Plant Height Measurement and Tiller Segmentation of Rice Crops Using Image Processing

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Abstract: Plant phenotyping is the process of completely assessing the basic and complex characteristics of the plant, which includes its height and tiller count. Automated plant phenotyping offers an effective substitute to manual visual assessments because it allows a regulated image analysis that can be reproduced and enables a high throughput because of the automation. This is to address the lack in accuracy, reproducibility and traceability in manual phenotyping. With this, the researchers developed an image processing system that automates the measuring of height and the counting of tillers of a rice crop, more specifically the C4 rice. The system is done by applying HSV and Thresholding for preprocessing, Canny Edge Detection (tiller) and Zhang-Suen Thinning Algorithm (height) for the plant structure and the Euclidean Distance for measuring the height. Tiller counting is done by counting the cluster of pixels in a given region of interest. The initial outputs were compared to the values manually measured by IRRI researchers from 50 plant images. There was a percentage error of 17.25% for height and 34.02% for tiller count. Errors may have been caused by plant not being able to fit the image frame and in result cut some parts of the plant. Another would be the effect of yellow leaves being removed during the preprocessing which produces an incomplete plant structure image. There are also leaves that are long that tend to bend and these leaves are then detected as the base instead of the real base.

Key Words: Image processing; phenotyping; plant; height; tiller

1. INTRODUCTION

Plant phenotyping is the process of completely assessing the basic and complex characteristics of the plant. The plant's complex characteristics include its growth development and yield (LemnaTec, n.d.). Some of the basic characteristics observed when phenotyping plants, specifically rice crops, are its height and tiller count. Plant height is related to the productivity and growth rate of a plant. Plants tend to grow to a certain height in each of its growth state (Sritarapipat, Rakwatin, & Kasetkasem, 2014). However, plants drop in growth rate when plants have diseases or lack in water, which results to lower yield rates. In rice crops, more tillers would generally mean more yield (Li et al., 2003). Tillers are the grain-bearing part of rice crops and it possesses the leaves (Tiller(Botany), n.d.). Leaf count indicates a plant's age and as it grows its leaves will develop and grow in size (Wood & Roper, 2000). Plants growing in good conditions develop leaves in a faster rate than those leaves growing in non-conducive environment for the plant.

According to Rousseau et al. (2013), phenotyping can be done through manual visual assessment but it requires properly tuned rating scales and well trained raters which adds to the cost and time. Furthermore, it is influenced by the subjectivity of raters making it lack in accuracy, reproducibility and traceability (Rousseau et al., 2013). Fatigue of experienced staff can also be one cause of the degradation of accuracy and efficiency (Yang et al, 2011).

It was also stated by Rousseau et al. (2013) that automated image processing of the phenotyping of plants offers an effective substitute to manual visual assessment. They also mentioned that automated phenotyping allows a regulated image analysis that can be reproduced because of the absence of subjectivity of manual visual assessment and it enables a high throughput because of the automation of the process. Moreover, calibrated protocols and data storage offer beneficial tools to trace or compare results (Rousseau et al., 2013).

1.1 Rice Crop Tillers & Panicle

This research would focus on phenotyping of rice crops. To further understand how phenotyping works, specifically of a rice crop's height and tiller count, its biology needs to be discussed. The two key part of a rice crop that is useful to this research are its tiller and panicle (shown in Fig. 1).

Tillers in rice crops appear as soon the rice crop is self-supporting (Maclean, Hardy, & Hettel, 2013). The first tiller usually emerges when the seedling has five leaves. This signifies the start of the tillering stage. From the main stem, another stem would develop. This new stem would be the tiller. Once these tillers are fully developed, they would develop flowers. These flowers are more commonly called as panicles. Tillers are used to measure the height of the rice crop. The height of the tiller with the longest leaf would be the height of the plant.

Panicles are the flowers of the rice. They are placed at the end of the tillers. The seeds or grains produced in the fertilization of the rice plant grow in the panicles of the rice crops. Panicles are one of the identifying quality of a fully developed tiller.

According to Rousseau et al. (2013), phenotyping of these traits can be done through manual visual assessment but it requires properly tuned rating scales and well trained raters which adds to the cost and time. Furthermore, it is influenced by the subjectivity of raters making it lack in accuracy, reproducibility and traceability (Rousseau et al., 2013). Fatigue of experienced staff can also be one cause of the degradation of accuracy and efficiency (Yang et al., 2011). This is the current situation in the International Rice Research Institute (IRRI).

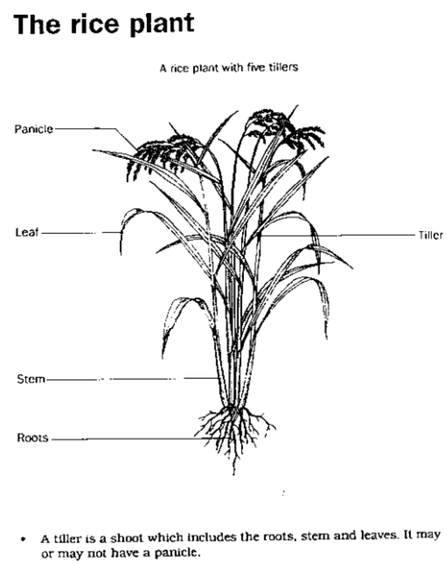

Fig. 1 Parts of a rice crop

1.2 Automated Plant Phenotyping

Automation of manual processes is becoming a trend now and it is widely adapted in different fields. There are a number of researches and systems that has been done that uses image processing in measuring height of plants and its number of tillers. They used different tools to measure the height of an object and number of tillers of plants while applying image processing techniques.

Sritarapipat, Rakwatin and Kasetkasem (Sritarapipat, Rakwatin, & Kasetkasem, 2014) used marker bars and a formula where the values are taken from the processed image to get the height of the rice crops. They used band selection, filtering, and thresholding to remove noises affected by the rain, wind, and outdoor light, in the images. They took images of rice paddies in a very low plain called Tha Cheen River, a part of a rice field in Suphanburi, Thailand. These images were taken by two Single-Lens Reflex (SLR) cameras controlled by the field server's control unit. However, there are a lot of images being taken and storing these images in high resolution will take up too much storage space. Therefore, they took images in lower resolution at 10:30 a.m. daily to resolve the issues with regards to storage space and data transfer rate. Local Thai Meteorological Department staff recommended that images be taken in the morning as clouds and precipitation has less effect than other times of the day.

According to Sritarapipat, Rakwatin and Kasetkasem (2014), the results were compared to the data of manually-measured rice crops. Its outcome was good. They were able to conclude that excess green had better results than red band. However, they also state that results are dependent on the marker used. Results might also change if there are plants present in the field image that are similar to rice crops, like wheat, since it will be identified as a rice crop. The system is limited to having only one marker bar and it should always be in the same position.

A system created by Ikiz et al. (2001) uses image processing techniques, like skeletonization, to measure fiber length. The system would be depended on these factors: sample preparation, lighting technique, resolution, preprocessing algorithm, and processing algorithm. There were two levels of sample preparation that Ikiz et al. (2001) did, the one with fiber crossovers and one without. There were also two types of lighting, frontlighting and backlighting to create negative images since the only concern is to know the pixels of the fiber and the background. For preprocessing, both images were assumed to contain single fiber and images that were assumed to have random crossovers, outline, thinning, and adding algorithms were applied.

The system that Ikiz et al. (2001) created achieved a 0.65 mm confidence level, higher than the 0.5 mm that is required. However, when running low resolution images through the adding algorithm, it results to negative bias. Added noises in the image, like dust or glare, causes points to disconnect resulting to shorter measurements.

Yang et al. (2011) created the H-SMART system that performs x-ray computed tomography (CT) to automatically count the number of tillers in rice plant. Pots of plants pass through the x-ray system through a conveyor belt and stops at a rotation platform. There is a distance of 1,122mm between the focal spot and the center of rotation. All computations are done in 20 seconds and image processing in 5 seconds. Filtered Black-projection (FBP) algorithm was used to create an image of the rice culms. Image processing methods, such as median filtering for image denoising, threshold operator for image segmentation, and some morphological operators are used to identify tillers in the FBP image. The researchers used three batches of rice, 50 pots each, from the tillering, heading, and flowering stages to test the accuracy of the system. The system was able to have a 95\% confidence in accuracy.

The systems, although well-advanced, are still noticeably young and can still be improved. Systems for measuring height are more common to researchers and many have tried different approaches and techniques but there are still a few things that can be improved. The use of marker bars and rulers, done by Sritarapipat et al. (2014) and Lee et al. (2008), with image processing techniques seems to be two of the most effective approaches. This is the same with the systems that count tillers, although there are fewer studies regarding this.

1.3 Importance of the Research

The problems presented by manual visual phenotyping, such as the additional cost and time due to the requirement of properly tuned rating scales and well trained raters which may be subjective and experiencing fatigue can cause the lack in accuracy, reproducibility and traceability (Rousseau et al., 2013) as well as the efficiency, led to the automation of phenotyping through image processing. It also speeds up the process of phenotyping which is a big factor for researchers. Rice crops, in particular, would benefit in the automation because of the growing population of the world, the demand for food increases (Sritarapipat, Rakwatin, & Kasetkasem, 2014).

Currently, in the Philippines, they are still using manual visual phenotyping and are experiencing the problems stated. The researchers proposes an image processing system, named Seight, that automates the measuring of height and the counting of tillers of a rice crop because although it's a fairly young field and many previous studies used image processing techniques for their systems, there are new and unused image processing techniques that can be used. Also, previous studies do not consider noises present in the image and its effect to the result. An appropriate infrastructure setup would be designed for the automated phenotyping. Seight would only focus in height measurement and tiller count.

2. METHODOLOGY

2.1 Data Gathering

The data to be gathered for this research are images of C4 rice crops. These are currently cultivated in the International Rice Research Institute (IRRI) in screenhouses. In Fig. 2, there are three cameras elevated at a specific height and at a specific distance, seen in Fig. 3, from the plant subject would be used to capture images. The researchers will focus on gathering data from three rows, each with a sample, of rice crops in this stage. Each bed would represent the stages of the growth of rice crops that would be used in the research, tillering, mid-tillering and flowering stages. These images will be gathered and stored in a computer.

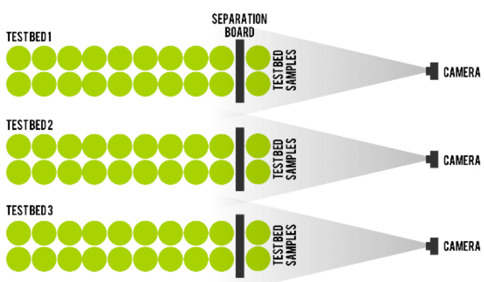

Fig. 2 Screenhouse setup

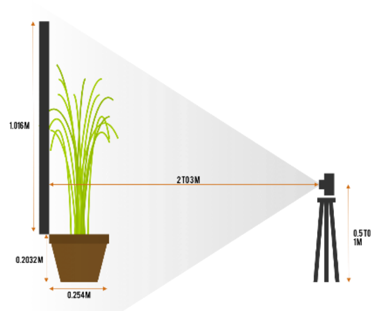

Fig. 3 Camera setup

2.2 System Design

To develop the system, the researchers came up with a system design with 6 modules: Data Capturing Module, Data Management Module, Preprocessing Module, Plant Structure Module, Height Module, and Tiller Module shown in Fig. 4.

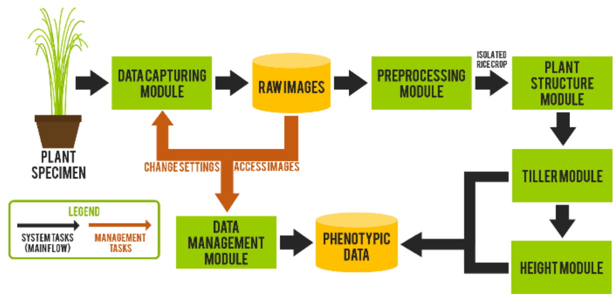

Fig. 4 System Architecture

2.2.1 Data Modules

The Data Capturing Module and Data Management Module are the modules responsible of gathering and handling of the plant images. For the Data Capturing Module, this includes the setup of the screenhouse (Fig. 2) and of the cameras (Fig. 3). The cameras to be used would be mounted IP cameras. The Data Management Module includes the database of the system and the settings to change the schedule of image capture of the plants.

2.2.2 Preprocessing Module

The Preprocessing Module of Seight prepares the raw images for analysis. Background removal, filtering and edge detection are the techniques that would be used for preprocessing. Background removal and filtering reduces noise present in the image. These techniques would, respectively, lessen the distortion and unnecessary details in the image. Edge detection is a subfunction of plant segmentation. Plant segmentation would segment the plants present in the image from each other. This allows the system to focus more on assessing a single plant which in turn increases in the efficiency of the assessment.

2.2.3 Plant Structure Module

The Plant Structure Module determines the structure or the skeleton of the plant. Edge detection and skeletonization would be used in this module. This module would be used for the later modules.

2.2.4 Tiller Module

The Tiller Module determines the tiller of the plant. It is in this module that the tillers would be counted.

2.2.5 Height Module

The Height Module is responsible for determining the height of the plant in the image. The height is computed by using Euclidean Distance in pixels which is then converted to centimeters with 1 cm to 8 pixels ratio.

3. RESULTS AND DISCUSSION

The pre-processing, plant structure, tiller count, and height measurement modules produces different images from one raw plant image, and outputs the tiller count and the height measurement. The raw plant image shown in Fig. 5 is the original image of the rice crop taken at IRRI. The image will undergo preprocessing by applying HSV and thresholding, shown in Fig. 6. It will result to the image retaining all its green values and removing its background. Fig. 7 shows the resulting image after the preprocessed image had undergone Canny Edge Detection. There are different colors in the picture that represents the edges of the plant. Fig. 9 shows the resulting image of Fig. 5 after applying preprocessing, thresholding and Zhang-Suen Thinning Algorithm.

Fig. 5 Raw plant image

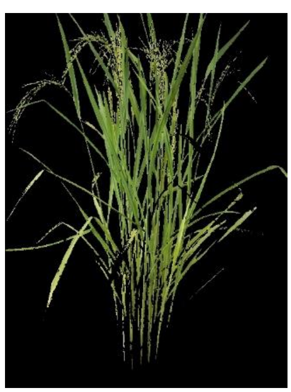

Fig. 6 Preprocessed image

For the first iteration, HSV segmentation algorithm and threshlding were used to preprocess raw images or plants. HSV was used because it changes pixels with non-green values into either black or white. However, there are parts of the plants that are yellow, especially the images of plants in the flowering stage. Thus a bigger threshold value is needed for yellow parts of the plants to be not removed.

In Fig. 7, it shows the images produced by the plant structure module applying Sobel and Canny edge detection algorithms to be used by the Tiller module. Between the two algorithms, Canny was able to detect edges Sobel was not able to. Zhang-Suen was the algorithm used for thinning to get the plant structure (Fig. 8). It transforms the plant structure into a white skeleton-like structure. However, there are some parts of the plant that are thin and is then omitted if it still go through the thinning process.

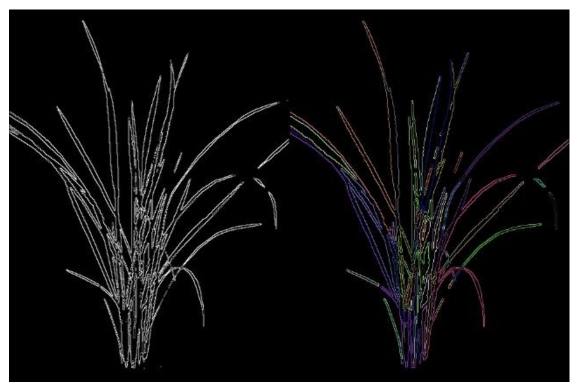

Fig. 7 Comparison of Sobel (left) and Canny (right)

Fig. 8 Zhang-Suen Thinning result

To measure the height of the plant in the image, Euclidean Distance method was used. The approximated values for the height measurement were able to get a 17.25% percentage error. One of the reasons for the cause of errors could be that the image was not able to capture the whole plant. There were plants that did not fit the image frame and in result cut some parts of the plant. Another would be the effect of yellow leaves being removed during the preprocessing and in turn the plant has some missing parts in the plant structure image. There are also leaves that are long that tend to bend and these leaves are then detected as the base instead of the real base.

Scanning was applied in getting the count of the tillers and it was able to get a percentage error of 34.02%. Errors have been caused because of the omission of yellow parts of the plant during the preprocessing and leaves hanging near the tiller base are counted as a tiller.

4. CONCLUSIONS

Plant phenotyping, the process of completely assessing a plant, is important in studying the growth and yield of the crops. The automation of plant phenotyping is essential in making it produce high throughputs and outputting results that are more accurate and reproducible. Seight is a system developed to automatically phenotype C4 rice crops. C4 rice is a rice that is being enhanced to increase yield. The system measures the height and counts the tiller of a rice crop through different image processing techniques. The plant is segmented from the image with HSV segmentation and thresholding. The height is measured by getting its structure using skeletonization and determining the distance between the base and the highest point of the plant. The tiller is counted by using the edge detection to separate the tillers. The system was able to get a percentage error of 17.25% for the height and 34.02% for the tiller. Errors may have been caused because of the omission of yellow parts of the plant during the preprocessing and leaves hanging near the tiller base are counted as a tiller.

5. ACKNOWLEDGMENTS

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