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Content

This NewsLetter is dedicated a Ph.D. project within the area of agricultural engineering – where focus is on the use of computer vision and methods to analyse crop canopy structure.

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Computer vision for global analysis of crop canopy structure

This Ph.D. project is under the research project ACROSS (Autonomous spatial-temporal crop and soil surveying), which is a collaboration between Aalborg University and Danish Institute of Agricultural Sciences. The objective of the project is to develop methods of measuring and managing information to support effective precision farming. The Ph.D. project deals with the problem of using computer vision for measuring the architecture of agricultural crop canopies in terms of leaf area index and leaf angle distribution.

Project background

Precision agriculture is a relatively new name for agricultural practices which take into account the spatial and temporal variability encountered in the field. One of the key ideas is doing the best thing at the right place at the right time. If applied properly, precision farming principles may imply ecological as well as economical benefits, for example through reduced use of fertilizers and chemicals.

The implementation of precision farming principles requires several tasks to be solved; one of these is collecting site-specific information about the crop. Manual inspection of a field is laborious and it would be advantageous if the task could be automated. Such an automated inspection of crops could be based on photographic information. Images could be acquired at different scales from photo sensing systems placed at various distances, spanning from satellite-based down to ground-based systems. The ACROSS project concerns the use of ground-based systems for monitoring and analysis of crops. Field and plot trials are conducted using the API field robot platform.



Figure: The API field robot platform

This Ph.D. project focuses on obtaining reliable estimates of the structure of crop canopies, which are important for e.g. crop modelling and irrigation scheduling. Also, there is a connection between water and nitrogen stress and the angular orientation of the leaves. Canopy structure is often described on a statistical level with the leaf area index (LAI) and the leaf angular distribution. The LAI has traditionally been measured using direct methods, e.g., harvesting. Alternatively, optical instruments can be used for indirect measurements if conditions are favourable. Some indirect methods are based on measurements of the frequency of vegetation gaps at different viewing directions. Most methods use manual below-canopy measurements of gap fraction, but this project regards above-canopy measurements, which are more operational for automated measurements in agricultural fields.

Goal & Results

Modelling and simulation

Gap fraction based canopy analysis is based on simplified theoretical models of vegetation canopies, which are used for “inversion” of gap fraction measurements by matching the measurements with model predictions. A simulation framework has been developed where such models are used to generate virtual crop canopies. Images are generated using ray tracing with virtual cameras that can simulate different lens types, depth-of-field blur, etc. This framework can be used for view planning and sampling strategy, and for studying the effect of imaging artefacts on gap fraction estimates.

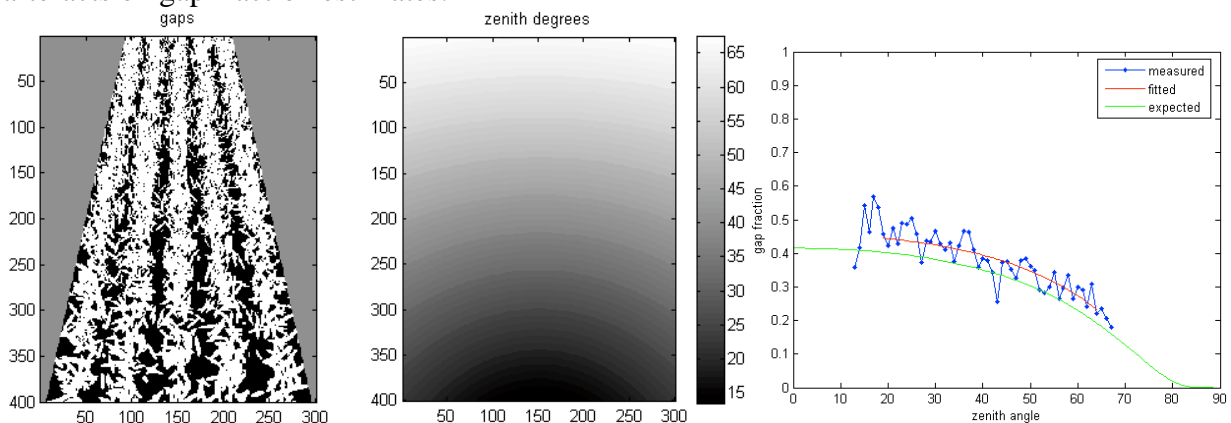


Figure: Left: Simulated image of a row crop. Middle: Zenith viewing angle map. Right: Measured gap fractions and fitted gap fraction curve predicted from model

Measurement of gap fraction and LAI

Experiments have been focused on wheat and barley, in greenhouse plots as well as in field plots and a full-scale field. Gap fraction measurements have been verified against laser range measurements and measurements from the LAI-2000 Plant Canopy Analyzer instrument from LI-COR. LAI estimates have been evaluated against harvested samples as well as estimates from the LAI-2000 instrument. It has been shown that it is possible to achieve good correlation between camera estimates and reference measurements, but there is plenty of room for improvements, especially in the automatic segmentation of images into vegetation and soil classes. The image quality plays an important role; until now, different types of RGB colour cameras have been used, but in this spring a colour-NIR camera will be evaluated for use. The construction of a robust segmentation algorithm is a major challenge due to the variability of not only vegetation and soil spectral quality, but also of the illumination incident to and within the canopy. Another issue is the problem of mixed pixels which is important for accurate gap fraction estimation.

Spectral unmixing for separation of reflection components

The light spectrum that is recorded at a pixel is often a mixture of several distinct source spectra. This may be caused by, e.g., mixed materials due the spatial extent of the pixel, different reflection types (diffuse and specular), and different light sources. The recorded mixture may be modelled as a linear combination of some source spectra, and if the basis for the scene is known, each pixel may be decomposed into its original components using linear inversion. Since the

maximal number of separable basis spectra is limited by the number of image bands, multispectral images are more suitable than RGB images for this type of analysis. A method has been proposed to unmix reflection components with higher-order scattering, and experimental results on multispectral images have demonstrated that it is possible to use the technique to detect e.g. specular reflections and interreflections. There is ongoing work investigating the possibility for using the unmixing results to better estimates of gap fraction and canopy structure.

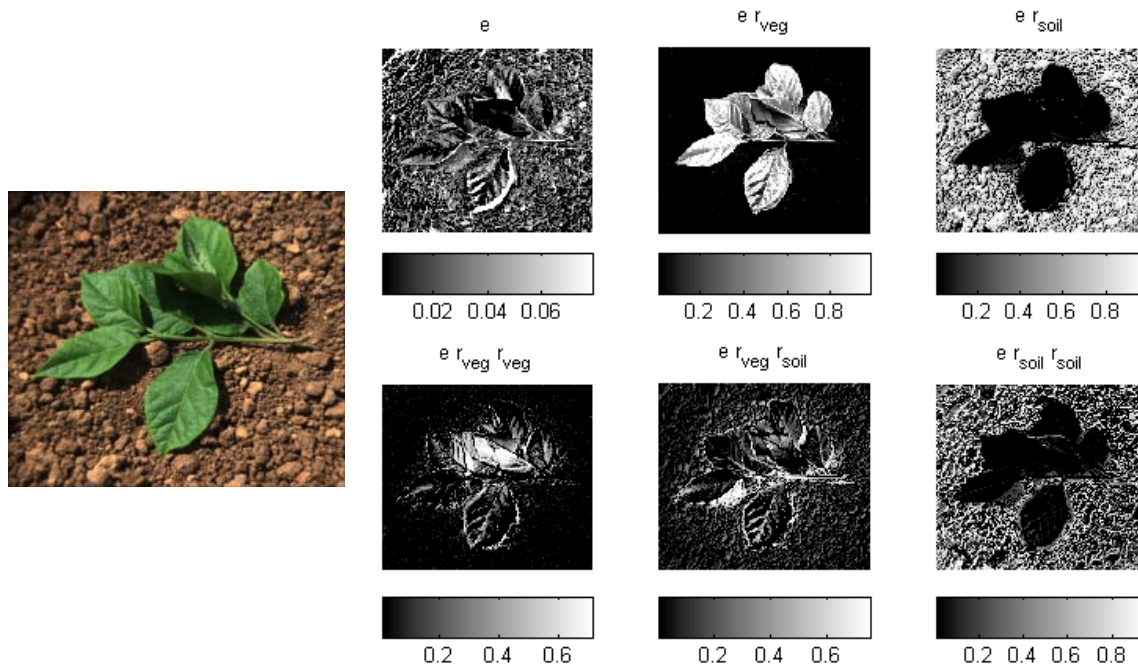


Figure: Left: Original image (shown in RGB colours). Right: Weight images for six separated reflection components, including single reflection from vegetation (top centre) and soil (top right), double scattering from vegetation (bottom left), and interreflections between vegetation and soil (bottom centre).

Ph.D. student



M.Sc. Kristian Kirk is enrolled as a student at Aalborg University (Laboratory of Computer Vision and Media Technology) with Prof. Erik Granum and Assoc. Prof. Hans Jørgen Andersen as advisors. He comes from a background as Master of Science, Informatics, with specialization in Computer Vision and Graphics, at Aalborg University.

For more information, contact Ph.D. student Kristian Kirk – through his homepage: <http://www.cvmt.dk/~kirk/>

Topics of coming newsletters

Navigation systems and IT in Denmark

A Vietnamese-Danish science transfer project in sustainable, sanitary and efficient management of animal manure for plant nutrition

Portraits of Ph.D. students in the area of agricultural engineering and technology