

Chapter 26

3D Imaging Systems for Agricultural Applications: Characterization of Crop and Root Phenotyping

Frédéric Cointault

University of Burgundy, France

Simeng Han

University of Burgundy, France

Gilles Rabatel

IRSTEA, France

Sylvain Jay

IRSTEA, France

David Rousseau

CREATIS, France

Bastien Billiot

Roullier Company, France

Jean-Claude Simon

University of Burgundy, France

Christophe Salon

University of Burgundy, France

ABSTRACT

The development of the concepts of precision agriculture and viticulture since the last three decades has shown the need to use first 2D image acquisition techniques and dedicated image processing. More and more needs concern now 3D images and information. The main ideas of this chapter is thus to present some innovations of the 3D tools and methods in the agronomic domain. This chapter will particularly focus on two main subjects such as the 3D characterization of crop using Shape from Focus or Structure from Motion techniques and the 3D use for root phenotyping using rhizotron system. Results presented show that 3D information allows to better characterize crucial crop morphometric parameters using proxy-detection or phenotyping methods.

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INTRODUCTION

In order to optimize crop management and take into account the intra-parcellar variability, precision agriculture has been developed over the past thirty years. It consists in a localized crop management using new technologies such as computing, electronics and imaging. Two types of imagery can thus be used: proxy-detection and remote sensing. The conception of a proxy-detection system is motivated by the need of better resolution, accuracy, temporality and lower cost, compared to remote sensing. The use of computer vision techniques allows obtaining this information automatically with objective measurement in contrast with the difficulty and subjectivity of visual or manual acquisition. However, information is often obtained in two dimensions which does not allow to provide some particular characteristics of plants such as growth or early yield estimation, determination of foliar volume ... Thus, the use of 3D information appears as an essential point.

Two main 3D representation families can be distinguished: the surface and the volume representations.

The first one is composed with 1) the depth maps, in which the value of each pixel corresponds to a distance between the corresponding point in the scene and the acquisition system; 2) the surfels (for surface element), composed of attributes describing a local sample of the surface like its coordinates, texture ...; and 3) the meshing, largely used for 3D representation, group of points defined by their 3D coordinates. The volume representation contains 1) the voxels (for volumetric elements), appellation of 3D pixel constituted with colorimetric information associated with spatial coordinates; and 2) the spherical harmonics allowing a frequency-domain representation of the 3D model in spherical coordinates.

Unlike the active vision, no adding illumination is needed for the “passive” methods to work. In this category of 3D reconstruction methods, we find triangulation methods using several cameras, methods based on image analysis and methods needing particular optics.

The objective of this chapter is not to detail all the existing 3D techniques but rather to explore the use of some of these methods in precision agriculture or viticulture. Thus we propose to present innovations on 3D tools and methods used in agriculture for different applications such as 3D characterization of crop using Depth imaging systems (Billiot et al., 2013; Chéné et al., 2012) or Structure from Motion techniques (Jay et al., 2015; Santos & de Oliveira, 2012) and 3D use for root phenotyping using rhizotron systems (Clark et al., 2011). Results for the different applications, in terms of 3D tools and image processing are presented, discussed, and improvement proposals are given before to detail future research directions.

Background

In agriculture, viticulture or orchard, a lot of researches have been done on the use of 3D information and images (Figure 1).

The design of a 3D acquisition system is required in order to obtain new parameters related to crops. Numerous 3D acquisition techniques exist and they have been the subject of active research for several decades. The overall principle is to determine the shape and structure of a scene from the analysis of the acquired images. The representation of depth information will depend on the type of acquisition technique used, e.g., 3D mesh representation or depth map. In all cases, the imaging methods aim at retrieving numerous parameters that characterize the crop row structure. They must be non-destructive since these measurements have to be carried out all along the plant life. They must also be fast and automatic so that a maximum of data may be processed with a minimum of user interactions. Plant structural information can be accurately retrieved from three-dimensional images that can be computed in several ways.

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