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Fenômica:
A Computer Vision System for High-Throughput Phenotyping

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ABSTRACT

Computer vision and image processing procedures could obtain crop data frequently and precisely, such as vegetation indexes, and correlating them with other variables, like biomass and crop yield. This work presents the development of a computer vision system for high-throughput phenotyping, considering three solutions: an image capture software linked to a low-cost appliance; an image-processing program for feature extraction; and a web application for results' presentation. As a case study, we used normalized difference vegetation index (NDVI) data from a wheat crop experiment of the Brazilian Agricultural Research Corporation. Regression analysis showed that NDVI explains 98.9, 92.8, and 88.2% of the variability found in the biomass values for crop plots with 82, 150, and 200 kg of N ha1 fertilizer applications, respectively. As a result, NDVI generated by our system presented a strong correlation with the biomass, showing a way to specify a new yield prediction model from the beginning of the crop.

KEYWORDS

Appliance, Biomass, Computer Vision, High-Throughput Phenotyping, Image Processing, NDVI

1. INTRODUCTION

The basic requirement of precision agriculture is to rapidly acquire trustworthy and reliable crop-growth information conveniently at low cost; this is also crucial to realizing accurate crop control and management (Ni et al., 2018). Information Technology is increasingly making contributions targeted to agricultural solutions. The periodic monitoring of aboveground biomass is a widely used agronomic parameter for characterizing crop growth status and predicting grain yield. For a long time, crop-growth information was acquired through destructive sampling in the field and indoor biochemical and biophysical measurements (Gnyp et al., 2014; Boschetti et al., 2007). Remote sensing as a non-

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destructive technique has been proved to have great potential in aboveground biomass estimation for crops, such as wheat (Cabrera-Bosquet et al., 2011; Fernández et al., 2019).

Up-to-date, non-destructive monitoring technologies based on characteristic description through reflectance spectra have shown various benefits, including non-destructibility, ready access to information, and excellent real-time performance. Hence, they have been widely used in the investigation into the monitoring of crop-growth indices and evaluation of agricultural devices. Although existing ground-based object spectrometers confer various advantages they also exhibit a few disadvantages, including high price, complex structure, tedious operation, and inconvenient field application (Ni et al., 2018) Development of imagery monitoring for crop growth promotes the development and implementation of some apparatus for crop-growth monitoring. The rapid and accurate estimation of aboveground biomass in a non-destructive way is useful for creating informed decisions on precision crop management. The current estimate of aboveground biomass is based on destructive measurements.

The monitoring of nitrogen is an essential tool for investigating many metabolic and structural processes in maturing wheat plants, such as yield formation and health status. Because nitrogen is not immobilized in soils and a plentiful reserve of plant-available nitrogen is not present, it is essential for optimal crop production to supply nitrogen by applying fertilizer during plant growth (Schirrmann et al., 2016).

To become more efficient, indirect methods using sensors for estimating those parameters have been proposed and implemented. At the plot scale, sensor principles are available that enable on-spot measurements without destructing the canopy, mostly with direct contact to wheat plants (Zhao et al., 2013). Devices measuring sunlight interception in the wheat canopy using radiative transfer models can model the leaf area index (Breda, 2003). Most of these principles involve time-demanding judgments or sophisticated determination protocols that can only be achieved manually in a stop-and-go style. Their use of high-throughput measurements was reviewed (Schirrmann et al., 2015).

Kipp et al. (2014) highlighted that the Normalized Difference Vegetation Index (NDVI) is a potential measure for detecting phenotypic differences in early plant vigor. Cabrera-Bosquet et al. (2011) reported that NDVI was useful to assess green biomass in addition to nutrient, pest, and water stress. NDVI was also used to calculate vegetation coverage from segmented transformed images to study canopies in field experiments using a mobile system (Svensgaard et al., 2014).

The objective of our work was to study the likelihoods of a low-cost imagery acquisition system for monitoring aboveground biomass of wheat under varying nitrogen fertilization. Therefore, this work presents the development of a computer vision system for high-throughput phenotyping, convening three modules. Firstly, an image capture software using RGB and IR cameras, linked to a low-cost and mobile appliance that provides a controlled environment at the field. Secondly, image-processing software for plant distinguishing measurement (morphometric and NDVI data). Lastly, a web application for the visualization of the relationship between NDVI and aboveground biomass.

This document is organized as follows. Section 2 presents the whole computer vision system developed and section 3 shows the results and discussion of a preliminary study considering the use of our system to compare NDVI and wheat biomass. Section 4 highlights our conclusions and future work about this study.

2. MATERIALS AND METHODS

This project based on the development of a computer vision system for high-throughput phenotyping, convening three modules, named "Fenômica". This system captures and registers images from an appliance, processes them in order to get NDVI information, and presents results for comparison with crop biomass data. Next sections expose materials and methods used in each of these system modules.