

Estimation of Leaf Area, Plant Height, and Fresh Weight of Lettuce in Plant factory using Structure from Motion (SfM) Technique⁺

Heesup Yun¹ Woo Jae Cho¹ Ji Song Jiang¹ Hak-Jin Kim^{1,2*}

¹Dept. of Biosystems Engineering and Biomaterials Science, Seoul National University, Seoul 08826, Korea

²Research Institute for Agriculture and Life Sciences, Seoul National University, Seoul 08826, Korea.

Introduction

Recently, Structure from Motion (SfM) algorithms and related commercial image processing software have been developed, which could easily perform the operation of image mosaicking and build 3D model. In our previous study (Jung et al., 2015), it was reported that leaf images could be used to analyze the status of lettuce growth and predict the fresh weight of lettuce. In this study, multiple images were mosaicked using SfM software to generate a 3D map of lettuce biomass containing information about the height and leaf area of each lettuce. Leaf areas of lettuce in plant factory were estimated using the acquired 3D image data and the estimates of leaf areas were used to predict fresh weights of lettuce using the relationship between fresh weight and leaf area previously developed.

Materials and Methods

The test bed for this study was located in an experimental plant factory with an automatic nutrient management system, and lettuces were transplanted to styrofoam bed in Aug. 25th, 2015 (Fig 1. (a)). A digital camera(Canon S110, Japan) was used for acquiring the images of lettuce. The images were obtained in sequence along with plant rows for all column of plant factory to take pictures of entire plant factory bed (Fig. 1(b)). And image mosaicking software (Agisoft Photoscan, Russia) was used to mosaic the images and generate 3D model from the taken images. Four markers were placed at the coner of the bed to assign metric criterion for the 3D model. Mosaicked images were transformed into ExG (Excess Green, 2g-r-b) Vegetation Index(VI) images using MATLAB(Ver 2015a). And Ostu's threshold method and image segmentation were used to calculate leaf areas based on plant pixel counts and pixel size. Fresh weights were measured after the termination of plant factory experiment by the analytical balance, and compared with the previous results (Jung et al., 2015).

Results and Discussion

Lettuce images acquired from the camera were mosaicked to single image (Fig. 2(a)), and a plant height map was generated based on the 3D model (Fig. 2(c)). And the ExG vegetation index was calculated using the mosaicked images, and the ExG images were segmented for individual leaf area calculation (Fig. 2(b)). The fresh weight measurements showed a similar trend to that measured in the previous study in the lettuce plants with low fresh weight and low leaf area. But there were some limitations because the lettuces showed healthy problems (Bacterial soft rot.). In future study, in situ crop height, leaf area and fresh weight will be measured to validate the leaf area and plant height map, and to develop volumetric estimation model of fresh weight based on the height map.

* Corresponding author : T. 02-880-4604, F. 02-873-2049 kimhj69@snu.ac.kr

+ This research was carried out with the financial support of the Open Research Program, Korea Institute of Science and Technology, Republic of Korea

References

- Bendig, Juliane, et al. 2014. Estimating Biomass of Barley Using Crop Surface Models (CSMs) Derived from UAV-Based RGB Imaging. *Remote Sensing* 6(11): 10395-10412.
- Hunt, E. R., Hively, W. D., Fujikawa, S. J., Linden, D. S., Daughtry, C. S., & McCarty, G. W. 2010. Acquisition of NIR-green-blue digital photographs from unmanned aircraft for crop monitoring. *Remote Sensing* 2(1): 290-305.
- Jung, D. H, Park, S. H, Han, Xiongze, Kim, H. J. 2015. Image Processing Methods for Measurement of Lettuce Fresh Weight. *Journal of Biosystems Engineering* 40(1):89-93.

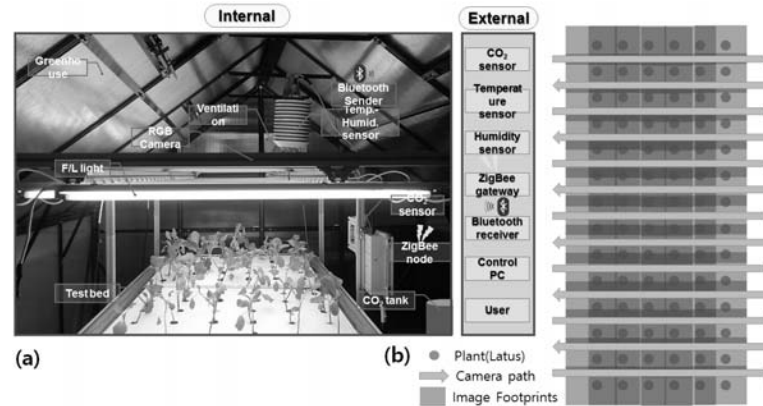


Fig. 1 Overview of Experimental Plant factory (a) and image acquisition method(b).



Fig. 2 Mosaicked images(a), segmented images and leaf area images(b), and generated Height map(c).

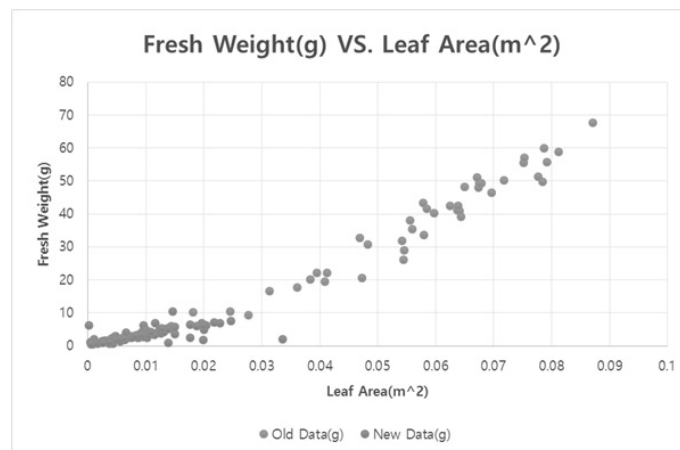


Fig. 3 Relationship between the measured fresh weights and the estimated leaf areas compared with the previous data (Jung et al., 2015).