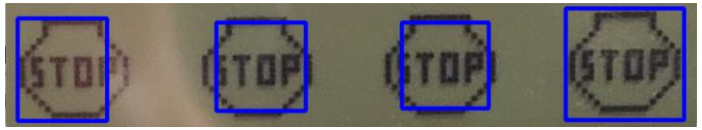
- If the number is 8 then all are working
- Need to do this for each seven segment display
- OCR also possible

Met de steun van VLAIO

Case 4: Results

Board computer

Thresholded target



Detected 4 symbols

Traction

Thresholded traction bar

Detected traction bar

Met de steun van VLAIO

Case 4: Opstelling

Created algorithms → Used in vision setup

- Enclosure with room for display
- Controller with Beckhoff controller
- Vision code in done in Twincat vision
- Displayed controlled using CAN-messages

→ Will be further developed by Beckhoff automation

Met de steun van VLAIO

Case 4: Hardware

How do you solve the reflection?

→ Earlier tests using IDS camera and polarised lights

Polarised lens

Lights on long side

Light perpendicular on display

→ Further tests will be done

Met de steun van VLAIO

VLAIO TETRA

Machine Vision for Quality Control (MV4QC)

Case 5

Inline determination of the fat absorption of donuts after frying

Vandemoortele

Met de steun van VLAIO

Case 5 - Bepalen van het vetgehalte in donuts na frituren





Doughmix	Extrusion en cutting	Proofing	Frying	Cooling
Flour, water, sugar, yeast, fat and donut mix and rework		Water ↑ Flour ↑	Fat ↑ Water ↓	Fat distribution uniformity ↓

Fat absorption (FA) = $\frac{F - P}{F} \times 100\ \%$

Met:

P Proofed dough weight

F Fried donut weight

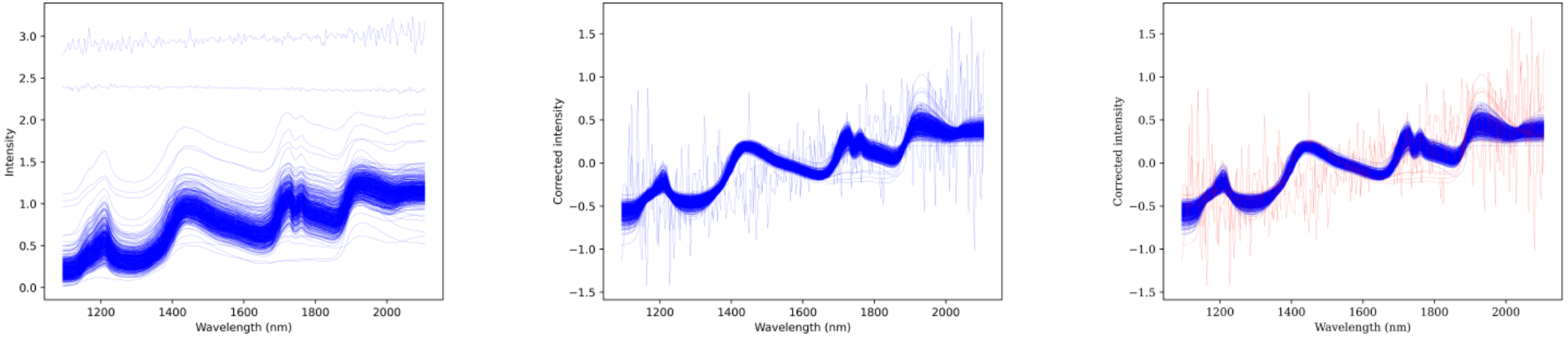
Met de steun van VLAIO

Case 5 - Data capture

- 10 Februari 2023
- **Covicon** voorziet de PAS-H-B01 probe met bijhorende NIR proces spectrometer.
- Opmeten van invloed van proofing, frying and cooling in meerdere stappen bij Vandemoortele R&D
- Vandemoortele bepaald referentie waardes via een chemische analyse

Met de steun van VLAIO

Case 5 – Data pre-processing



(a) (b) (c)

Fig. 1: The raw data (1a) is preprocessed by MSC-correction (1b) and outlier (red) filtering (1c)

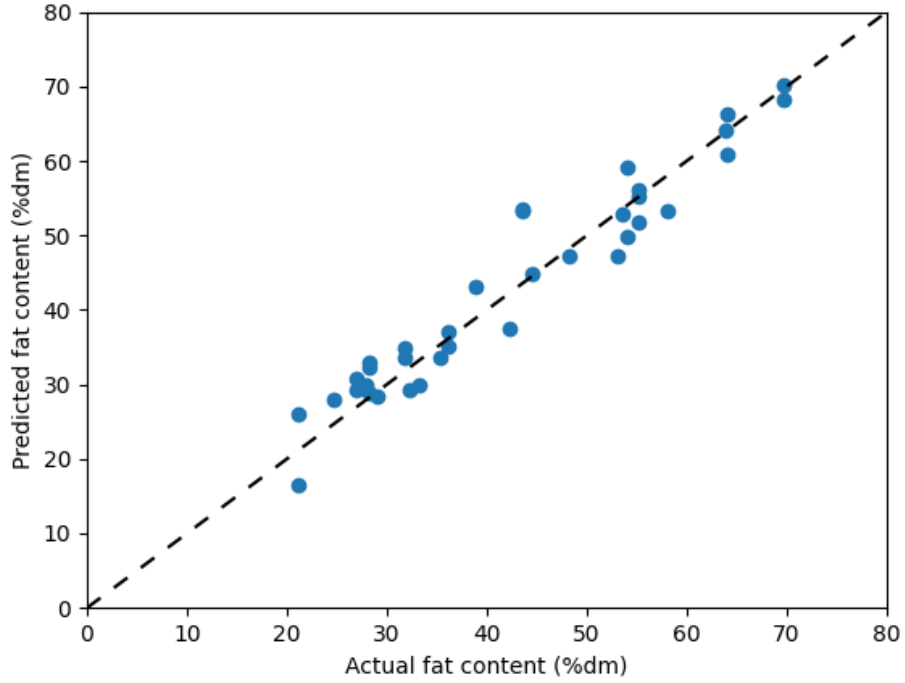
Met de steun van VLAIO

Case 5 - Fat & Moisture prediction

Huidige methode (Weibull-Stoldt)
RMSECV = 1.44

Hyperspectrale analyse
RMSECV = 4.2

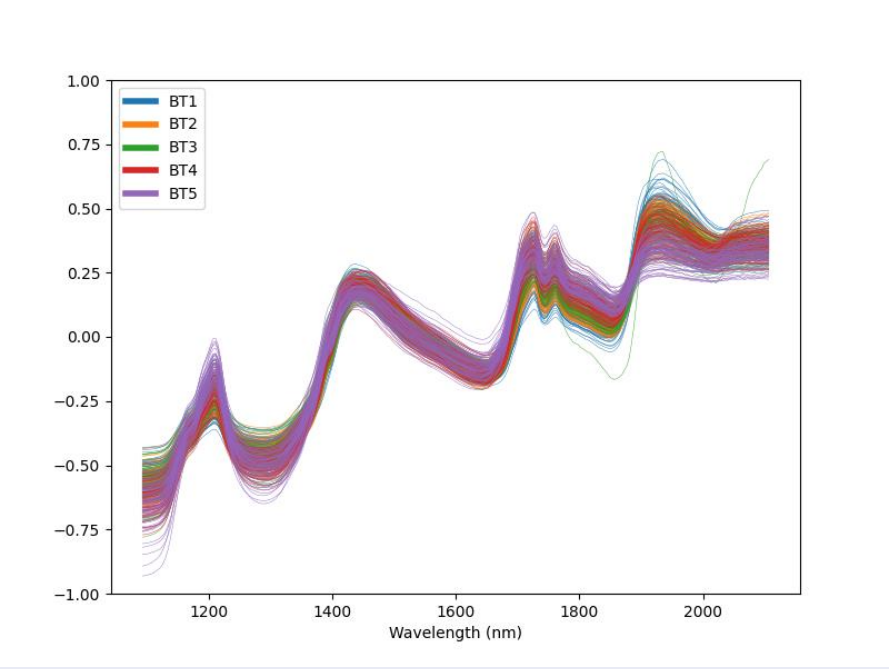
Label	Model (preprocessing)	Number of features	Cross-validation		Prediction	
			Rc^2	RMSECV(%)	Rc^2	RMSEP(%)
Fat	PLSR (SNV + SD)	81	0.89	4.20	0.92	3.8
	LS-SVM (SNV)	79	0.68	7.32	0.75	7.14
Moisture	PLSR (SNV + SD)	60	0.88	1.83	0.92	1.61
	LS-SVM (SNV)	63	0.68	2.96	0.83	2.39

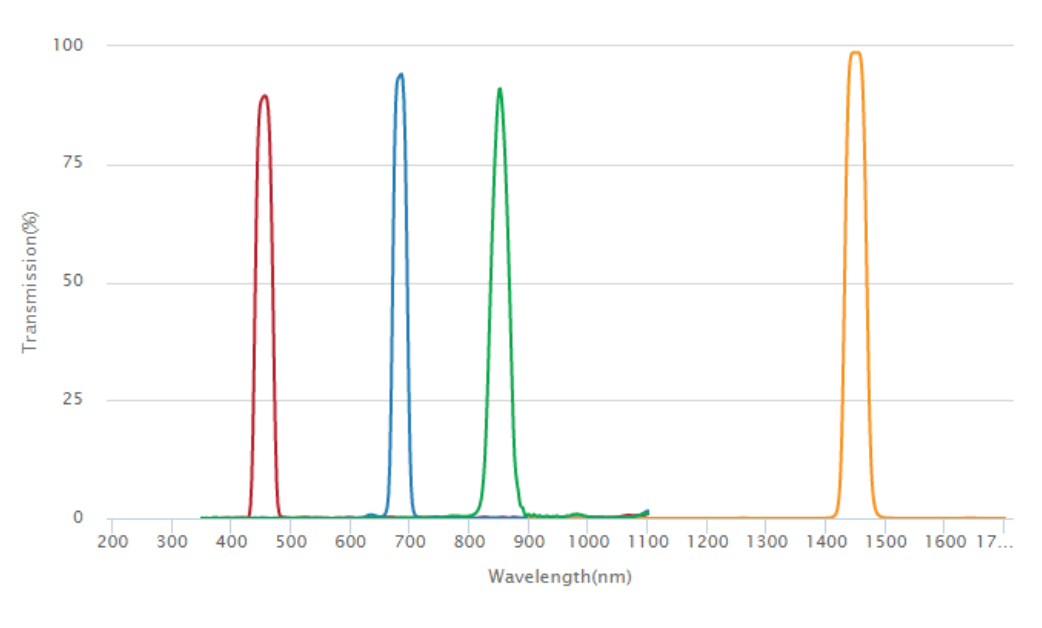


Met de steun van VLAIO

Case 5 – Next steps

Hyperspectraal	Multispectraal
81 Banden van 8 nm	Meerdere commercieel beschikbare filters





Met de steun van VLAIO

Case 5 – Next steps

- Valideren van resultaten voor potentiële implementatie
- Mogelijkheden overleggen met **integratoren** voor opstellen van testopstelling + kostenschatting

Met de steun van VLAIO

VLAIO TETRA

Machine Vision for Quality Control (MV4QC)

Case 6

Detection of a sufficient presence of nuts and sauce on Cornetto’s

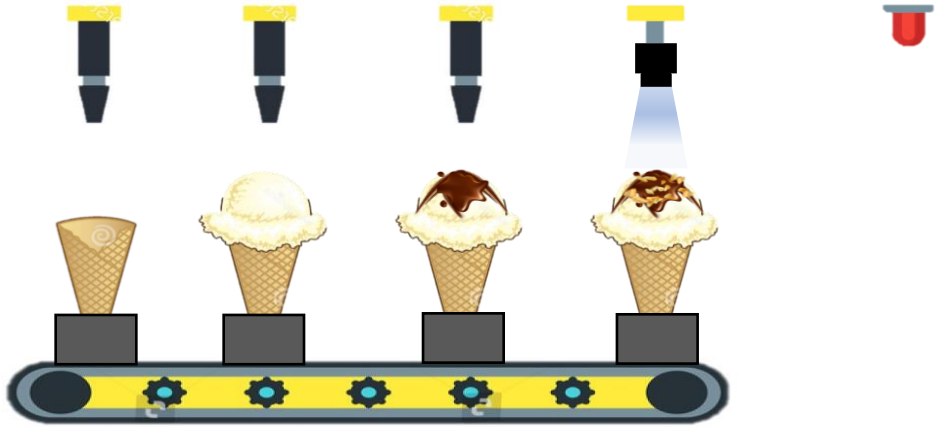
Ysco

Met de steun van VLAIO

Case 6 – Summary last meeting

- Quality control based on the topping present (sauce, nuts, curls, …) on Cornettos

- Production process:



Met de steun van VLAIO

Case 6 – Summary last meeting

- Data captured 
- Data pre-processed 
- Model training: 
  1. Binary classification model
  2. Multi-label classification model

Quality	Sauce	Nuts/Curls
Good	Good	Good
Bad	Bad	Good
Bad	Good	Bad
Bad	Bad	Bad

Met de steun van VLAIO

Case 6 – Performance metrics

- Imbalanced dataset
- P = bad quality; N = good quality

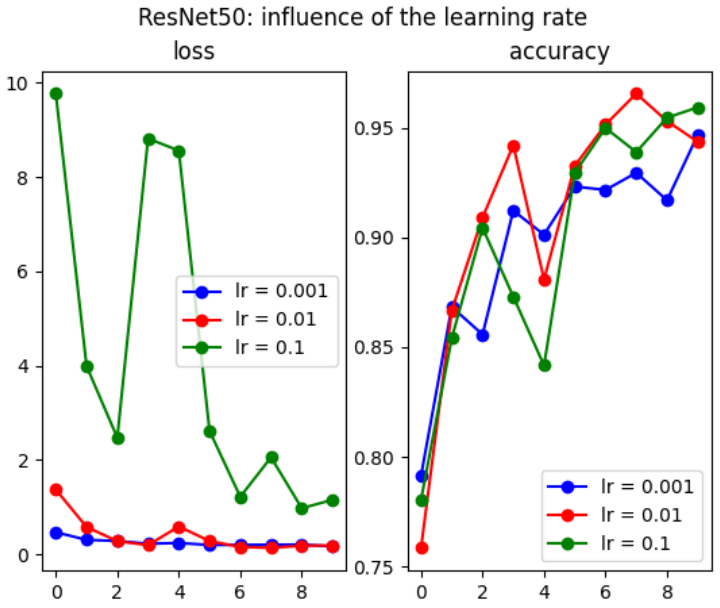
Accuracy	VS	F1 score
$\frac{\#\ correct\ predictions}{\#\ total\ predictions}$		Harmonic mean precision and recall
Data distribution ✗		Data distribution ✓

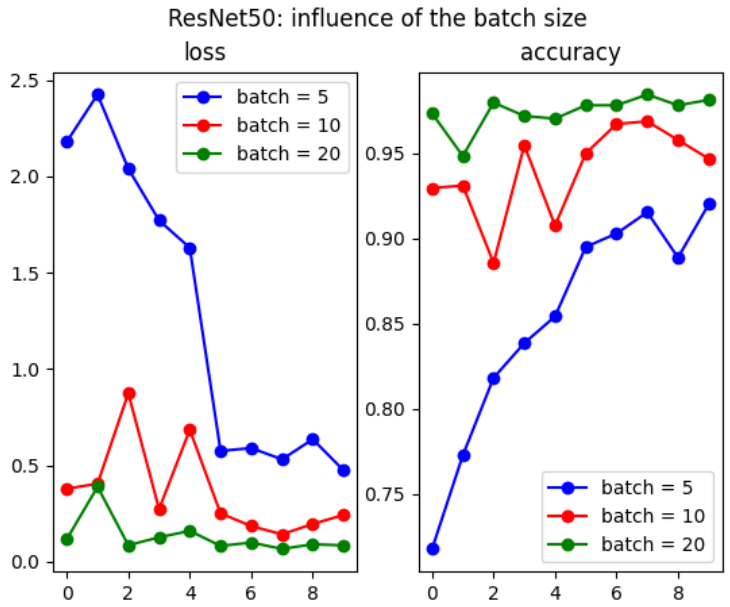
Met de steun van VLAIO

Case 6 – Binary classification

- ResNet 50
- Hyperparameters:

Epochs	Learning rate	Batch size
10	0.01	20





Met de steun van VLAIO

Case 6 – Binary classification

- Best models:

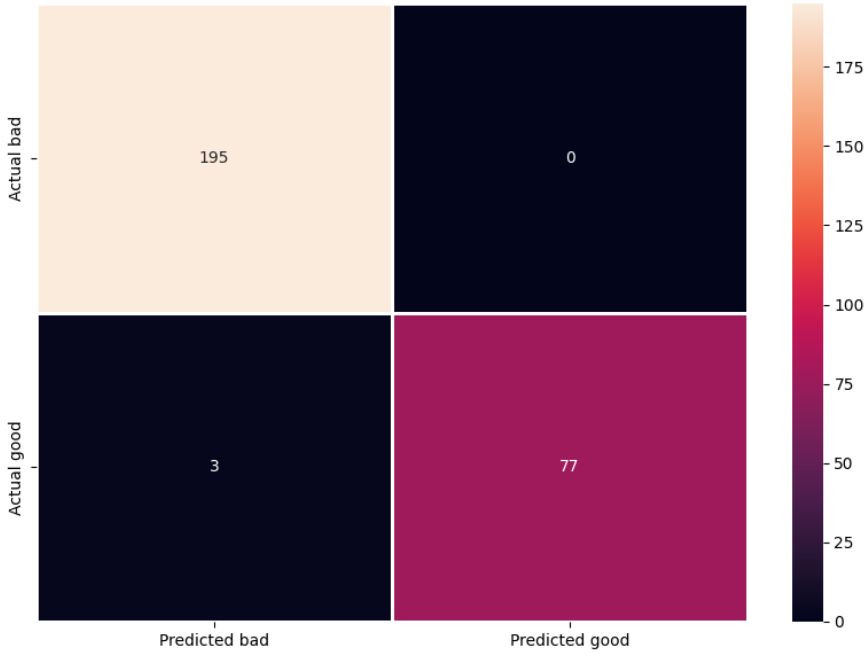
Variant	Precision (%)	Recall (%)	F1 score (%)
Vanilla	98.48	100.0	99.24
Strawberry	94.17	97.94	95.80
Chocolate	94.94	94.41	94.68

Met de steun van VLAIO

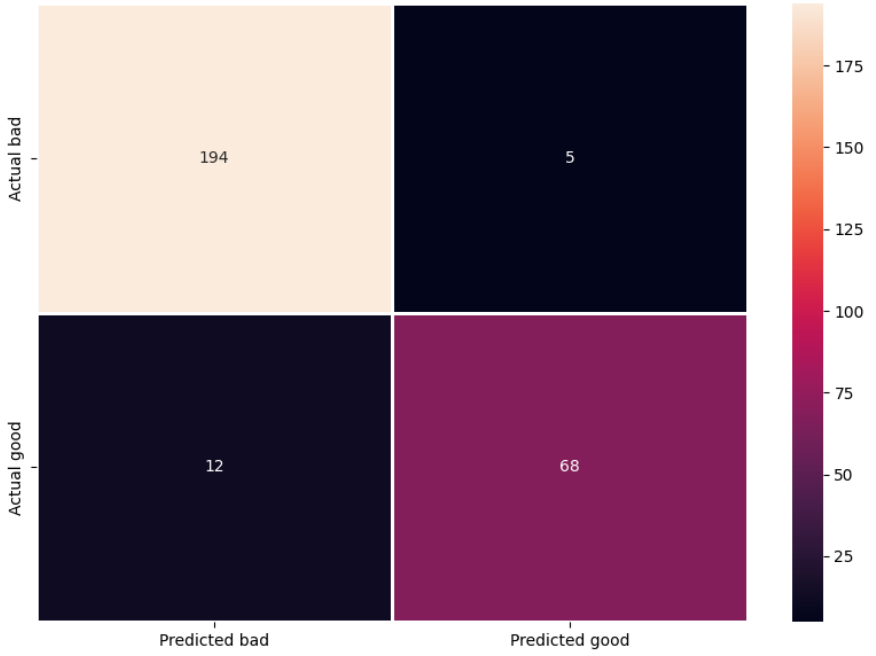
Case 6 – Binary classification

- Confusion matrices:

Vanilla



Strawberry

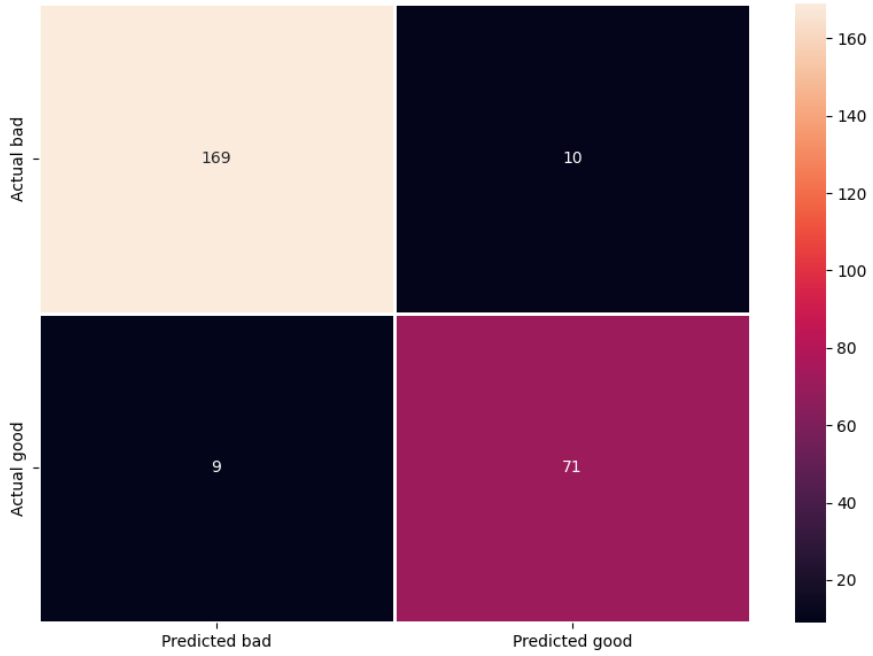


Met de steun van VLAIO

Case 6 – Binary classification

- Confusion matrices:

Chocolate



Met de steun van VLAIO

Case 6 – Binary classification

- Possible reason for drop in performance:
  - Strawberry:

  - Chocolate:

Met de steun van VLAIO

Case 6 – Multi-label classification

- ResNet 50
- Hyperparameters:

Epochs	Learning rate	Batch size
10	0.01	10

- Only vanilla and chocolate variants

Met de steun van VLAIO

Case 6 – Multi-label classification

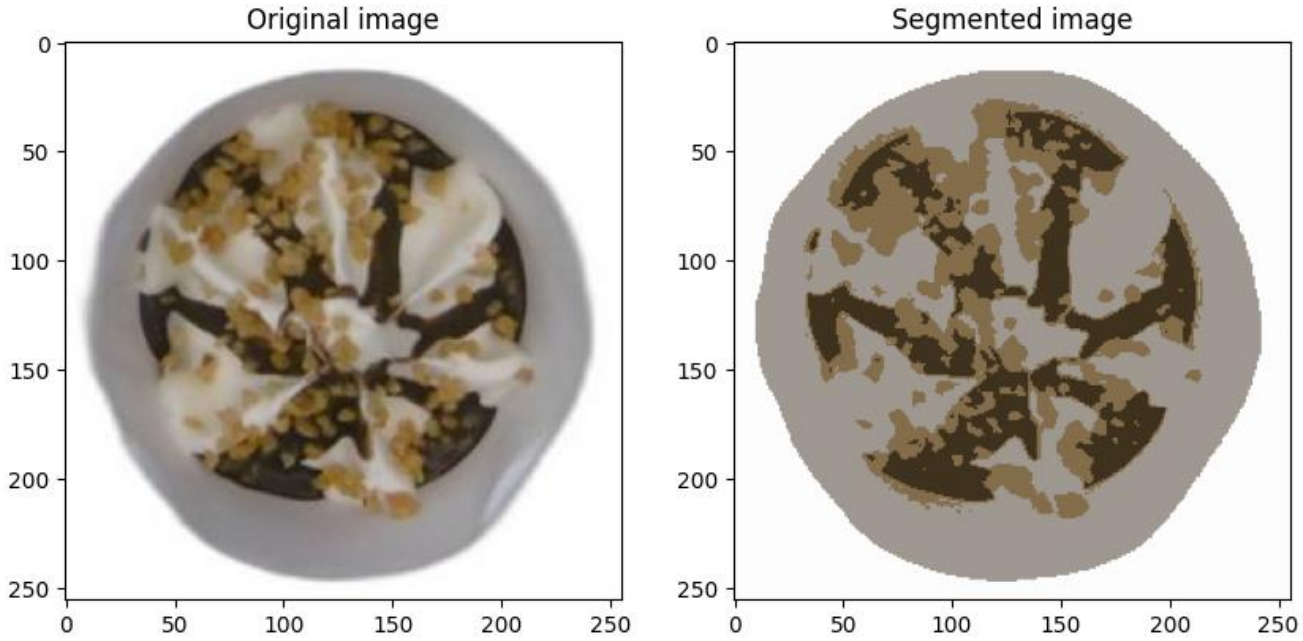
- Best models:

Variant	Label	Precision (%)	Recall (%)	F1 score (%)
Vanilla	Sauce	98.31	99.15	98.72
	Nuts	99.07	99.07	99.07
	Quality	98.45	98.96	98.71
Chocolate	Sauce	96.23	94.44	95.33
	Curls	94.84	90.18	92.45
	Quality	94.09	95.63	94.85

Met de steun van VLAIO

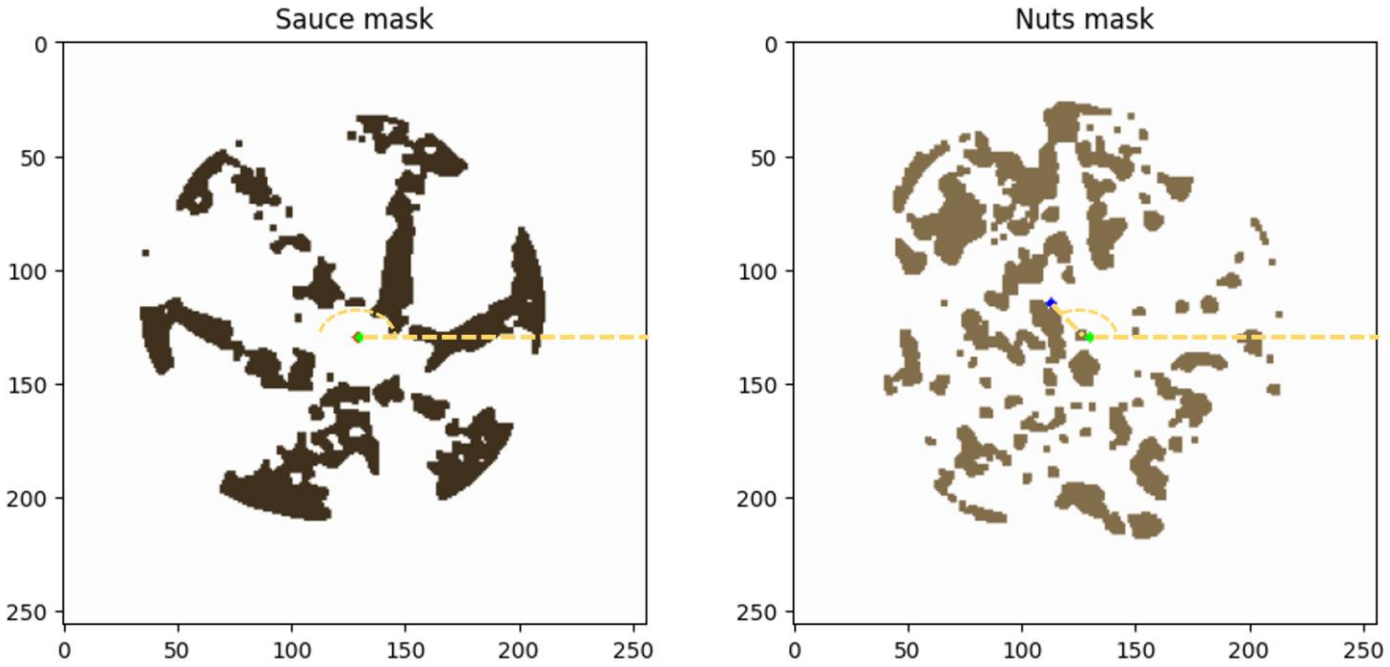
Case 6 – Segmentation

- K-means segmentation
- Vanilla variant:



Met de steun van VLAIO

Case 6 – Segmentation



Mask	Centroid (x,y)	Size (w,h)	Position (d,a)
Sauce	(129,130)	(178,178)	(1,180°)
Nuts	(113,115)	(192,175)	(23,139°)

Met de steun van VLAIO

Case 6 - Conclusion

- Good performance for both approaches
- Explainability vs performance
- Segmentation provides usefull insights
- Chocolate variant
- Further work

Met de steun van VLAIO

Toelichting cases

Fase 2

Met de steun van VLAIO

Nieuwe integratoren

- Jonathan Kesteloot
- www.captic.be

- Tom Piette
- www.innomatic.be

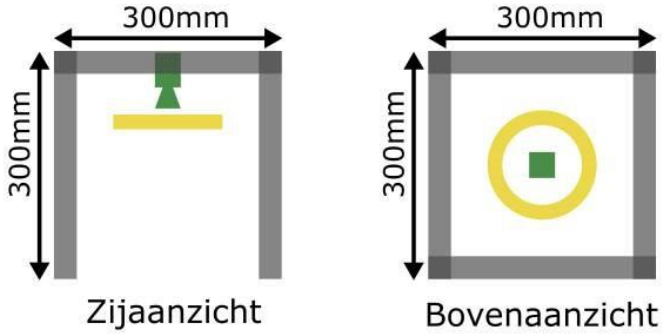
Case 1 – Detection of surface damage on flat sheets (Decospan)

- Consortium – Decospan & Innomatic
- Objectieven:
  - Haalbaarheidsstudie naar detectie van defecten (deuken, scheuren, etc.)
  - Voorstel tot softwareoplossing

Met de steun van VLAIO

Case 1 – Detection of surface damage on flat sheets (MCAM)

- Consortium – MCAM & Covicon
- Objectieven:
  - Maken van een kleine mobiele setup die inline data kan opnemen
  - Verdere analyse van de bekomen data
  - Klassificatie van de defecten



Case 2 – Detection of the optimal cut line for chicory

- Consortium – Inagro & Captic
- Objectieven:
  - Haalbaarheidsstudie naar detecteren van snijlijn
  - Voorstel tot softwareoplossing

Met de steun van VLAIO

Case 3 – Inline determination of the length of fish per category

- Consortium – ILVO & Innomatic & Vintecc
- Objectieven:
  - Haalbaarheidsstudie naar robuuste detectie van lengte van vissen op de boot
  - Vintecc werkt verder op synthetische data
  - Voorstel tot softwareoplossing

Met de steun van VLAIO

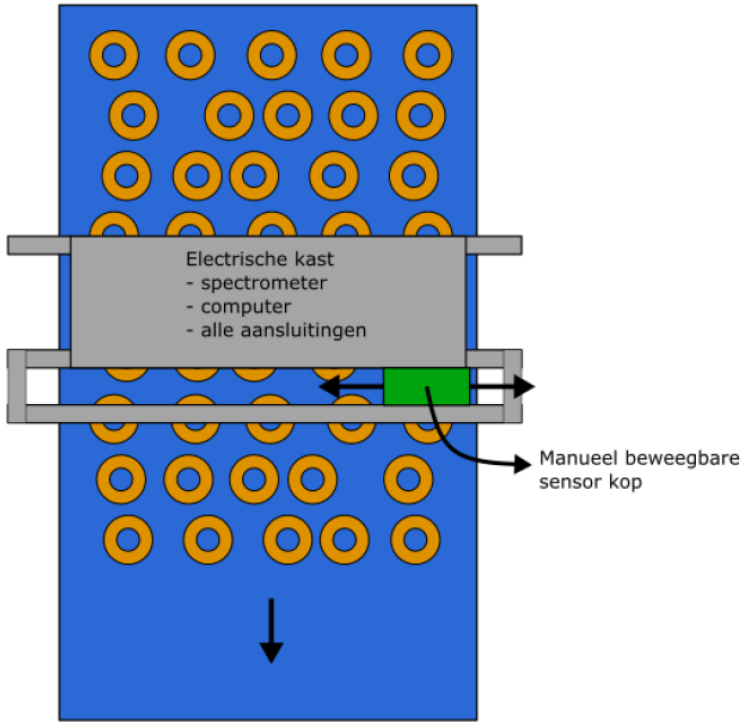
Case 4 – Determination of the proper functioning of a LED display

- Consortium – TVH & Beckhoff
- Objectieven:
  - Development of TVH setup in demonstrator using Beckhoff components
  - Development of software for demonstrator in TwinCat Vision
  - Translation of findings to real TVH setup

Met de steun van VLAIO

Case 5 – Inline determination of the fat absorption of donuts after frying

- Consortium – Vandemoortele & Covicon
- Objectieven:
  - Maken van een setup met een beweegbare spectrometer dat één punt kan meten
  - Bepalen van de vetabsorptie uit de spectraalbeelden
  - Communicatie met MES/SAP; monitoring and logging



Met de steun van VLAIO

Case 6 – Detection of a sufficient presence of nuts and sauce on Cornetto's

- Consortium – Ysco & Captic & Vintecc
- Objectieven:
  - Haalbaarheidsstudie naar detectie van toppings (saus, nootjes, etc.)
  - Voorstel tot softwareoplossing

Met de steun van VLAIO

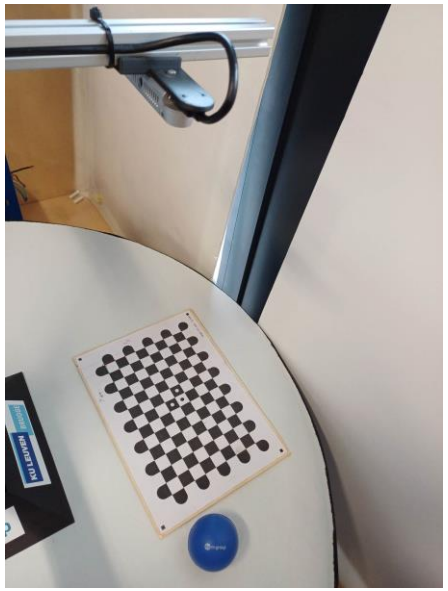
Toelichting demonstratoren

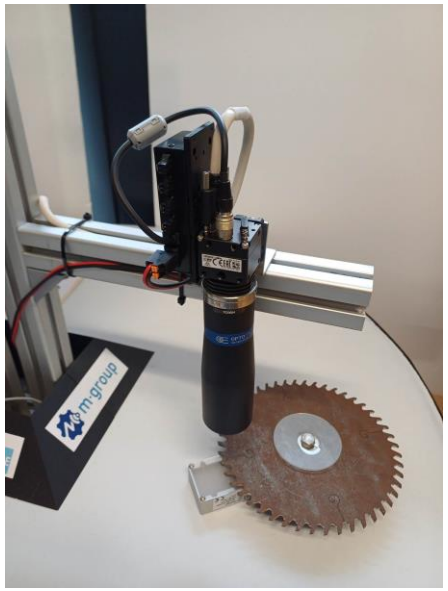
Met de steun van VLAIO

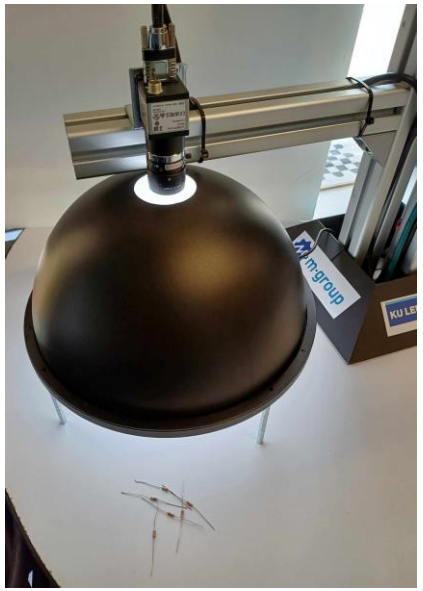
Demonstrator 1

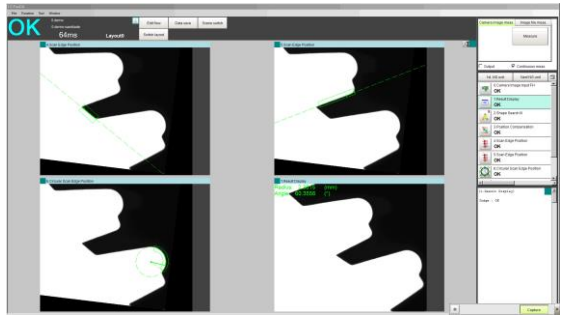
- Variatie aan leveranciers: Omron, IDS, Cognex, Intel
- Variatie aan applicaties: 3D, meting, kleur, klassificatie
- 50% klassieke machinevisie en 50% data-gedreven
- 50% open source en 50% commerciële software

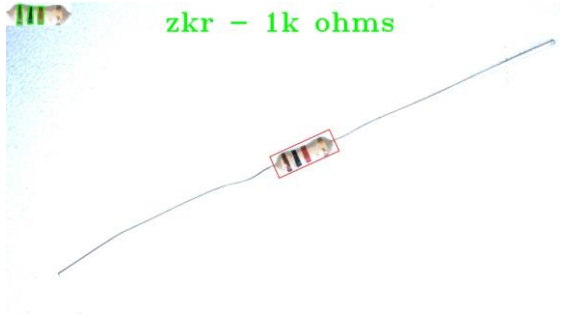
Demonstrator 1

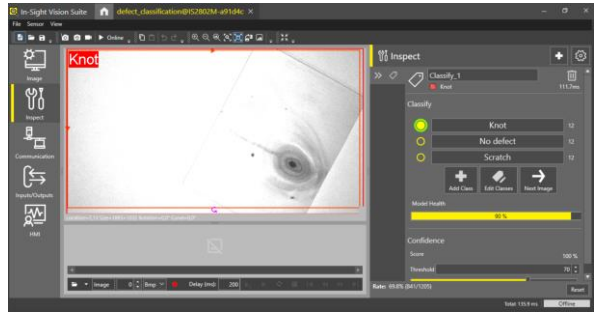












Met de steun van VLAIO

Demonstrator 2

Met de steun van VLAIO

Masterclass Machine Vision

- Wanneer? Van maandag 23/10 tot dinsdag 24/10 (9:00 – 16:30)
- Waar? KU Leuven Brugge – Spoorwegstraat 12, 8200 Brugge
- Prijs? 840 euro basisprijs – 50 euro voor leden TETRA
- Broodjes en koffiepauzes inbegrepen.

Met de steun van VLAIO

Website

https://www.mv4qc.be

Met de steun van VLAIO