Spy-See - Advanced vision system for phenotyping in greenhouses.

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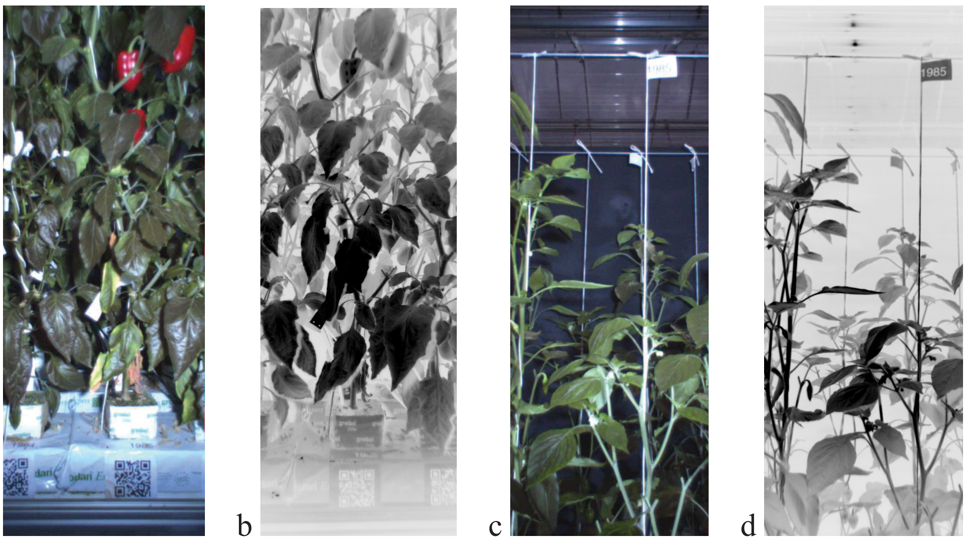
Introduction

The EU project SPICY (Smart tools for Prediction and Improvement of Crop Yield) aims to develop a suite of tools for molecular breeding of crop plants for sustainable and competitive agriculture. The tools help the breeder in predicting phenotypic response of genotypes for complex traits under a range of environmental conditions. Pepper will be used as a model crop.

Molecular breeding will not completely replace large scale phenotyping. Traditionally phenotyping involves human interpretation of a large number of features related to complex characteristics of plants. These measurements take a lot of time and sometimes also are hampered by different perception and/or interpretation for different observers.

Hence, automated and fast high-throughput tools to reduce the amount of manual labour necessary in phenotyping experiments are called for. In the SPICY project an image analysis tool will be developed to measure large numbers of phenotypic traits automatically. This abstract will describe the technical details of the vision system we designed (Spy-See).



a b c d

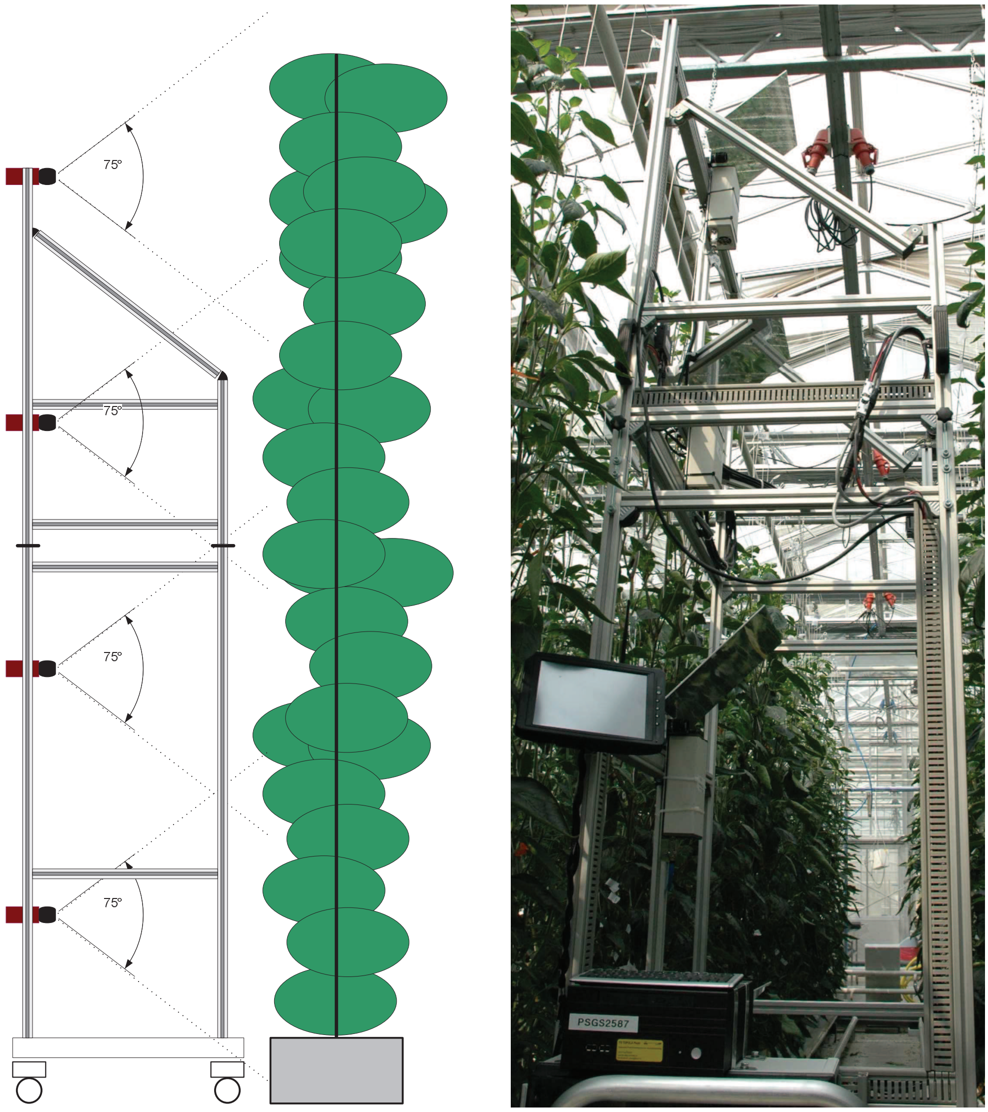
RGB images ((a) and (c)) and infrared images ((b) and (d)) of pepper plants in the greenhouse. Images (a) and (b) show the lower quarter, whereas (c) and (d) show the upper quarter. In total 4 cameras per type at a height difference of 75 cm will record the fully grown plants.

System design

Important features for phenotyping peper plants include number and size of leaves, flowers and fruits, time of flowering, and color of leaves and fruits. The human observer perceives the information in a three dimensional (3D) scene. Therefore it is important that the imaging system also produces 3D images, in order to relate the measurements to human perception.

The plants grow in rows with a row distance of 1 m. In between are heating pipes. The maximum height of the plants is about 3 m. We designed a system on a trolley which can travel over the heating pipes. The distance to the plants is very short, therefore to cover the whole 3 m height we use high resolution cameras with a very large field of view lens at four height positions. Three different cameras are used:

1. high resolution color cameras
2. high resolution infra red cameras (750-900 nm)
3. low resolution range cameras, based on the TOF (Time of Flight) Principle



Side view drawing and photo of the trolley

Close-up of color and infrared camera and strobe

For illumination xenon strobed flashlights are used. For image capture all cameras and flashlights are triggered simultaneously using an encoder on one of the wheels of the trolley. In this way images are captured automatically at a fixed interval when the trolley moves over the heating pipes. The very short duration of the strobe and camera shutter (~50 µs) eliminates disturbing light sources as direct sunlight and assimilation light. By capturing a large number of overlapping images, and with the low resolution information from the range cameras we expect to be able to do high resolution 3D reconstruction.

a  b 

Intensity (a) and depth (b) image of pepper plants produced by the TOF range camera. In image b the distance scale is 80 cm (black) to 150 cm (white).

Conclusion

The Spy-See vision system described here functions very well and produces a huge amount of detailed image information. This image information together with manual measurements will be used as input for the image analysis tool that will be developed in the SPICY project.