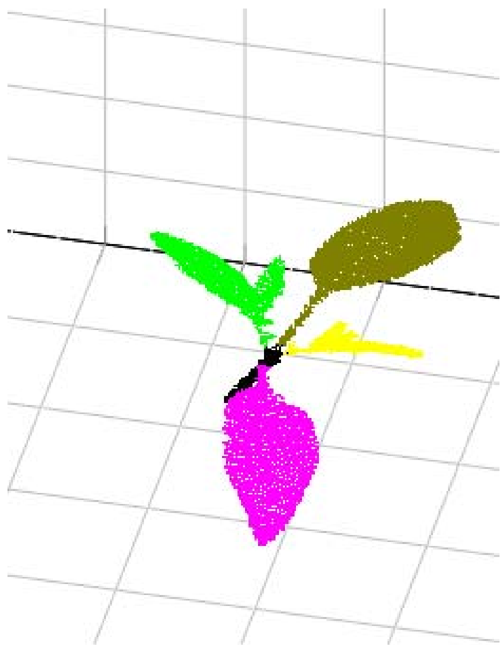
Developers' Workshop of the European Plant Phenotyping Network

Novel Sensor Technologies for Plant Phenotyping

13 and 14 September 2012, Wageningen, The Netherlands

The European Plant Phenotyping Network (EPPN) is an EU-funded infrastructure project with the overall goal of creating structural and functional synergies among plant phenotyping institutions in Europe by linking phenotyping experts, user communities and technology developers. The developers' workshop 'Novel Sensor Technologies for Plant Phenotyping' is organised by EPPN with the aim of identifying technologies that are not yet utilized by the EPPN platforms and to foster joint technology development projects beyond those already available at phenotyping platform locations.

The scope of our workshop covers novel sensor technologies, including, but not limited to, novel sensor development, new vision and new robotics techniques suitable for application in plant phenotyping. The topics will be presented by leading experts from outside the EPPN, with many possibilities for networking and for exchange of ideas and experience. The technologies developed and utilized by the EPPN partners and at Wageningen UR will be presented in poster sessions. After each session, there will be opportunities to further discuss interesting leads with the speakers at so-called speakers' corners.



Workshop venue
Hotel de Nieuwe Wereld, Marijkeweg 5,
6709 PE Wageningen, The Netherlands
http://www.denieuwewereld.nl/

Information about the FP7 EPPN project
http://www.plant-phenotyping-network.eu/

Second Announcement

Novel Sensor Technologies for Plant Phenotyping
September 13th – 14th , 2012
Hotel de Nieuwe Wereld, Wageningen, The Netherlands

Thursday, September 13th , 2012

12.00-13.00 *Registration, sandwich lunch*

Opening Session

13.15-13.25 Welcome by Prof. Dr. Raoul Bino, Wageningen UR

13.25-13.35 Introduction to Wageningen UR Green Vision, Drs. Rick van de Zedde

Session 1: Novel Sensors for Phenotyping

13.35-14.00 *Monitoring the Plant Water Status with Terahertz Waves,*
Dr. Gunter Urbasch,, University of Marburg

14.00-14.25 *Wireless Sensor Networks for Precision Agriculture: Methods and Experiences*,
Dr. Antonio-Javier Garcia-Sanchez, Technical University of Cartagena

14.25-14.50 *Characterization of the Root Structure by Electrical Impedance Spectroscopy*,
Dr. Tapani Repo, Finnish Forest Research Institute

14.50-15.00 Poster pitch I: EPPN

15.00-15.20 *Refreshments*

15.20 - 16.00 Parallel sessions I
Speakers' corners with speakers of Session 1
Poster session I: EPPN posters

Session 2: Novel Vision for Phenotyping

16.00-16.25 *Plant Phenotyping using Depth Cameras*,
Prof. David Rousseau, University of Lyon

16.25-16.50 *Three Dimensional Analysis for the Plant Phenotyping Process from the Root to the Leaf,*
Dr. Norman Uhlmann, Fraunhofer Development Center X-Ray Technology EZRT

16.50-17.15 *Possibilities and Challenges of 3D High Resolution X-Ray Computed Tomography for Plant Structure Investigtion,*
ir. Denis Van Loo, Ghent University

17.15-17.40 *SPICY: Towards Automated Phenotyping of Pepper Plants*,
Dr. Ir. Gerie van der Heijden, Wageningen UR

17.40-17.50 Poster pitch II: WUR

17.50–18.20 Snacks and refreshments

18.20 - 19.00 Parallel sessions II
Speakers' corners with speakers of Session 2
Poster session II: Wageningen UR

19.30–22.30 *Dinner in the city centre (optional)*

Friday, September 14th , 2012

8.30-9.00 *Coffee*

9.00–9.30 *Keynote speech: Potential of (Portable) NMR and MRI for plant phenotyping,*
Dr. Henk van As, *Wageningen UR*

Session 3: Novel Robotics for Phenotyping

9.30-9.55 *Studying Plant Communities and Phenotypic Traits by UAV- Based Close Range Remote Sensing and Image Analysis*,
Dr. Torsten Prinz / Prof. Christian Knoth, University of Münster

9.55-10.20 *Smart Technological Solutions Inspired from Behaviour and Adaptive Strategies in Plant Roots*,
Dr. Barbara Mazzolai, Center for Micro-BioRobotics, Italian Institute of Technology

10.20-10.45 *Multisensor Platforms for Field Phenotyping of Low and High Density Plants*,
Lucas Busemeyer, University of Applied Sciences Osnabrück

10.45-10.55 Poster pitch III: Company R&D

10.55-11.05 Closing remarks / Announcements

11.05-11.20 *Refreshments*

11.20 - 12.00 Parallel sessions III
Speakers' corner with speakers of session 3
Poster session III: Company R&D

12.00-13.00 *Sandwich lunch*

Session 1 Novel Sensors for Phenotyping

Monitoring the Plant Water Status with Terahertz Waves

Gunter Urbasch

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Research in plant breeding and plant nutrition has to face the challenge of handling shrinking resources and increasing demands for yield and nutritional qualities. The evaluation of leaf water content is of great importance to farmers and horticulturists as well as to scientists like plant physiologists or biochemists. It provides valuable information in irrigation management and helps to avoid plant drought stress. Owing to the growing scarcity of water in an increasing number of regions of the world, knowledge of the water content in plant leaves will become increasingly important to control its usage in irrigation.

A novel, non-destructive method for determination of changes in leaf water content in the field based on terahertz (THz) technology is presented. The reliability of this innovative method was verified by monitoring changes in the leaf water content of plants in parallel using classical, destructive thermogravimetrical measurements as well as by THz spectroscopy.

Measuring changes in leaf water content during drought stress induced dehydration highlight the tremendous potential of this novel technique and its high reliability. This provides the basis for THz-based *in vivo* determination of changes in the leaf water content under field conditions.

Wireless sensor networks for precision agriculture

Antonio Javier Garcia-Sanchez

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Wireless Sensor Networks (WSNs) consist of multiple unassisted embedded devices (nodes) which transmit data previously acquired by their different on-board physical sensors. The main advantage of WSNs is their ability to monitor large areas at low-cost, by deploying hundreds or thousands of resource-constrained nodes (regarding memory, processing capability and energy), mainly, in outdoor scenarios. In particular, WSNs have significantly contributed in what we know as precision agriculture, collecting environmental data (temperature, humidity, pressure, gases, soil moisture, etc.) from the crop in real time and transmitting the sensed information to the end-user independently of its final location. In this field of expertise, our work group actively works on the design, development and exploitation of video-based services, providing new capabilities and value-added features to WSNs. On the other hand, Plant Phenotyping is an emerging technology addressed to investigate the functional plant body during plant growth by means of, principally, non-invasive sensors including different types of cameras that capture images within a large wavelength range (e.g. visible, infrared, non-infrared, etc). In real crops, the integration of these camera sensors into WSN nodes and the programming of the software to satisfy specific applications will further improve the decision–making process in the Plant Phenotyping arena and help to the researches and final users to follow appropriate contingent measures with the purpose of obtaining a high-quality product. In addition, these technological advances are focused on assuring efficiently the best yield of the crop what includes the reduction of the resources employed as well as the production costs associated.

Characterization of tree roots by electrical impedance spectroscopy

Tapani Repo

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Studies of roots non-destructively are difficult. In this presentation will be dealt with the results of electrical impedance spectroscopy (EIS) on tree roots. Some bases of EIS are introduced. Results of EIS studies on roots of willow cuttings raised in hydroponics will be presented. The best fit electrical models for root/stem system are discussed. Preliminary results of EIS studies of roots of Scots pine seedlings raised in perlite will be presented. The effects of freezing temperatures on electrical impedance spectra of roots were studied and analysed by CLAFIC algorithm that employs PCA (principal component analysis). According to the results, the electrical models for willow cuttings in hydroponics fit well with EIS experimental data. Root resistance decreased with increasing the root surface area in contact with the cultivation solution. When stem was in contact with the solution, sensitivity to detect root surface area declined, especially as root electrical resistance is considered. Root electrical capacitance correlated with root surface area. CLAFIC algorithm (PCA) was a powerful method for detection of differences in electrical impedance spectra of roots as affected by freezing.

References: Repo, T., Cao, Y., Silvennoinen, R. & Ozier-Lafontain, H., 2012. Electrical Impedance Spectroscopy and roots. *In* Measuring roots - An updated approach (Ed. S. Mancuso), 25-49. Springer-Verlag Berlin Heidelberg

Session 2 Novel Vision for Phenotyping

Plant phenotyping using depth cameras

David Rousseau(a), Yann Chéné(b), Etienne Belin(b), François Chapeau-Blondeau(b)

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This talk briefly presents the technical principle of depths camera and motivates the basis for their potential usefulness in the context of plant phenotyping, especially in situations where conventional RGB imaging is poorly contrasted. An algorithm recently introduced in [1] for leaf segmentation in depth-images is detailed. Various applications of this algorithm are then given for illustration in controlled indoor-conditions including architectural measurements, plant disease monitoring, circadian cycles, plant growth monitoring. Field applications are then discussed. Results are obtained with a low-cost depth camera based on structured lighting. Comparison is given with a higher precision laser scanning depth camera.

[1] Y. Chéné, D. Rousseau, P. Lucidarme, J. Bertheloot, V. Caffier, P. Morel, É. Belin, F. Chapeau-Blondeau. On the use of depth camera for 3D phenotyping of entire plants. *Computers and Electronics in Agriculture* 82 : 122–127 (2012).

Three dimensional analysis for the plant phenotyping process from the root to the leaf

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X-ray computed tomography (CT) and optical measurement methods enable new possibilities for plant phenotyping in the sprout and root area. Industrial CT systems can be used in order to generate a complete 3D volume dataset of the object, also if it is covered with leaves or earth. If the objects are uncovered, optical 3D measurement can be used. This allows the visualization and detailed virtual analysis of hidden structures like roots or tubers in substrate or a detailed structural analysis of sprout features like caulis, leaves and branches.

An overview of the methods and system setups for X-ray imaging and optical imaging focussed on 3D volume data set generation and the possibilities and limits according to plant phenotyping will be presented. Both aspects, on one hand the high resolution application for structural analysis, and on the other hand the high speed inline system for high throughput phenotyping will be discussed. Examples of highest resolution scans with voxel sizes of less than 1 µm are discussed as well as examples of larger objects with moderate resolution.

SPICY: Towards automated phenotyping of pepper plants

Gerie van der Heijden

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In the EU-project SPICY, an imaging platform has been developed, along with a collection of image analysis tools to monitor and measure tall (3 meters high) pepper plants in the greenhouse. The recording and image analysis is challenging: the high plants are intertwined and have to be recorded in a narrow space with uncontrolled lighting conditions.

By combining low-resolution Time-Of-Flight range cameras and high resolution stereo-vision RGB cameras, the 3D surface of the canopy is reconstructed. Features like average leaf area and plant height were extracted and compared with manual measurements.

The imaging platform was tested on a RIL-population of 150 genotypes of pepper. The image analysis features were used in a statistical analysis to examine their potential to distinguish between genotypes (heritability). They were further used in a statistical analysis with molecular markers to find quantitative trait loci (regions in the genome that are associated with a particular phenotypic trait).

Combining hi-res colour images (stereovision) with low-res TOF range images appeared to be a promising approach to measure tall plants in the greenhouse and can be further developed into a standard tool to be used by the plant breeding industry for automatic phenotyping of a population of tall plants.

Session 3 Novel Robotics for Phenotyping

Studying Plant Communities and Phenotypic Traits by UAV-Based Close Range Remote Sensing and Image Analysis

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Unmanned aerial vehicles (UAVs) like multicopters have recently gained growing attention in various research fields as they provide a new highly flexible platform for all kinds of remote and in-situ sensors. The aim of this talk is to introduce remotely controlled multicopters as new sensor platforms for multiple scopes including for example landscape monitoring and precision agriculture. The presentation will give a short overview of the "ifgicopter" group and some projects that have been conducted using multicopters. The focus is laid on the studies of plants and plant communities in bog restoration and precision agriculture. Here the high flexibility of UAVs especially regarding flight level and corresponding ground resolution of images, combined with sophisticated data analysis methods, enables the study of plant communities at different scales. This includes scenarios ranging from continuous agricultural areas (e.g. biomass mapping) to individual plants (e.g. leaf shape). Our research indicates UAVs to be promising sensor platforms also for the effective and non-invasive analysis of phenotypic traits.

Smart Technological Solutions Inspired from Behaviour and Adaptive Strategies in Plants

Barbara Mazzolai

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The concept of taking ideas from Nature to improve technology has been pursued by many scientists and engineers. For the past five hundred million years organisms have appeared on earth as the result of tough selection processes. Consequently, it seems reasonable that engineers should look at Nature for trying to solve similar problems appearing in technology, concerning materials, structures, and even mechanisms. Plants show interesting features to consider as inspiration for designing innovative technological solutions for several application fields, e.g. for soil exploration and environmental monitoring. Actually, plants have evolved very robust growth behaviours (tropisms) to respond to changes in their environment and a network of highly sensorized branching roots to efficiently explore the soil, mining minerals and up-taking water. In the root apparatus, each single root has to move through the substrate, orienting along the gravity vector, negotiating obstacles, and locating resources. This behaviour is partially achieved by osmotic-based actuation systems located in the tip of each root, the apex, which senses several chemical and physical parameters from the surrounding environment and mediates the direction of root growth accordingly. An entirely new generation of robotics and ICT hardware and software technologies can be designed, developed and validated basing robotic research on such original cues. New concepts of artefacts inspired from plant roots, called PLANTOIDS and endowed with distributed sensing, actuation, and intelligence for tasks of environmental exploration and monitoring will be presented.

Multisensor platforms for field phenotyping of low and high density plants

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Non-destructive phenotyping of crops is a challenging and strongly requested field of research. Although there is a growing interest for applicable outdoor phenotyping platforms from the breeding industry, the focus of the phenotyping community is put on indoor plant phenotyping facilities. To widen this bottleneck, we developed two different multisensor outdoor phenotyping platforms using several kinds of innovative optical sensors, for example light curtain imaging, hyperspectral imaging and 3D-Time-of-Flight cameras. The first platform, developed in the interdisciplinary research project “BoniRob”, is an autonomous field robot and was designed to measure single plant properties of maize in early developmental stages. The second platform, developed in the interdisciplinary research project “BreedVision”, is a tractor pulled system and was designed to predict dry biomass yield of small grain cereals in plot based breeding field trials. The focus in project “BoniRob” was put on the development of a multisensory system to detect and re-detect single plants during repeated measurements as a first application for an autonomous field robot. The focus in project “BreedVision” was put on the development and calibration of a multisensor platform to predict dry biomass yield of triticale for ongoing breeding experiments.