Characterization of cereal crop growth dynamics by stereoscopic vision

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Objectives

The purpose of this study is to characterize **plant growth dynamics** in cereal crops at the average single-plant level. It aims at monitoring the evolution of morphological and architectural features at the organ level by means of a customized stereovision system.
Relevant features will be evaluated to determine the growing stage on the Zadoks scale (Zadoks et al., 1974).
This measurement methodology is being developped to meet the need of innovative phenotyping tools in crop variety evaluation. Furthermore, it will be used in an ecotron facility, an ideal tool to assess the crop growth dynamic response to future climate scenarii.

Measurements

Canopy level

Leaves	Leaf area index (LAI) Average leaf angle (ALA)
Tillers	Count Evolution Productive tillers

Growth stages detection
Zadoks (1974)

Organ level

Stem	Length Elongation rate Main and tillers' stems
Flag leaf	Shape Orientation
Ears	Spikelet count Spike architecture development

Experimentation infrastructure

Variety testing occurs in microplots to study crop phenology, above-ground biomass, grain yield and quality, disease sensitivity, response to fertilization modes, etc. The advantages of sampling in such conditions are a variety of morphologies linked to genotype and spatial variability. Such experimentations are of course subject to weather and pedological uncertainties.

Figure 1 - Image acquisition in field conditions

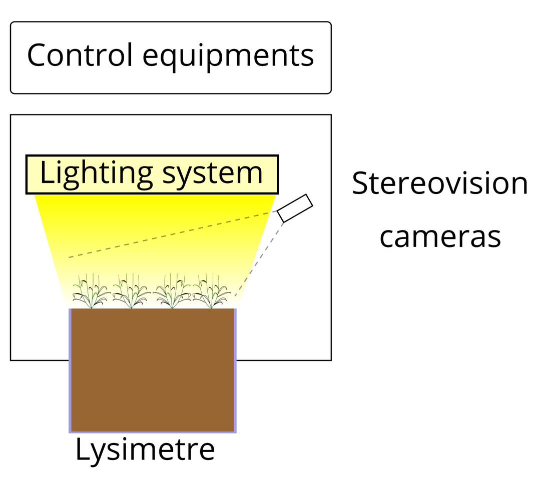

Figure 2 - Ecotron chamber layout

In order to address such uncertainties and benefit from the advantages of a controlled environment, an ecotron facility will be used. Future climate scenarii will be simulated and the crops' response will be studied through dense time series.

Material and methods

Data acquisition

Image acquisition is carried out using a stereovision device formed by a set of twin 5-MP color cameras[1], both equipped with objectives of focal length of 16 mm. The baseline separating the two sensors is 50 mm. The equipment was chosen and designed to provide a sturdy and resilient device, in order to avoid decalibration issues. The distance between the sensors of the cameras and the observed plants is defined at around 1.2 m. To adress occlusion issues, two point of views will be tested (namely, a top view and a view with a 30° angle with respect to the vertical).

Image treatment

3D reconstruction	Point clouds are reconstructed from rectified stereo images and converted to real-world units (i.e. mm)
Organ segmentation	Segmentation process to separate plant material from background and identify organs of interest
Geometric measurements	Organs of interest are characterized thanks to the conversion of 3D data to real-world units
Correlation with observations	Image features are compared to reference measurements and expert observations

This quite regular processing workflow could be challenged by new deep learning techniques, such as that proposed by Pound et al. (2017).

[1]: JAI-5000C-USB

Preliminary results

Leemans et al. (2013) proposed a method for LAI estimations based on stereo images of winter wheat crops. After the segmentation of plant material in the images, leaf area was computed as the sum of the areas of the triangles belonging to plant material. Areas of these elementary triangles were computed through the cross product of vectors joining triplets of adjacent pixels in a metric coordinate system (Figure 3, Equation 1). This method already showed satisfying results in terms of LAI estimations and will contribute to the characterization of wheat canopy measurements.

$$A_{tot} = \frac{1}{2}\sum_{i}^{n}\left|\overrightarrow{CP_i}\right| \qquad \text{(Eq. 1)}$$

This method already showed satisfying results in terms of LAI estimations (Figure 4) and will contribute to the characterization of wheat canopy measurements.

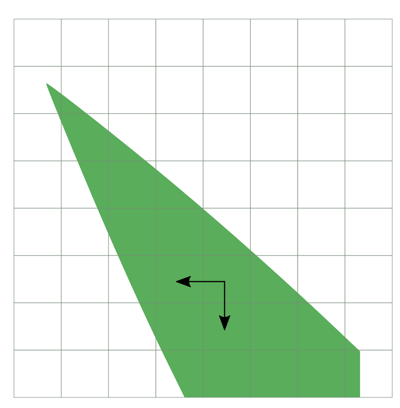

Figure 3 - A couple of vectors joining adjacent leaf pixels used in the leaf area estimations

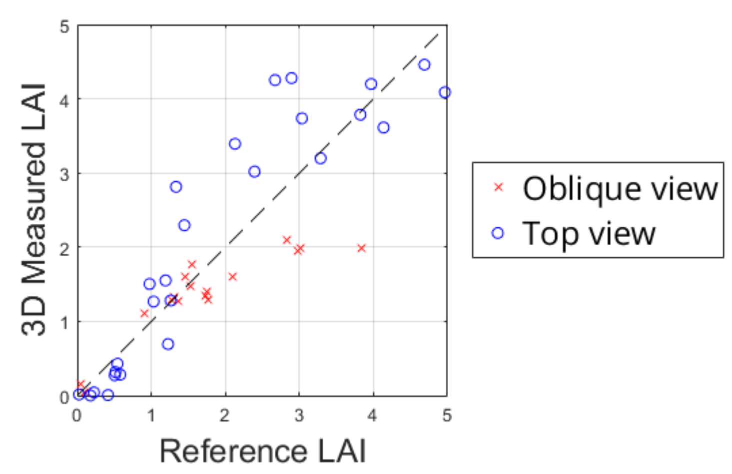

Figure 4 - Image acquisition in field conditions

Literature cited

Leemans, V, B Dumont, and M.-F. Destain. 2013. "Assessment of Plant Leaf Area Measurement by Using Stereo-Vision." 3D Imaging (IC3D), 2013 International Conference on, 1–5.

Pound, Michael P., Jonathan A. Atkinson, Alexandra J. Townsend, Michael H. Wilson, Marcus Griffiths, Aaron S. Jackson, Adrian Bulat, et al. 2017. "Deep Machine Learning Provides State-of-the-Art Performance in Image-Based Plant Phenotyping." GigaScience 6 (10). Oxford University Press:1–10.

Zadoks, Jan C, Ting T Chang, and Cal F Konzak. 1974. "A Decimal Code for the Growth Stages of Cereals." Weed Research 14 (6):415–21.

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