Proceedings of the 7th International Conference on Functional-Structural Plant Models, Saariselkä, Finland, 9 - 14 June 2013. Eds. Risto Sievänen, Eero Nikinmaa, Christophe Godin, Anna Lintunen & Pekka Nygren. http://www.metla.fi/fspm2013/proceedings. ISBN 978-951-651-408-9.

Shape reconstruction of fruit tree from colored 3D point cloud

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Highlights: An automatic and accurate method was presented for structure reconstruction of fruit tree from laser scanner measured colored point cloud. The color characteristics of different organs were selected as rules to segment point cloud into small point cloud. A skeleton of the tree was then extracted from some small point clouds, and final 3D reconstruction was achieved by combining some distribution model of leaf and shoot.

Key words: 3D Reconstruction, fruit tree, 3D point cloud, modeling plant structure

INTRODUCTION

Rapid and automatic reconstruction of plant structure is an interesting and challenging topic both in computer graphics and agronomic research. In most applications of 3D modeling for fruit tree, an entire and detailed mesh model is expected to enable potentially further application (e.g. calculating light intersection of canopy, demonstrating the difference between varieties and outside appearance). As such popular methods for modeling plant structure (e.g., L-systems, functional-structural model and interactive design method) will meet difficulties in reconstructing a 3D model of fruit tree with a satisfying accuracy for these kind applications, recently digitizing data from real objects have been used extensively for creating 3D models, and more methods reproduce virtual 3D plant models from real measured data. Electromagnetic digitizers were used earlier to measure the spatial position and orientation of stems and leaves for giving a quantitative assessment to the tree geometry (Sinoquet and Rivet, 1997; Sonohat et al., 2006) However, it is a tedious and time-consuming job in digitizing tree structure by using electromagnetic digitizers, and often not precise enough for accurately capture the detailed organ geometry. Recently non-contact laser scanners have been used for various plant measurement and reconstruction (Kaminuma, et al., 2004; Dornbusch, et al., 2007). Laser scanners enable us to rapidly quantify the surface of an object as a dense set of points. But if an organ or part of the plant is invisible to the scanner, its information will be missed in the captured point cloud. The missing information can be estimated by using existing or statistic knowledge about morphological structure of plants (Xu, et al., 2007). But this will lose accuracy for the measured plant. So these methods are more suitable for digital entertainment rather than agronomic research. In this paper, we aim to provide a method for automatic and accurate reconstructing the structure of fruit tree from laser scanner measured colored point cloud, and demonstrate some experimental results.

MATERIALS AND METHODS

A 10-year-old pear tree was chosen for data measurement at its fruiting stage. And a large range laser scanner (Focus3D 120, FARO Technologies, Inc.) was used to finish the measurement. Three stations scanning around the tree were made to obtain enough points for later reconstruction (see Fig. 1. left).

Fig. 1. Scanning pear tree by using FARO Laser Scanner Focus3D(left:); the measured colored point cloud(right).

Software FARO SCENE 5.0 (www.faro.com) was used to process the multi-station scanned data, which produce the 3D point cloud of the tree from these measured data. Each point also brings a RGB color as such we get a colored point cloud (see Fig. 1. right). We also use this software to remove noise points manually (coming from the ground and other trees) in the colored point cloud interactively.

SHAPE RECONSTRUCTION

The shape reconstruction process includes five steps. Firstly a pre-process was done to the point cloud because there are too many points in the origin scanned points (especially coming from leaves, see Fig.1 Right). A distance based noise points deleting method was used to remove noise points, and this could result in a simplified point cloud.

The second step was to segment the point cloud into several small organ point clouds. In other words we wish to separate different organs from the point cloud of the canned tree. We found that the color of each organ in pear tree is very different to other organs' , as such we can distinguish each organ from the point cloud by using its color feature. Firstly organs of pear tree were classified three categories (leaf, fruit, trunk and branch respectively). Then we calculated the color character of each category by selecting manually 20 points from the point cloud of this kind organ and computing average color value (RGB) of these selected points. The resulted average color value was used as the color character of this kind organ. After all color character of were calculated, a checking process was conducted to the simplified point cloud to check the nearest color character for each point basing on its color. The point cloud was then segment into three small organ point clouds. Fig.2 (left) shows the trunk and branch point cloud. A lot of data-missing could be found resulted from shelter of leaves.

In the next step we target to extract a skeleton of the tree directly from the trunk and branch point cloud. A constrained Laplacian smoothing method (Su et al., 2011) was used to extract the skeleton. Then we generated a skeleton model (see Fig.2 right) from the extracted . Some knowledge about the morphological structure of pear tree were used in this step to improve the skeleton because there are many discontinuous branches in the extracted skeleton. For example, some branches may be apart from the trunk, and one branch may be divided into several segments in the initial extracted skeleton, and these branches need to be connected to form a smooth skeleton of tree.

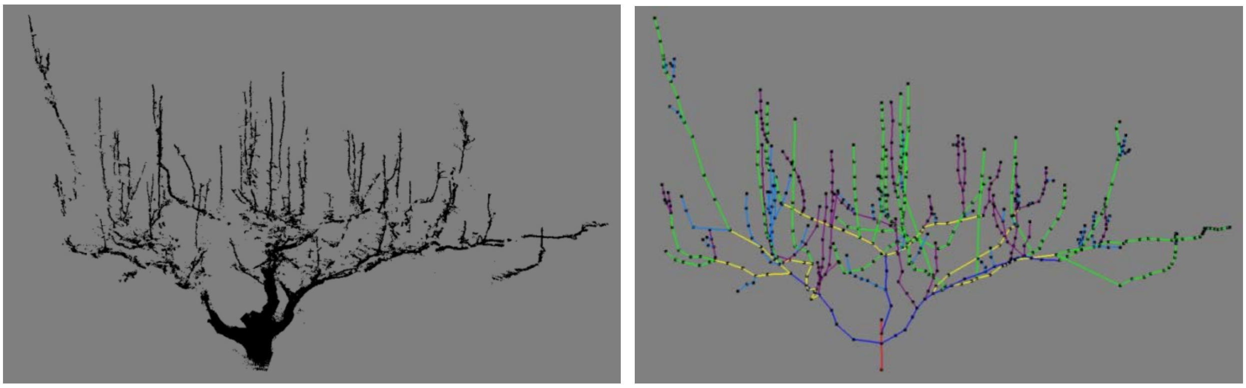

Fig. 2. The trunk and branch point cloud (left); projection vector of internodes (right).

The fourth step was to calculate the information of fruits from the fruit point cloud. A distance-based cluster algorithm was used to further divide the fruit point cloud into small point clouds. And each small point cloud represents a fruit and all points in this point cloud coming from the same fruit. Then the center coordinate of a fruit point cloud was calculated, which would be used as the position of the fruit in the final reconstruction step. The radius of a fruit was also calculated from its point cloud data.

Based on the extracted skeleton and fruit information, we finished the entire reconstruction of the scanned tree. But the little shoots and leaves were still missing in the extracted skeleton, which need to be restored for a complete reconstruction. Currently we addressed this problem by using a knowledge-driven strategy which could repair the missing little shoots and leaves. Concretely, we used distribution models about shoots and leaves based on how locating on different types of branches, which supplys little shoots and leaf model for the extracted skeleton model. In which a leaf model was a mesh surface measured from the real fruit tree by using a hand-held laser scanner.

RESULTS AND DISCUSSION

A pear tree has been reconstructed by proposed method, in which the number of fruit, the conposition and radius of each fruit all were calculated at the fourth step. Five leaf models (with texture mapping) were used in the reconstruction to achieve a more realistic results(see Fig.3).

The automatic 3D reconstruction of a whole plant from laser scanned data points is presently still an open problem.Currently we just use some knowledge about leaf distribution on the canopy to orient the reconstruction, instead of using the scanned leaf point cloud, since it is a very difficult task to restore the 3D surface of leaves directly from the scanned leaf point cloud. And our further study expect to remove errors which may be caused by knowledge-oriented method.

Fig. 3. The shape reconstructed result of the pear tree

Acknowledgments. This work is supported by China National Science and Technology Support Program (No. 2012BAD35B01) and Beijing Science and Technology Project of China (No. D111100001011002).

LITERATURE CITED

Sinoquet H, Rivet P. 1997. Measurement and visualisation of the architecture of an adult tree based on a three-dimensional digitising device, Trees: Structure and Function. 11,265-270.

Sonohat G, Sinoquet H, Kulandaivelu V, Combes D, Lescourret F. 2006. Three-dimensional reconstruction of partially 3D digitised peach tree canopies, Tree Physiology. 26:337-351.

Kaminuma E, Heida N, Tsumoto Y, Yamamoto N, Goto N. 2004. Automatic quantification of morphological traits via three-dimensional measurement of Arabidopsis. The Plant Journal. 38:358–365

Dornbusch T, Wernecke P, Diepenbrock W. 2007. A method to extract morphological traits of plant organs from 3D point clouds as a database for an architectural plant model. Ecological Modelling. 200: 119–129.

Xu H, Gossett N, Chen B. 2007. Knowledge and heuristic-based modeling of laser-scanned trees. ACM Transaction On Graphic. 26(4):19

Su Z, Zhao Y, Zhao C, Guo X, Li Z. 2011 Skeleton extraction for tree models. Mathematical and Computer Modelling，54: 1115－1120.