CORN 3D RECONSTRUCTION WITH PHOTOGRAMMETRY

W. Zhang [a, b, c, *], H. Wang [a, b, c], G. Zhou [a, b, c], G. Yan [a, b, c]

[a] School of Geography, Beijing Normal University, Beijing 100875, China – (wumingz, gjyan)@bnu.edu.cn, wang_haox@mail.bnu.edu.cn, gzhou@odu.edu
[b] State Key Laboratory of Remote Sensing Science, Jointly Sponsored by Beijing Normal University and the Institute of Remote Sensing Applications of Chinese Academy of Sciences
[c] Beijing Key Laboratory for Remote Sensing of Environment and Digital Cities

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ABSTRACT:

Corn is a common crop which is often studied in the applications of remote sensing and precision agriculture. In both cases, it is important to know the geometrical structure of the corn, for example, the diameter and height of stem, the leaf areas and leaf directions. It is convenient to measure these geometrical structural data on a 3D corn model. In order to generate such a corn 3D model, an image-based method is proposed. On the basis of photogrammetry, a 3D corn model is reconstructed from captured images. Considering the features of corn, the proposed solution extracts the boundaries and central vein at first; then these curves are matched and reconstructed to 3D leaves; finally, the 3D leaves and stem are assembled to form an integral 3D corn model. The current results show the proposed method is feasible. But more efforts should be made to improve the automation and practicality of this method.

1. INTRODUCTION

1.1 Overview

The three-dimensional (3D) geometrical structure of plant is very important to remote sensing. With proper 3D vegetation structure, a suitable vegetation model can be developed, and then used in the real scene simulation of remote sensing pixel and the inversion of vegetation biophysical parameters. Sometimes, the 3D geometrical structure parameters are needed to be measured as ground truth to validate the inversion result of remotely sensed data; these parameters include the height and diameter of stem, leaf area index (LAI), leaf angle distribution (LAD) and so on (White, 2007). The 3D geometrical structure of plant is also very important to precision agriculture. In order to study the crop growth or crop type, a precise crop 3D geometrical model should be constructed previously. Another example is automatic farm-produces-harvesting. In this case, the real-time 3D model of plant should be provided to assistant the farm-produces-harvesting robot automatically walking and harvesting.

Some researches have been carried out to model the 3D structure of plant and these methods can be classified as either rule-based or measure-based. Rule-based methods use compact rules or regulations for creating 3D plant model. L-system is one of well-known rule-based plant modelling method; it is widely used in crop growth simulation and tree modelling. Although rule-based method is capable of synthesizing impressive looking of natural plants, it is hard to generate a model that very closely resembles an actual plant under real-world conditions. Measure-based methods directly measure the plant's parameters and then model it. There are several ways to accomplish this work. Traditionally, the plant geometrical parameters are measured using tape and protractor. The tools are the simplest, while the procedure is the hardest and the result is not accurate. Nowadays, more researches are focused on measuring the plants using digital camera, 3D digitizer or LiDAR. With data captured by these instruments, the model can be reconstructed more precisely. But the data processing is more complicated than the traditional way.

1.2 Motivation and Aims

Among these measure-based methods, image-based method, in other words photogrammetry, is the most promising one. Because the instrument of photogrammetry is camera, the cost is much lower than 3D digitizer or LiDAR. Further more compared with the 3D point clouds of LiDAR, the captured images have abundant semantic scene information, which is very helpful to reconstruct the complicated plant model.

As we know, photogrammetry is widely used in modelling the real 3D world. The aerial photogrammetry can obtain the terrain and large-scale buildings, and the close-range photogrammetry is adopted in ground-based 3D survey. However, photogrammetry methods, either aerial photogrammetry or close-range photogrammetry, are mostly applied in simple scene with regular objects in it. For example buildings or workpieces, both have the straight lines or regular shapes. The natural things such as plants remain one of most difficult kinds of object to model due to their complex geometry and wide variation in appearance (Quan, 2006).

The corn is selected as study case, because it has curved leaves. The previous studies generally regard the leaf as simple plane, so we want to do some different research. There are two main parts of a corn model, respectively stem and leaves. The reconstruction of stem is relatively easier; it can be modelled using several cylinders. The difficulty of corn model mainly

* Corresponding author. Tel.: +86-10-58801865; fax: +86-10-58805274.
E-mail address: wumingz@bnu.edu.cn.

lies in leaf reconstruction. As mentioned, the leaf of corn is curved; it can not be represented with a simple plane. Moreover, the appearance of each leaf is similar; it is even hard for a human being to distinguish, to say nothing of computer. It is a challenge to reconstruct the 3D corn model (Chapron, 1993) by photogrammetry means.

In this paper, we proposed a photogrammetry solution to reconstruct the 3D model of individual corn. The paper is organized as follows. In section 2, we introduce the features of corn leaf and the procedure of the proposed image-based method; the leaf boundary extraction algorithm and individual leaf 3D reconstruction algorithm are also described in detail. Section 3 is the current results and discussions such as improving the proposed method taking account of automation and assembling leaves and stem into an integral 3D corn model. Final section is conclusion and future works.

2. METHODOLOGY

2.1 Features of Corn and Reconstruction Strategy

The corn contains several layers; there is a pair of leaves in each layer. There doesn't exist a view angle that leaves in all layers can be seen. We have to reconstruct the leaf models in every layer one by one; every individual leaf models are registered; together with stem model, entire 3D corn model is created.

It should be noticed that the corn leaf consists of three curves: two for the leaf boundary and one for the central vein. The work flow of modelling an individual corn leaf is described as follows.

1. Calibrated cameras are used to simultaneously capture the stereo imagery pairs.
2. Edge extraction operator is applied to all images to extract both two boundaries and one central vein of the leaf.
3. Match the homologous curves among these stereo imagery pairs under the guide of epipolar constraint (Ma, 1998).
4. Compute the 3D curves representing a leaf by space intersection algorithm; the form of 3D curve is cubic B-spline.
5. Select two edges and the central vein to generate triangulated surfaces among them; and the surface of the leaf is represented by these triangulated surfaces.
6. If not all of the leaves are processed, then repeat the step 2 to step 5 to remain leaves.
7. If all leaves are reconstructed, then reconstruct the 3D corn stem.
8. Assemble reconstructed 3D stem and 3D leaves to form an integral 3D corn model.

Figure 1 illustrates the work flow of the proposed method for corn 3D reconstruction.

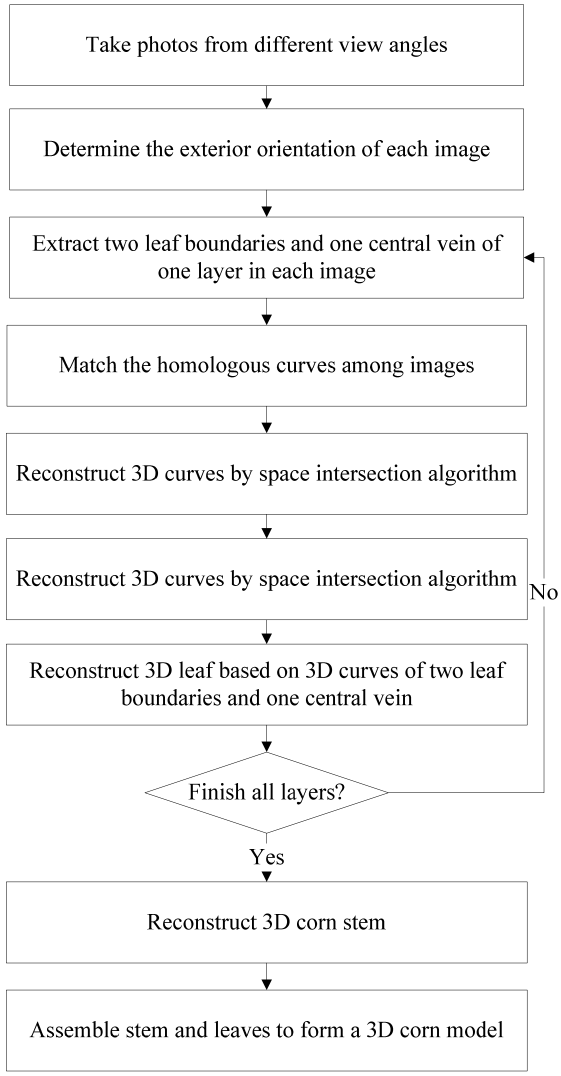

Figure 1. Flow chart of image-based 3D corn reconstruction

2.2 Leaf Boundary Extraction Algorithm

Several images are taken from different view angles; figure 2 is one of them. We will take the circled leaf as an example to demonstrate the leaf boundary extraction algorithm.

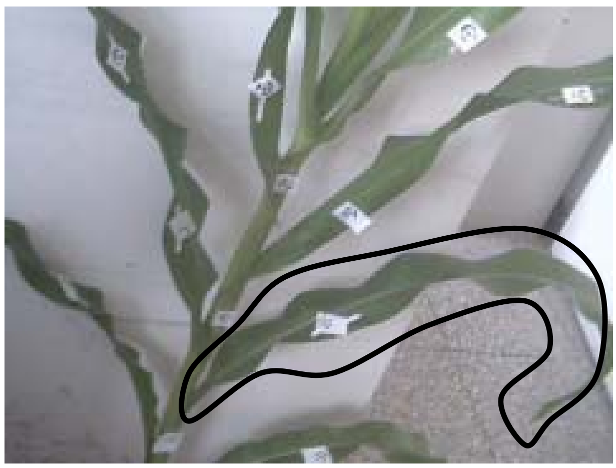

Figure 2. One of images taken from different view angles

First, canny operator (Zhang, 1997) is applied to detect the edges. We can find in figure 3 that not only useful boundaries of leaves are extracted, but also some edges that do not belong to leaves are extracted.

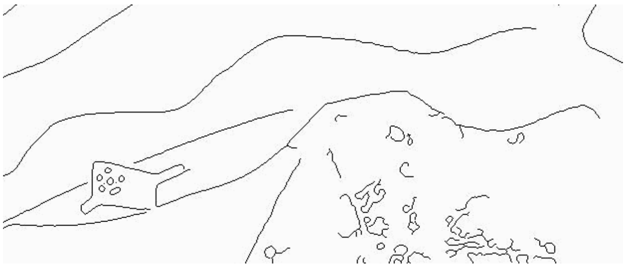

Figure 3. Edges detected by canny operator

It should be observed that the color of corn is green, however the background is not. If we can separate the edges of green leaves from the edges of background, then these unwanted edges can be easily removed. To achieve this goal, the image is changed to CIELAB color space. Figure 4 is the demonstration of CIELAB color model. The three coordinates of CIELAB represent the lightness of the color (L, L = 0 yields black and L = 100 indicates diffuse white), its position between red/magenta and green (a, negative values indicate green while positive values indicate magenta) and its position between yellow and blue (b, negative values indicate blue and positive values indicate yellow).

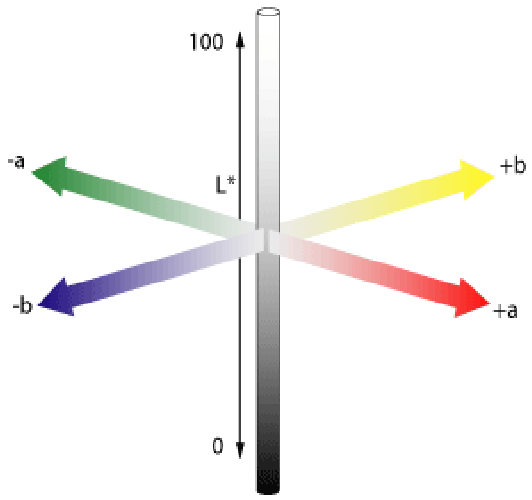

Figure 4. CIELAB color model

When a pixel belongs to an edge, and the value of ***a*** of this pixel is less than zero, then this pixel is guaranteed to be on the edge of leaf and it should be reserved. Otherwise, a pixel is on the edge belonged to background, and it should be removed as noise.

After the above step, there are still some minor noise edges in the image. A slide window is used to detect and get ride of these edges, whose length is shorter than a given threshold. When the edges in the background and minor noise edges are cleared by the proposed procedures, only the edges belonged to leaves should be kept. It should be looked like figure 5.

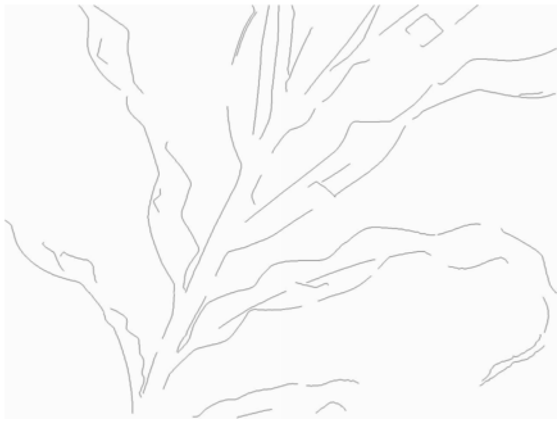

Figure 5. Edges of leaves after noisy edges are filtered

2.3 Leaf 3D Reconstruction Algorithm

The leaf 3D reconstruction algorithm is based on photogrammetry, in other words stereo vision. The principle of photogrammetry reconstructing 3D information from 2D images is that the homologous projections in different images corresponding to the same 3D object should be matched. The matching procedure is under the guide of epipolar constraint.

When the 2D curves in stereo images are matched, the 3D curves can be calculated out using space intersection algrithom. The 3D reconstructed two boundaries and one central vein of a leaf is shown in figure 6.

Figure 6. Reconstructed 3D leaf curves

Leaf surface can be built up based on the reconstructed 3D leaf boundaries and vein. Figure 7 shows leaf surface represented by triangulations

Figure 7. Reconstructed 3D leaf surface

3. CURRENT RESULTS AND DISCUSSIONS

3.1 Current Results

When all leaves and stem are reconstructed, these components should be assembled to form a complete 3D corm model. Two synthesized views of the reconstructed 3D corn model are demonstrated in figure 8.

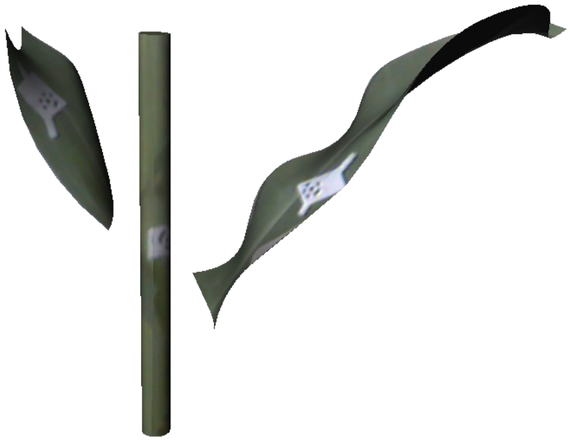

Figure 8. Synthesized view of 3D corn model

3.2 Leaves Registration

It should be noticed that the current reconstructed 3D corn model is simple; it only contains one stem and two leaves. These two leaves are in the same level, and only parts of leaves are reconstructed.

All leaves can not be reconstructed at current stage because we did not take enough images. In the future, more images should be taken from different view angles so that every leaves can be reconstructed.

Different leaves are reconstructed by different stereo pairs, so different leaves have different coordinate reference frame. In order to form an integral 3D corn model, these different coordinate reference frames must be unified. That is to say, all leaves and stem must be registered. It is not easy to solve the registration problem of nature object. More efforts should be paid out to obtain an integral 3D corn model.

3.3 Automation and Practicality

Although the edges of leaves are automatically extracted, but at present the matching procedure still needs human computer interaction. We should pay more attention to improve the automation and practicality of this image-based method. Some feature points may automatically detected to assist the matching procedure. Epipolar constraint will also facilitate the matching procedure.

3.4 Non-destructive Method

Some researchers ever utilized stereo vision to form the 3D corn model and scene (Ivanov, 1995). Two cameras were hung above the corns. Only the top layer leaves can be captured. In order to reconstruct all layers of leaves, the top layer leaves must be cut off when they were taken by cameras. So this is a destructive method.

We want to do something different, we want to develop a non-destructive photogrammetry based method to reconstruct the 3D corn model. Although more efforts will be made to achieve this objective, but the proposed procedure be competent for this goal.

4. CONCLUSION AND FUTURE WORKS

The proposed photogrammetry solution can extract the 3D corn model from imagery. Then the traditional in-situ plant parameters measuring task can be carried out on 3D model. And the 3D plant model can be used to form the simulation scene of remote sensing pixel, or used to study the crop growth, etc. The 3D geometrical parameters measured by proposed solution can also be used as ground truth to validate the inversion result of remotely sensed data.

The research in this paper is only a beginning. There are a lot of works to do in the future. More images should be taken to reconstruct an integral corn model. The accuracy of the proposed method should be evaluated in a proper way. The automation degree of the proposed method should be improved.

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