

3-DIMENSION RECONSTRUCION OF CACTAS USING MULTI-SPECTRAL IMAGES

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ABSTRACT

Using 3D reconstruction result to investigate plant morphology has been a focus of virtual plant. And multispectral imaging has proved to carried biological information in quite a lot work. This paper present a idea to investigate chlorophyll spatial variability of cactus using a bunch of multispectral images. 46 multispectral images are taken at equally distributed angles surrounding the tree and have over 80% overlap. Structure from motion approach has been used for dense point cloud generation mesh building and texture filling.

Keywords: 3-D reconstruction, Multispectral image, Structure from motion

INTRODUCTION

3D reconstruction has been a commonly used method to investigate crop morphology . It uses computer vision technology image matching and shape modeling. There are a lot methods to reconstruct plant's 3D morphology. (DePiero and Trivedi, 1996)reviewed structured light issues in its design, calibration and implementation, and (Hui et al., 2013) uses structured light and VTK for plant 3D morphological visualization and registration they proposes a method ICP(Iterative Closest Point) to improve matching accuracy, and test it with rape leaf, the reconstruction result is visualized using VTK(Visualization ToolKit) in Microsoft visual studio C++ IDE.

J. Phattaralerphong (Phattaralerphong and Sinoquet, 2005)develops a method to reconstruct tree crown volume from a set of eight photographs, the eight photos is taken at correctly N, S, E,W, NE,NW, SE and SW. The process consist of

three steps: 1, estimate tree size; 2. construct a 3D array of voxel; 3, remove empty voxel from the array. The result is tested with 3-dimensional digitalized walnut plant, the result shows that 10cm -40cm voxel shows best correlation with the digitalized data.

Laser scanner uses the phase difference technology, which means a continuous wave is emitted, and the phase difference between the emitted and received wave tells the distance and shape of the object. (Sensen et al., 2009) describe the use of laser scanner for biological surface modeling and analysis in detail in chapter of book *Advanced Imaging in Biology and Medicine* and it can be a promising use for leaf and tree 3-D reconstruction. (Seidel et al., 2011) tests practicability and accuracy of portable laser scanner. They use ZF imager 5006 3D scanner for measuring total above ground biomass, axes' biomass, leaves biomass of 63 experiment trees. The results show a good correlation with traditional harvest data.

(Wu et al., 2014) introduce a way to reconstruct 3D tree without foliage from two images and point cloud is conducted into PROE for FEA (Finite Elements Analysis) dynamics analysis. They add a truck shaker for impact test and a predicted optimal vibration frequency model is established.

All work above focus on the method of shape and architecture reconstruction of plant and their analysis. No one integrates the rich information in NIR spectral zone into plant 3D reconstruction. Multispectral imaging technology originates from remote sensing application for mineral exploration (Vaughan et al., 2005) and now prove to be a powerful way for biological investigation. Multispectral image consists of three or more layers: two in visible and one or more in near infrared region. Image layer in NIR region can tell difference in tissue and chemical component, which is invisible in RGB computer vision system. (Kleynen et al., 2005) develop a multispectral vision system to detect defects in apple. Defect part shows in 750nm and 800nm band image. (Lu, 2004) uses multispectral image to predict apple firmness and SSC (soluble solid content). His system consists of a point light source and a multispectral camera and collects the backscattered light from the experiment apple. The ratio profiles of different bands were used as input to a back propagation neural network to predict firmness and SSC. The result ($r=0.87$ for firmness and $r=0.77$ for SSC) is satisfactory.

Structure from Motion (SFM) is a computer vision way to reconstruct a 3D scene of object from a set of unmatched pictures. It has been widely used in facial reconstruction (Lee et al., 2011), antique modeling (Berninger et al., 2009), archaeology (Stal et al., 2014). It is specially used when the observed scene remains stable and the camera position changes around the object. After analyzing the changes between photos, preselected points are found and match. In this way, a 3D point cloud is created to reconstruct the scene. The SFM starts with random consensus: pictures are randomly marked with points (significant points). Then uses SIFT (scale invariant feature transform) to find match point in each photo and compute image pairing. The last step is to determine the point position in 3D

space. Besides the program, a high-quality camera (usually a SLR camera) and a high processing speed computer with huge RAM are needed. Comparing with laser scanner, this 3D reconstructing method is quite cost effective. Since the data processed is really large and algorithm is sophisticated, processing time can be quite long. The obtained 3D model can be highly detailed and filled with texture. There are quite a few excellent SFM software in use, like open source software (Visual SFM, Bundler), free web services (Microsoft Photosynth), and commercial software (Agisoft Photoscan, Photomodeler). The object of this paper are:

- To illustrate how to take a series of multispectral of digital photos of a biological plant at different angles, do radiation calibration and assemble different layers into a color picture.
- To demonstrate how these color picture be converted into detailed tetureed 3D model, and assemble the accuracy of this model.

RESEARCH DESIGN AND METHODS

The multispectral camera is ADC (Tetracam, America). It can measure visible light wavelength (red, green) and infrared (up to 920nm),. It equips with 3.2 megapixel lens, reaching 2048*1536 resolution and a 4.5 to 10mm CS mount zoom lens. has data processing software Pixelwrench2 to calculate NDVI and SVI index image. This camera has a zoom lens and its aperture is adjustable. Data processing software Pixelwrench assemble separate layer data into a color picture. (Lan et al., 2010) have described its feature and use in detail in their review.

Table 1. ADC technical parameters

Lens	3.2 megaPixel CMOS sensor(2046*1536)
Band	Green, Red and Near Infrared(TM2, TM3, Tm4)
Data format	10bit DCM, 8bit RAW, and 10bit RAW
Shell material	CNC aluminum shell
Lens size	Standard 8mm lens(optional 4.5~10mm zoom lens)
Picture capacity	About 3 MB



FIG 1, Experiment field and illumination condition

The author choose cactus as study object for the following reasons: 1, simple shape, cactus's shape is relatively simple comparing with spermatophyte plants. The one chosen for study grows a little bit quickly and appears like a pillar. The simple shape reduces processing difficulty and improve matching accuracy, in spermatophyte plants, a lot overlaps exist in leaf can lower SFM performance ; 2, easy to get, cactus is usually used to purify office air and they are easy to keep. The one in use is transplanted from another cactus by vegetative reproduction means.

The photos are taken at April 10,2014 in our lab with two sunlight lamp. (30.29838N,120.090737E). Sunlight lamp emits full spectrum light just like sun does. We do it at night to keep arbitrary daylight reflectance away. Two lamp doesn't shine directly on cactus to avoid overexposure. Attention should be paid when shooting photos, too much or strong light will cause the photo overexposed and the background reflection light will interfere with object part in image, while too little light will cause the photo too dark to identify object. Photos are taken at three level: horizontal, 45°, vertical. Notice that, image background needs proper amount of texture, textureless background may result in bad image match and failure in image alignment. We paste a newspaper on experiment desk to add content in background. Photo overlaps should be around 70-80% among same level and 40% between levels, as it shows in figure. 45 photos are collected for 3D modeling.

DATA PREPARATION

Before these photos are put into SFM software, they need to be radiation calibrated and calculate their distortion model to eliminate background interference.

Radiation calibration is done with a Teflon board with 99% reflectance rate. It is a standard Lambert body which all light are diffused with very little specular reflectance. All DN(digital number) are collected when shooting photo and pixel arrangement follows Layer mode, like the figure below. Raw 10bit DCM data will be interpolated in pixelwrench. Then radiation calibration will be done layer by layer in ENVI 5.0(ERSI, America) to generate 8bit color picture as illustrated

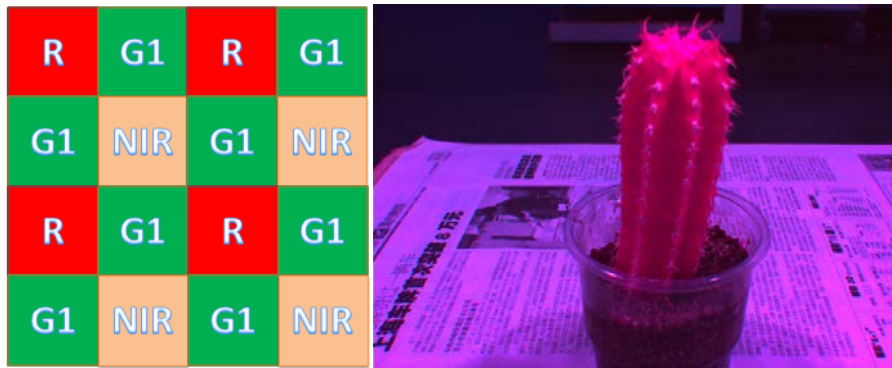


FIGURE 2, PIXEL ARRANGED IN LAYER MODE AND CALIBRATED IMAGE

in equation:

$$I = \frac{I_0 - D}{W - D} \times 255$$

Distortion correction is done by three steps: 1, filming a chessboard at four slightly different angles. Chessboard should fill 100% of the photo; 2, conduct the photos into Lens(Agisoft, Russia) for camera internal parameter estimation, choose Brown's model with k_1 , k_2 , k_3 three parameters; 3, Save calibration model when it is done. The camera internal parameter is $K1=-0.179471$, $K2=0.7892$, $K3=-1.8072$.

After all these steps are done, image and data is prepared for 3D modeling.

3D MODELING AND ANALYSIS

3D modeling is done following Agisoft Photoscan user manual. Agisoft is an advanced image-based 3D modeling software to create professional quality 3D shape from still images. Photos can be taken from any position, providing that the object to be reconstructed is visible on at least two photos. Both image alignment and 3D model reconstruction are fully automated. The program is run on my personal computer with AMD Phenom II 970 2.2GHz×4, 4GB RAM, HD 6650 Graphical card, Windows 8 64bit operational system. Agisoft supports OpenCL acceleration in geometry reconstruction. Computation will cost a lot computer resource. To prevent calculation crash and out of memory problem, all other courses are closed to save memory space. Bigger project will request workstation level computer.

The first step in 3D modeling is photo alignment. After conducts all 46 photos and camera calibration results into program, all images are to be randomly dotted as common points for image feature matching (SIFT) (Fig. 3). Camera position will be estimated and optimized for image orientation based on bundle adjustment (Shi and Tomasi, 1994). We choose 80000 maximum points in every picture, generic pair preselection and high matching accuracy in this experiment. In dense point cloud generation, for that our object structure isn't complex with numerous small details on the foreground, we choose moderate depth

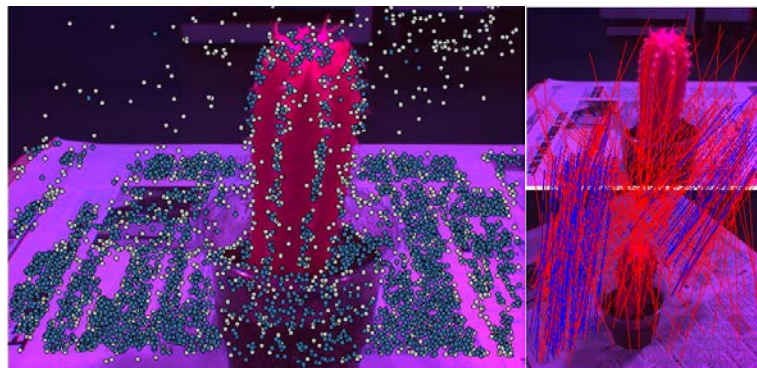


FIG. 3 RANDOMLY POINTED AND MATCHED

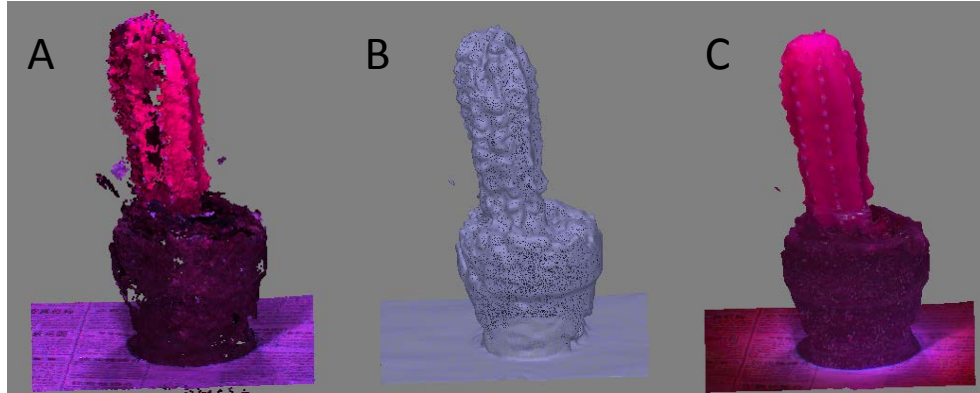


FIG. 4 DENSE POINT CLOUD, MESH AND TEXTURE MODEL
 filtering with high quality in order to be able to sort out important feature. Adjustment and modification is needed to eliminate unwanted background and singular point in dense cloud generation.

The second step is triangulation and building cactus mesh. This process requires the intersection of two known rays in space (Hartley and Sturm, 1997). Mesh is built based on dense cloud and interpolation is enabled. Three nearest points make a triangular and joint triangular generate mesh. 59303 faces with 29844 vertices are rendered in the mesh (FIG. 4, A and B).

The last step is texture mapping. At this stage PhotoScan parametrizes a surface and possibly cut it in smaller pieces, and then blends source photos to form a texture atlas.

RESULTS AND DISCUSSION

Crop plant 3D reconstruction has been successfully applied to investigate plant morphology. This research aims to integrate multispectral image into cactus 3D reconstruction and gets a good result. A Tetracam ADC multispectral camera is used to get multispectral image. After calibrated and converted, these images are conducted into Photoscan for 3D reconstruction. The model generated by a professional software is accurate enough for further spatial analysis.

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