Procedural Geometric Modeling for Plant Phenomics by Blender: Case Study of Maize

○王　浩舟 [1)]，加藤　洋一郎 [1)]，郭　威 [1)]

1) 東京大学大学院農学生命科学研究科，〒113-0032　東京都文京区弥生 1-1-1

Abstract

The plant 3D models are fundamental resources for the computer graphics (CG) industry and provide the basis of digital twin applications for smart agriculture. However, conventional manual modeling is not feasible to describe the individual structural differences among thousands of experimental crops. Hence, procedural modeling has emerged to control model structure by parameters, but the stability and accessibility of these self-designed engines are hard to say user-friendly compared to the commercial modeling software. This study proposes a method that implements parametrically adjustable maize models based on actual scanned 3D data by using the open-source commercial modeling software Blender and testing this method's feasibility. The proposed approach is also expected to be used to generate large numbers of annotated training data and solve the occlusion problem in fields.

Keyword

Programmable modeling, parametric models, geometric nodes

Background

The digital twin in agriculture is expected to increase productivity and efficiency (Nasirahmadi & Hensel, 2022). An accurate representation of the plant 3D model is the fundamental resource for digital cloning the actual farm to the cyber farm to help the growers simulate and predict the field's performance.

There are two main methods to get plant 3D model, modeling and reconstruction (Okura, 2022). The modeling creates non-existent plant model from shape and structure simulation, while the reconstruction builds the model of existing plants.

The manual modeling method is the most common way to get plant models, and some platforms (e.g., <www.poliigon.com/> 2022) also provide commercial plant models. However, this is not suitable for agricultural purposes because agriculture applications expect more from the variation and accuracy of each actual cultivar. It is not realistic to manually model the detailed differences among thousands of plants.

In contrast, the reconstruction method seems more suitable for agricultural applications, and several studies applied technologies like laser scanning or structure-from-motion and multi-view stereo (SfM-MVS) to get accurate maize point cloud models (Gao et al., 2021; Schunck et al., 2021). Those methods use equipment to generate the point cloud of a plant, then run the meshlization process to generate a 3D model. However, they are time-consuming if one wants to reconstruct high-quality that close to actual plants. Moreover, the disorderliness of point cloud outputs also brings difficulties in further data analysis and model adjustment.

Another promising direction is procedure modeling, which is generating or controlling model structure by several self-defined parameters. Industrial applications use it to generate buildings or city blocks by specifying the number of floors, rooms, and streets. Plant communities also developed L-system, which uses strings to generate plant models. To compensate the L-string's readability and usability, the python (OpanAlea, Pradal et al., 2008) and c++ (L-studio|VLab, Prusinkiewicz et al., 2000) programming gramma are integrated to generate the L-string. Previous studies utilize such system to generate simplified maize models to simulate the effects of density (He et al., 2021). While Cieslack et al., (2021) obtained interactive adjustable maize models.

Although previous studies have provided valuable and effective attempts at parametric modeling of plants, the stability and usability of their self-developed platforms are still not comparable to those of commercial platforms. Moreover, their customized data structures are not conducive to cross-software use. Using maize as the first trial material, this study aims to develop a method that can generate a plant 3D model as close as an actual plant that grows in the field using free commercial modeling software, Blender (<www.blender.org/> 2022).

Obtain Maize Point Cloud Data

The maize is grown in the greenhouse in pots, and several coded targets and scalebars are placed before taking images for 3D reconstruction (Fig.1a). The Agisoft Metashape software (<www.agisoft.com/> 2022) was used to build maize point cloud models (Fig.1b). Then maize plant part (Fig.1c) was segmented and organized manually by CloudCompare (<https://www.danielgm.net/cc/> 2022).

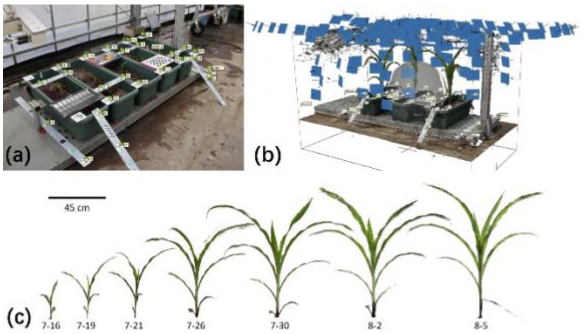

Fig. 1 Time-series maize reconstruction device

Preliminary result of Maize 3D Model

Instead of building the whole maize directly, the maize is separated into several parts called phytomers. Each maize phytomer includes the internode stem with one leaf (Fig.2a). For the leaf part, the points of leaf midrib and two edges are extracted and expressed as blender Bezier curve lines (currently do this by manual). For the internode stem, the leaf base point, internode stem radius, and length are extracted and estimated as control parameters (Fig.2b). Finally, the Blender geometry node and python API are used to assemble the above part into maize phytomer models. The model is adjustable for leaf inclination angle, leaf azimuth angle, and tri-axial scales, etc.,

Although most parts mentioned above on the point cloud are still operated by manual, the feasibility of the method has been demonstrated. The point cloud will be analyzed to build a model automatically using deep learning segmentation and edge detection algorithms.

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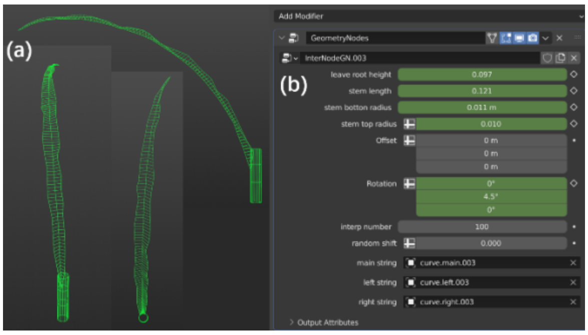

Fig. 2 The internode model and control parameters.

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