

Chapter 81

3D Plant Modelling Using Spectral Data From Visible to Near Infrared Range

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ABSTRACT

Plant phenomics research requires different types of sensors employed to measure the physical traits of plant surface and to estimate the biomass. Of particular interests is the hyperspectral imaging device which captures wavelength indexed band images that characterize material properties of objects under study. This chapter introduces a proof of concept research that builds 3D plant model directly from hyperspectral images captured in a controlled lab environment. The method presented in this chapter allows fine structural-spectral information of an object be captured and integrated into the 3D model, which can be used to support further research and applications. The hyperspectral imaging has shown clear advantages in segmenting plant from its background and is very promising in generating comprehensive 3D plant models.

INTRODUCTION

Plant phenomics is an area of plant biology that studies the influence of genetics and environment on both the physical and biochemical traits of plant organisms (Furbank & Tester, 2011). One of the main tasks in this area is dissecting plant function and performance via measurement of plant appearance. Such measurements provide inputs to other key tasks in plant phenomics, including investigating carbon partitioning and photosynthesis in plants as well as finding mechanisms for drought tolerance and flowering behaviour. Therefore, robust and accurate plant measurement methods are of great importance.

The development of sensing technology has enabled many measurement tools such as radar, RGB camera, infrared camera and hyperspectral camera to be embedded in plant observation processes.

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Amongst them, there is particular interest in hyperspectral imaging devices which provide tens or hundreds of contiguous narrow spectral band images indexed by the light wavelength. These images contain rich information on spectral and spatial distributions of distinct surface materials. They enable more accurate and reliable object detection and material classification than using panchromatic or multispectral imagery. As a consequence, hyperspectral imaging techniques have been widely used in remote sensing, environmental monitoring, and surveillance in agriculture, industry and military (Gupta, 2008). When applied to plant research, hyperspectral imaging has shown success in detecting traits of disease or nutrition deficient (Bock, Poole, Parker, & Gottwald, 2010) (Fu, Robles-Kelly, & Zhou, 2006).

Incorporating hyperspectral imaging technology into plant phenomics has many interesting advantages. Firstly, due to its high spectral resolution across the electromagnetic spectrum, hyperspectral imaging is an ideal tool for depicting plant surface materials critical for modelling plant structure and discriminating plants from their complex surrounding environment. This enables the spectral signature of each image pixel to be intrinsically related to the material composition of plant body or its surrounding environment. Secondly, exploring the spatial relationships among the different spectra in a neighbourhood enables more accurate segmentation and classification of the sensed image (Picon, Ghita, Whelan, & Iriondo, 2009). This is important for plant structure modelling in a cluttered environment and for biomass estimation. Thirdly, the fusion of hyperspectral images with data from other sensors provides information that is more comprehensive about plants. This will enhance other important aspects of plant phenomics research, such as automatic photosynthesis analysis that requires both leaves detection and temperature measuring. Fourthly, the wide span of visible to near-infrared bands of the hyperspectral sensor makes it possible to develop an integrated solution for plant phenomics practice so that a limited number of useful bands can be selected to build low cost devices, which will greatly facilitate the adoption of the technology. Finally, hyperspectral imaging associated with chemometric methods can be used to quantify and study the spatial distribution and evolution of particular chemical compounds within plant organs (e.g. photosynthetic pigments or water-soluble carbohydrates).

Despite its advantages in object detection and analysis, research on hyperspectral imaging in computer vision is still very limited. In recent years, thanks to the production of relatively low cost hyperspectral imaging devices, computer vision researchers have started to explore this area. More understanding of the statistical properties of hyperspectral imagery have been reached (Chakrabarti & Zickler, 2011), while some traditional or new computer vision topics have been covered, such as camera sensitivity analysis (Han, Matsushita, Sato, Okabe, & Sato, 2012), feature extraction (Liang, Zhou, Bai, & Qian, 2013), and illumination estimation (Gu, Robles-Kelly, & Zhou, 2013).

Due to the high dimensionality and information-rich nature of hyperspectral data, conventional computer vision and pattern recognition technology cannot be directly applied to hyperspectral imagery. This chapter addresses one of the fundamental problems of computer vision, 3D reconstruction, in the context of plant modelling using hyperspectral images. As far as we know, although some research have already incorporated hyperspectral data into 3D models, such work has not explicitly built 3D models directly from hyperspectral data. The work presented in this chapter attempts to build a 3D model of plant directly from a sequence of hyperspectral images captured in a controlled lab environment. The spectral data is first used to segment plant from its background. Then keypoints are extracted at the boundary of plants which are used to find correspondences between a pair of spectral images. Finally a structure from motion based model is developed to reconstruct the 3D plant model. The initial results show that the spectral data can be used for effective plant segmentation-an essential step for 3D model-

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