Morphological data capture system through image analysis during rice plant growth

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***Abstract*—Plant phenotyping is currently developed with high cost devices. This article presents a low-cost image capture system which allows obtaining quantitative data of the morphology and architecture of the rice plant. The proposed method is based on the analysis of images, which through an acquisition system, allows capturing photos of rice plants from different views or angles. The pre-processing and analysis of the images is achieved for obtaining quantitative data of the rice plant using the open source software PlantCV. The data obtained is formatted in json files, which are the input to another system that manages to model the rice plant in 3D, during its growth.**

***Index Terms*—Plant phenotyping, image acquisition, image analysis, morphological data, PlantCV.**

I. Introduction

WORLD population growth is expected to double during the first 45 years of the 21st century. As a consequence, food production will have to triple, forcing even an increase in agricultural productivity. In addition to the imperative of achieving food security, biotic and abiotic stresses have altered the productive sustainability of crops (in some cases critically, e.g. climate variations that affect the survival of some crops, such as cocoa; the metal content of soils that affect the development of any crop and compromise its use for human consumption; or unwanted greenhouse gas emissions in essential crops, such as rice, are some examples). In this context, the development and sustainability of new varieties it is necessary, but for this it is necessary to know the genotype and phenotype of the plant, soil and environment [1].

The phenotyping of plants is and has been of interest to the entire community in general, and has been carried out more than ten thousand years ago, when the first farmers selected seeds with desirable characteristics for the next crop. At that time, phenotyping was the only option to improve cultivation, since the genotype of plants has started to be studied relatively recently. However, currently, plant phenotyping is still important for plant breeding and crop sustainability [2].

Some works related to plant phenotyping are based on various methods such as 2D image analysis, 3D reconstruction, and High-resolution volumetric imaging [3]. A method using 2D image analysis [4], makes use of HTPheno software for the analysis of different phenotypic parameters of different plants in the laboratory. The measured variables are height, width and projected area of plant shoots from the planting stage to the ripening stage. Another non-invasive method uses 2D image analysis for biomass estimation in cereal crops [5].

There are several methods of 3D reconstruction for plant phenotyping, some using 2D images from multiple views, where a 3D model is obtained and data or parameters of the plants are obtained on the structure of that model [6], [7], [8], [9], [10], [11], [12]. Another method is the scanning with laser on the plants to obtain point clouds and a solid 3D model [13].

Most of the methods used for high-throughput phenotyping use cameras, lasers, or sensors such as LiDAR and very high cost laboratories or structures. In this paper, we use the 2D image analysis method, which through a low cost image acquisition system, is able to capture multiple images that allow to obtain morphological and architectural data of the rice plant during its growth, (e.g. height, stem and leaf width, leaf shape, leaf angle and curvature, etc). For this we use the open source software PlantCV, which works with OpenCV and Python.
This work is the first phase of a larger project, so the data obtained is used in another phase that seeks to computationally model the rice plant in 3D during its growth. As can be seen in Figure 1, the first phase marked in the red box refers to this work. The paper is organized as follows: first we show the methodology used in which we describe the system, then the results with their respective analysis, and finally the conclusions of this work.

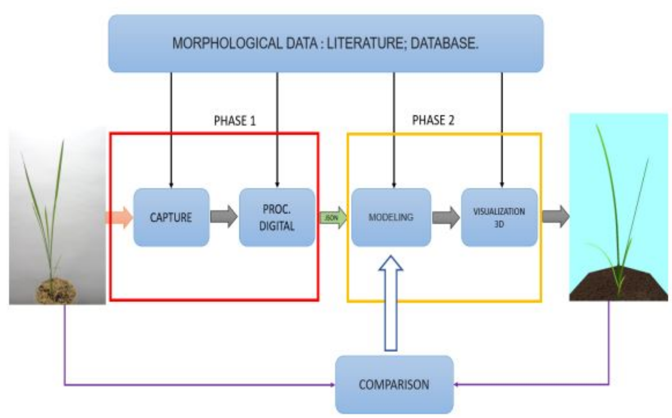

Fig. 1. Phases of the joint project.

II. Metodology

Methodology is divided into three main schemes. The first consists of the acquisition of images, for which a system has been developed that allows captures of the rice plant to be obtained in optimal conditions and without altering or invading the rice plant. The second consists of the processing of the acquired images to obtain the quantitative data of the morphology and architecture of the rice plant. Finally the data output, in which we describe the format of the data recollected.

A. Capture system

1) Physical system: The physical system is mainly composed of the rice plant. For this paper, a single plant is exemplified and described, which is beginning the tillering stage. To obtain a good image of the capture system, several conditions must be taken into account. The first is the background, preferably white and uniform. The rice plant must be in the center of the image and must be completely visible from any perspective.

2) Image acquisition: The acquisition system is mainly composed of a static celphone camera, with which images of the rice plant are captured. A rotating platform is the base to hold the plant, which will rotate in constant degrees to obtain captures from different perspectives of the plant. Finally interpolate the data obtained in each image to different perspectives.

B. Image processing

This part of the system consists of processing the image to obtain the morphological data of the plant, but before that it is necessary to carry out a pre-processing, which consists of filtering the image to obtain only the plant and not secondary objects such as the background or the earth. That may affect processing. To achieve this, the PlantCV Python library is used, which has a great diversity of functions and methods to process images of plants with characteristics similar to that of rice.
All the images are analyzed to interpolate real values of the plant. This guarantees that if from one perspective a leave does not have its actual length from another perspective, possibly, and therefore graphs and diagrams are made to obtain the best value that is close to real data of the plant. The same happens with the curvature of the leaves, the length of the stem and the angles of incidence of the leaves.

C. Data output

The data output is organized in json files. These data serve as input to another work platform that seeks to model the rice plant in 3D during its growth. With these data, the model is expected to be more accurate.

The methodological scheme applied in this paper and the phases described previously is show in the Figure 2.

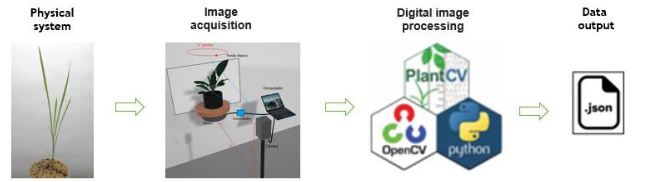

Fig. 2. Methodology of the image capture system to obtain morphological data of the rice plant.

III. Results

Figures 3 and 4 show the rice plant after being acquired and processed by the system.

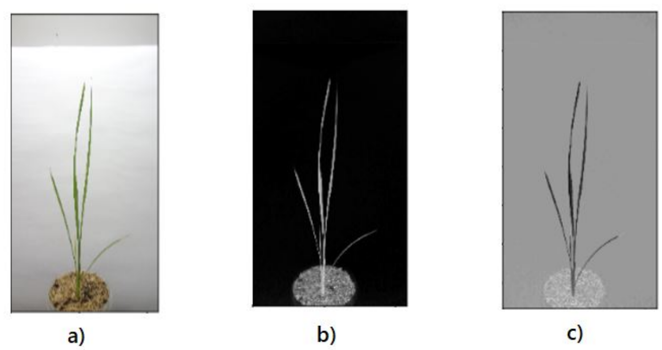

Fig. 3. a) RGB capture of the rice plant. b) HSV grayscale image. c) LAB image of the rice plant.

Figure 3 a) shows a RGB capture of the rice plant using the capture system from 50 cm away with the camera of the Huawei P20 Lite cell phone. Figure 3 b) shows the HSV grayscale image, in which the white color is replaced by a black tone to distinguish objects with a different tone. Finally, a LAB image of the rice plant is obtained, as shown in Figure 3 c), note that the rice plant has a dark color to its surroundings.

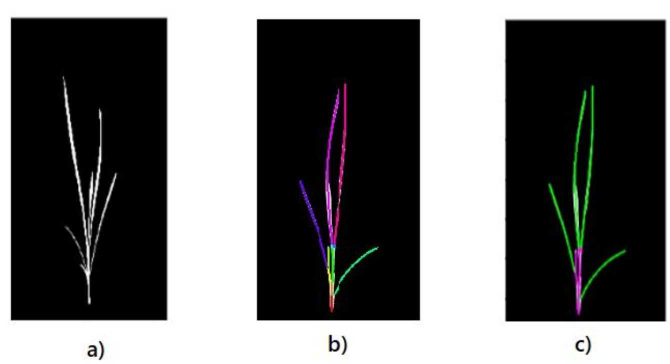

Fig. 4. a) Binary image of the rice plant in the final stage of preprocessing. b) Skeletonized and segmented image. c) Segmented image of the rice plant.

The mask on which the data is obtained is shown in Figure 4 a), this is a binary image of the rice plant in the final phase of preprocessing. The skeletonized and segmented image is shown in Figure 4 b). For each segment the program adds a color to better identify the plant. Finally, the segmented image of the rice plant is shown in Figure 4 c). The green color represents the leaves and the fuchsia color represents the stem. Figure 3 and Figure 4 are some of the examples that describe how the algorithm works.

Figure 5 show quantitative data from the segmented image. For example, the lengths of the leaves of the rice plant were obtained in centimeters. Each pixel of the plant is equivalent to 0.025 cm since the distance at which the image was captured was 50 cm from the plant. Data such as number of leaves, length, curvature and angle of inclination of each leaf of the plant are shown in the Figure 6. This program is also carried out automatically for the rest of the images that were acquired from different perspectives, to later interpolate a more exact data to the real value of the plant.

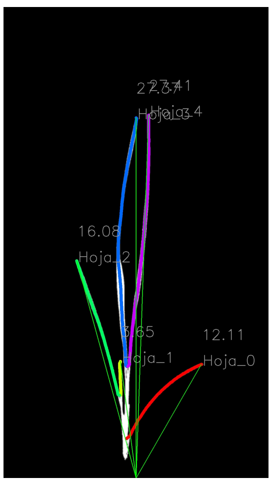

Fig. 5. Quantitative data of the segmented image.

Leafs	Length (cm)	Cuvature (>1)	Inclination angle (Degree)
Hoja_0	12.11	1.095	45.70
Hoja_1	3.65	1.002	87.12
Hoja_2	16.08	1.079	72.46
Hoja_3	27.37	1.043	87.48
Hoja_4	27.41	1.029	85.12

Fig. 6. Data table of the leaves of the rice plant. The length is in centimeters, the inclination is 1 if the leaf is parallel to the stem or greater if it is the opposite. The angle is measured horizontally taking as reference a linear regression of the each leaf.

For a single plant leaf, an example of interpolation of data taken from multiple perspectives can be seen in Figure 7. The vertical axis represents the length in cm and the horizontal axis the samples in different degrees. In this case, the image acquisition system was able to rotate the platform that supports the plant in steps of 30 degrees. This helped to identify leaves that were not seen from a perspective and therefore the quantitative data is more accurate.

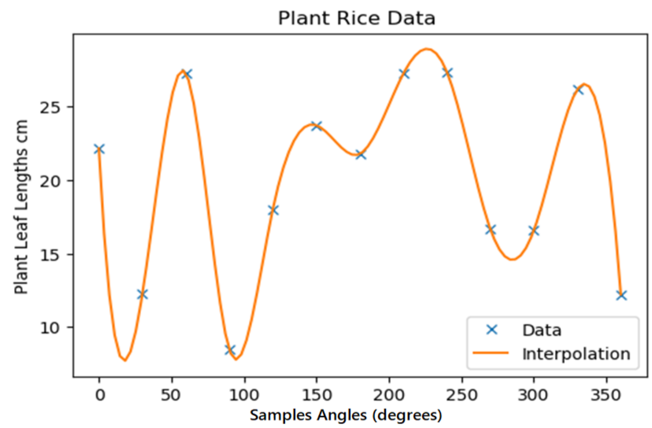

Fig. 7. Interpolation of data of the length of a single leaf of the rice plant.

Figure 8 shows the stem length comparison between the ruler method and the method in this paper. Samples were obtained for 77 days the growth of the rice plant.

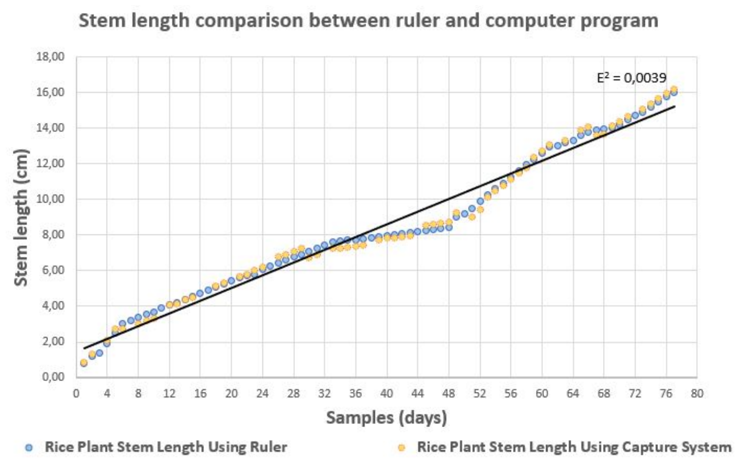

Fig. 8. Rice plant stem data taken by two different methods for 77 days. The value of E is the difference between the coefficient of determination of each linear regression obtained from the samples.

IV. Conclusion

The automatic system for plant morphology acquisition obtains results very similar to those obtained by the rule method, with an error of less than 10%. It is expected that the quantitative variables obtained from the architecture and morphology of the plant will allow the extraction of growth patterns of the rice plant and that the implemented method will contribute to the phenotyping of crops. The data obtained helped another work to model the rice plant with greater precision in 3D during its growth.

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