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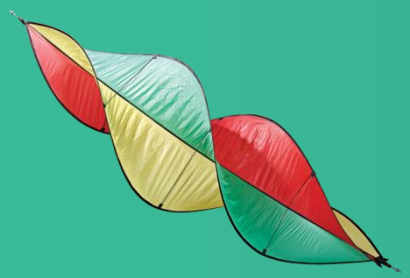

Automated visual fruit detection for harvest estimation and robotic harvesting

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Introduction

- ✓ Rising trend in agriculture -> autonomous robotic harvesting of fruit and vegetables
  - Robotics & grippers: mechanicly solved problem
  - Robustly localizing objects: still a major challenge
    - Variations: size, occlusion, lighting conditions, …
    - Up till now: segmentation based approaches

- ✓ Object categorization: detect a complete object class with single object model, including intra-class variance (shape, size, colour, texture, etc.)

Introduction

- ✓ We propose
  - A fully automated semi-supervised system(during learning phase)
  - Able to identify unique object instances
  - In unseen images / scenes

- ✓ Furthermore suggest techniques to
  - Improve separation of clusters into individual objects
  - Speed up the progress using scene specific knowledge

Related Work

✓ Fruit detection and localisation

2D segmentation based approaches

Add information layer using LWIR, hyperspectral, …

Move to 3D scanning techniques

=> good segmentation = tedious job of parameter fine tuning

=> extra info = rise computational complexity

=> expensive hardware @ limited resolutions

=> controlled lab environments

Datasets

- ✓ Data collected in cooperation with Octinion, VITO & Research Center for Fruit.
- ✓ Strawberry dataset
  - AVT Manta camera (1292x964)
  - Trinocular stereo setup
  - Bottom-up and side-view
- ✓ Apple cultivar dataset
  - Samsung NX3000 (3648x5472)
  - 2 different cultivars: Gala & Red Delicious
- ✓ All data annotated by domain experts

Table 1. Data overview for both applications: number of images, number of annotations, model dimensions and the amount of negative window samples.

		strawberry		appleGala		appleRedDelicious	
		train	test	train	test	train	test
pos	#images	205	750	30	30	32	32
	#labeled	1500	/	1595	625	1075	1160
	dimensions	35x38		65x65		62x66	
neg	#images	200	/	30	/	30	/
	#windows	5000	/	4000	/	3000	/

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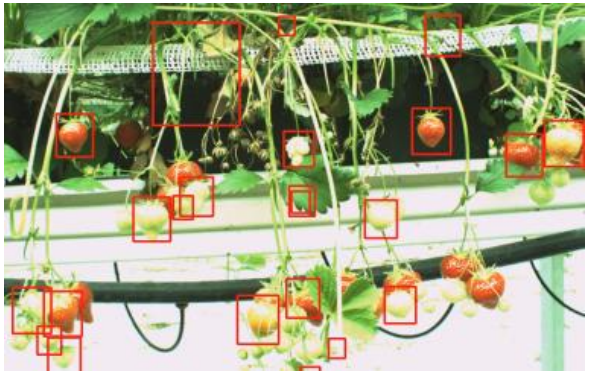
Suggested Approach: Cascade of weak classifiers

- ✓ Detection model is learned using the Viola & Jones boosted cascade of weak classifiers technique *(OpenCV implementation)*
  - Features = Local Binary Patterns
  - Boosting type = AdaBoost
  - Pre-processing: histogram equalization

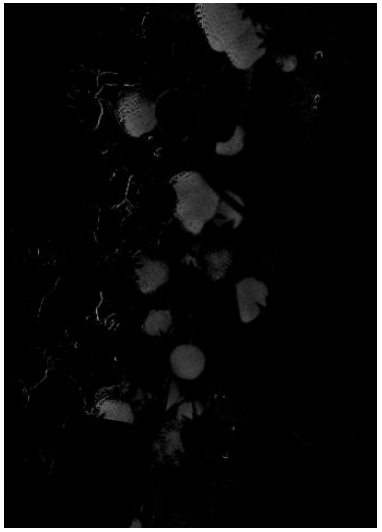


- ✓ Two models trained
  - Ripe + unripe strawberries as object training data
    - Mediocre results in separating objects from background
    - Does not solve goal of detecting only ripe strawberries
    - False positive detections still a large issue
  - Ripe strawberries as object training data and unripe strawberries as background training data
    - Colour information ignored by algorithm → greyscale feature descriptor
    - No ability to separate data robustly

Suggested Approach: Scene specific information

- ✓ How to incorporate colour information into grayscale feature descriptor?
  - Based on work of Dollar et al., incorporating colour channels.
  - Incorporate a pre-filter based on a specific colour transformation.

$$I_{RG} \begin{cases} 0 & if\ I_R - I_G < 0 \\ I_R - I_G & if\ I_R - I_G > 0 \end{cases}$$



  - Support red regions, while ignoring greener regions in the image.
  - Projecting the RGB colour space on an axis between G(0,1,0) and R(1,0,0).
  - Can be incorporated as a
    - Post-filter: OTSU + 50% white pixels = good detection → less false positives
    - Pre-filter: apply rule to training data and learn model from that I_{RG} data
      → more true positives + less false positives

Suggested Approach: Scene specific information

✓ Difference between scene constraint post- and pre-filtering

Trained on RGB

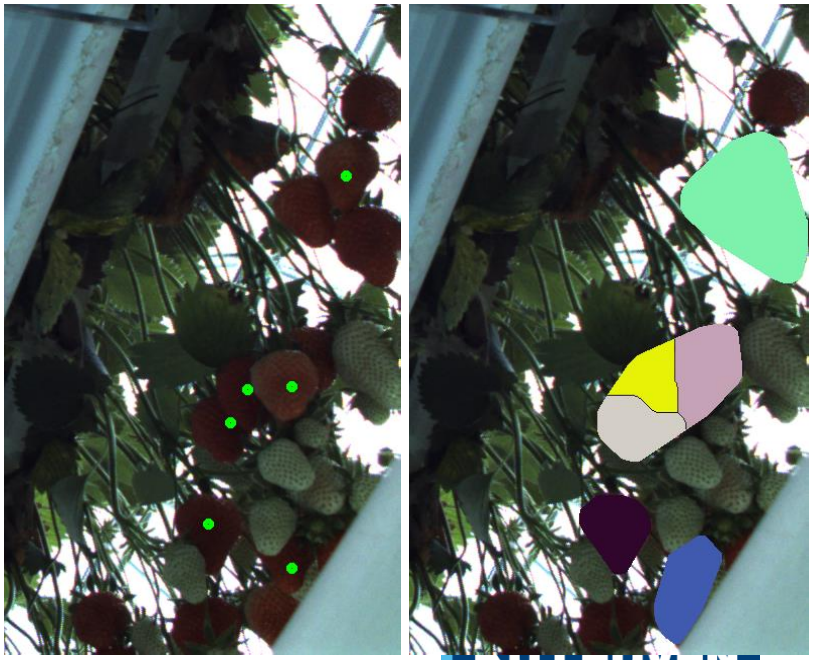
Trained on RGB + I_{RG} post-processing

Trained on RGB + I_{RG} pre-processing

Suggested Approach: Splitting clusters in object instances

- ✓ A re-occuring issue in object detection using segmentation is the existence of object clusters.
  - ✓ We propose to use the output of the detector to separate objects inside a cluster efficiently, since it already focusses on single objects
  - ✓ Suggestion 1: Watershed based segmentation
    - OTSU thresholded I_{RG} image
    - Merge blobs together inside single detection
    - Use detection centres as seed points
      + random background seed point
    - Split larger blobs into individual blobs

DOWNSIDE: harsh separation boundaries and objects not found by the detector will not initialize a seed point for the segmentation.



Suggested Approach: Splitting clusters in object instances

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  - ✓ Suggestion 2: Trinocular stereo triangulation based segmentation
    - Calibrated trinocular stereo setup
    - Detector in 2D images
    - Use a Difference of Gaussians filter to find the strawberry seeds
    - 3D triangulations on seeds
    - Resulting depth edges can be combined with I_{RG} OTSU image

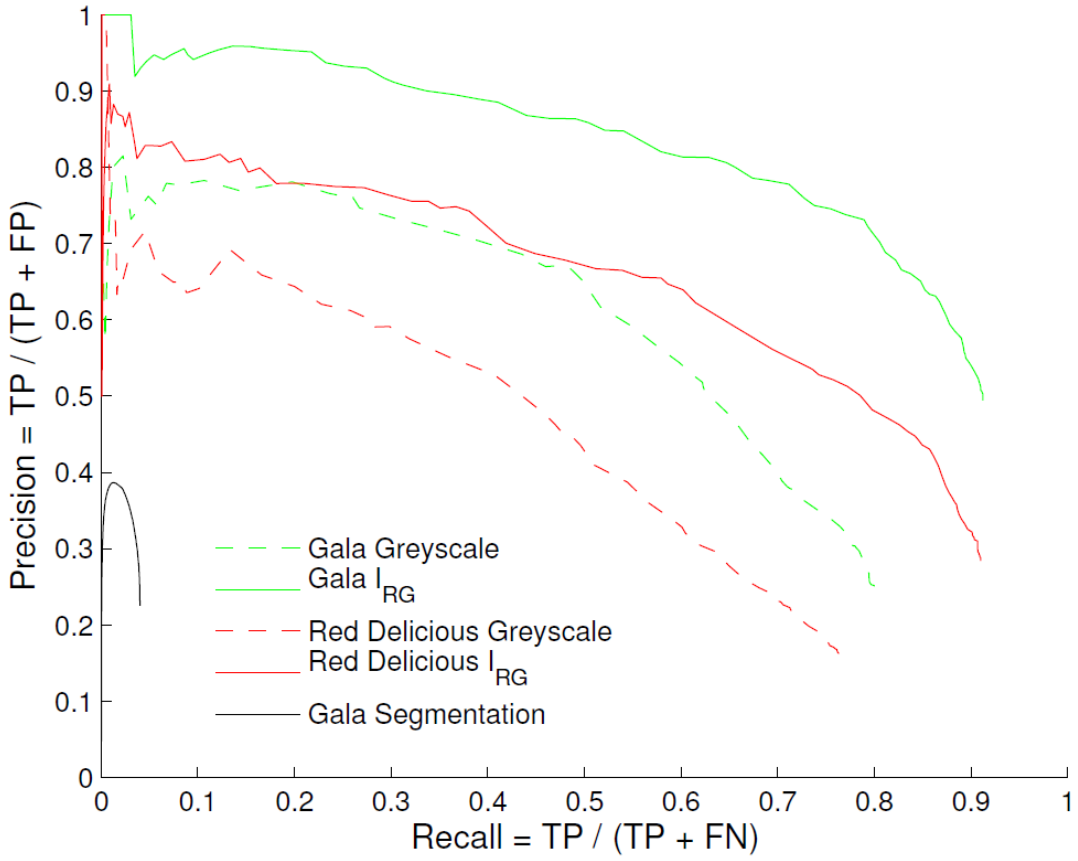
DOWNSIDE: needs a texture inside objects you want to detect.

Results: Strawberry test case

- ✓ We had no ground truth data for strawberry case, due to no consensus on what is defined as `ripe` strawberry.
- ✓ Sticked to visual detection results for this case.
  - Train and detect on IRG filtered input image
  - Then visualized as detections and detection centres on input image

Results: Apple cultivar test case

- ✓ Ground truth data for test set available
- ✓ Qualitative accuracy analysis using precision recall curves
- ✓ Compared to basic background segmentation approach



Results: Apple cultivar test case

✓ Visual results – Gala

Discussion and conclusion

- ✓ We smartly combine object categorization with scene and application specific pre-filtering creating a promising pipeline for automated fruit harvesting.

- ✓ Several parts can be further improved:
  - Investigate influence of adding more training data to the models and tweaking the training parameters.
  - Consider deep learning techniques as a newer learning algorithm.
  - Improving the separation of object clusters, in order to avoid damaging the food as less as possible by retrieving robust outlines/contours.

Thank you for your attention!

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