Robust pixel-based classification of sweet-pepper plant parts using multi-spectral imaging

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Background

A sweet-pepper harvesting robot is under development within the EU CROPS project “Clever Robots for Crops”. As part of this project, obstacles for motion planning need to detected and classified into hard (construction element, stem, fruit) and soft (leaves, petiole) obstacles

Objective

1) Detect plant vegetation in a crop row
2) Segment supporting wires and construction elements
3) Classify vegetation into 5 classes
   a. Stem (hard obstacle)
   b. Green Fruit (hard obstacle)
   c. Top of a leaf (soft obstacle)
   d. Bottom of a leaf (soft obstacle)
   e. Petiole (soft obstacle)

Materials and methods

Imaging wavelengths:
- 447 nm - bandwidth 60 nm
- 562 nm – bandwidth 40 nm
- 624 nm – bandwidth 40 nm
- 692 nm – bandwidth 40 nm
- 716 nm – bandwidth 40 nm
- >900 nm – longpass

Figure 1. Labelling of ground truth into five classes: stem, fruit, top of a leaf, bottom of a leaf and petiole.

Pixel-based Features

NDI; Entropy; PCA; SAM; Mahalanobis Distance

Data
- 12 scenes of sweet-pepper cultivar “Viper”
- 3 million labelled pixels

Classification
- Classification and Regression Tree (CART)
- SFFS feature selection algorithm
- A new ´robust and balanced accuracy´ performance measure is introduced in which robustness is assessed by the standard deviation of true-positive detection rate among scenes

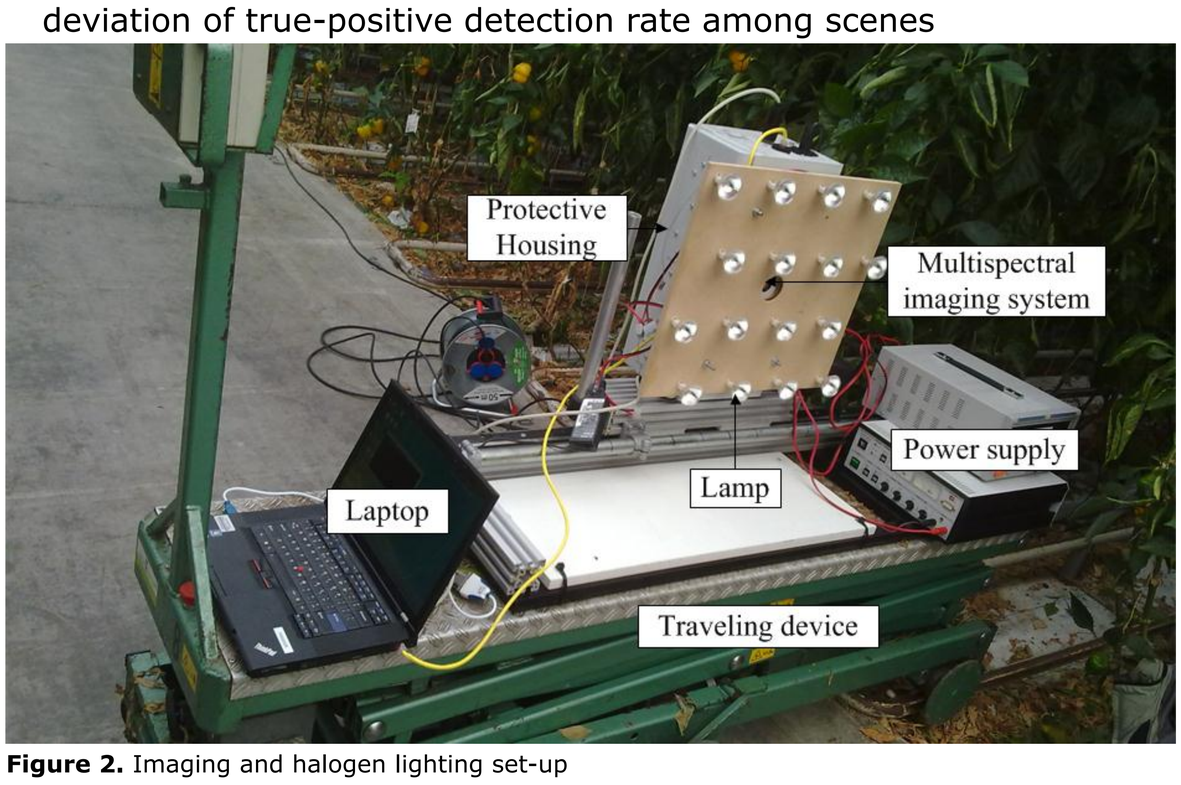

Figure 2. Imaging and halogen lighting set-up

Results

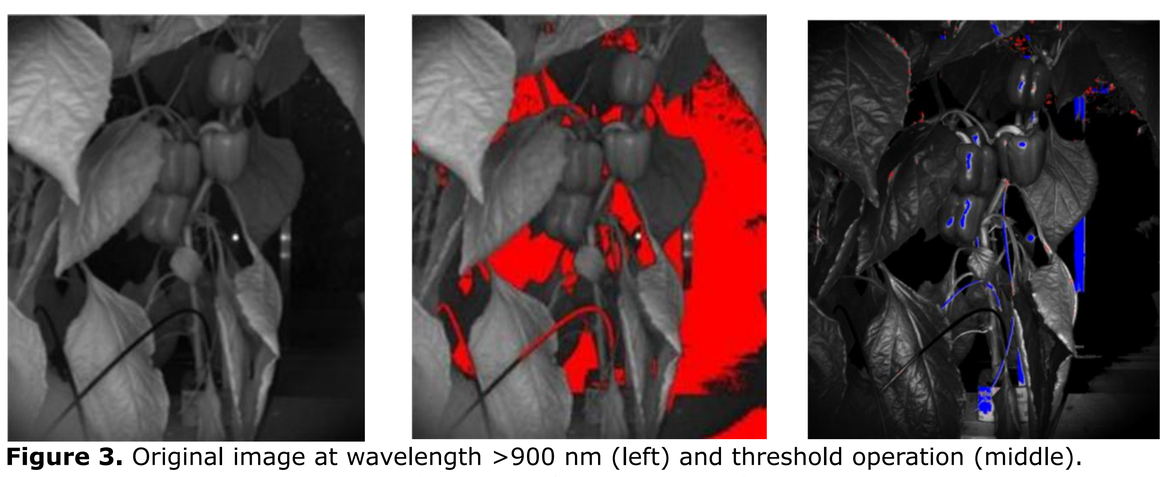

Figure 3. Original image at wavelength >900 nm (left) and threshold operation (middle). Overexposed regions (>300 pixels) are classified as hard obstacles and smaller regions are removed (right)

Plant part classification

Figure 4. Result after pixel-based classification into hard (red) and soft obstacles (white)

Figure 5. Subsequent classification into stem (red), fruit (yellow), top of a leaf (green), bottom of a leaf (blue) and petiole (purple)

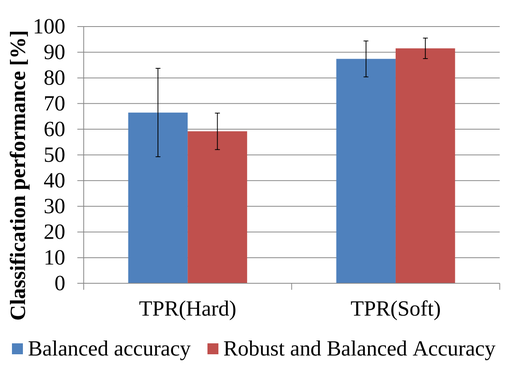

Figure 6. Considering standard dev. among scenes results in more robust classification

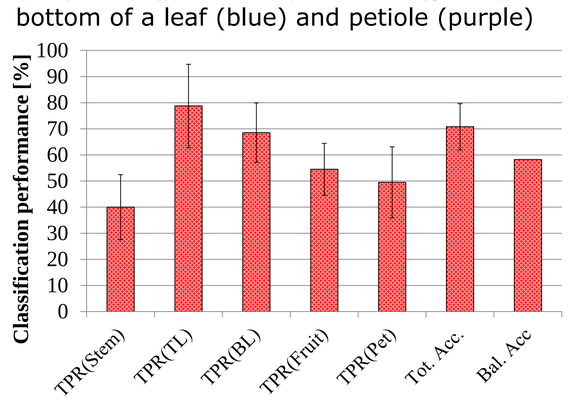

Figure 7. Stem and petiole true-positive rates are < 50 %, while leaves and fruit > 55 %.

Conclusions

- Due to robustness criteria, classification standard deviation among scenes drops by more than 50 % without significant loss in accuracy!
- True-positive detection rates:
  - 59 % on hard obstacles
  - 92 % on soft obstacles
- In continuation research, object-based features will be added to improve classification accuracy

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