Oct 09, 2020

Photographing Agave for 3D reconstruction using Structure From Motion

In 1 collection

DOI
dx.doi.org/10.17504/protocols.io.bm67k9hn

David S LeBauer[1]

[1]University of Arizona

David S LeBauer
University of Arizona

DOI: https://dx.doi.org/10.17504/protocols.io.bm67k9hn

Protocol Citation: David S LeBauer 2020. Photographing Agave for 3D reconstruction using Structure From Motion . **protocols.io** https://dx.doi.org/10.17504/protocols.io.bm67k9hn

Manuscript citation:

Davis, Sarah C., et al. "Toward systems-level analysis of agricultural production from crassulacean acid metabolism (CAM): scaling from cell to commercial production." New Phytologist 208.1 (2015): 66-72.

Protocol status: Working
We use this protocol and it's working

Created: October 09, 2020

Last Modified: October 09, 2020

Protocol Integer ID: 42943

Keywords: Structure from motion, phenotyping, agave for 3d reconstruction, photographing agave, pictures of an agave plant, 3d models of plant canopy, 3d reconstruction, handful of 3d reconstruction, 3d point cloud, triangular mesh representation of the plant, 3d model, agave plant, software such as agisoft metashape, triangular mesh representation, agisoft metashape, biomass estimation, simulation of light interception, photograph, triangluar mesh, photo, structure from motion, light interception, plant canopy,

Abstract

This protocol was used in 2014 to capture 3D models of plant canopies. The technology has certainly advanced since this time!

Our goal was to obtain a representation of a plant as a triangluar mesh that could be used for phenotyping, biomass estimation, and simulation of light interception. All of the data collected in this effort is available here: https://uofi.box.com/v/ebi3Dcanopy. This folder contains images of five agave plants and a handful of 3D reconstructions https://uofi.box.com/v/dec2014agave.

The general approach is to take photographs of a plant from all angles. This could be as much as sixty photographs, in three rounds of twenty - to give a conservatively high number. This should be done on a day with low wind and difuse light (the sun should not be visible - either fully cloudy or when sun is below the horizon).

Here we describe how to take pictures of an *Agave* plant to generate photos that can be reconstructed into a 3D point cloud or triangular mesh representation of the plant using Structure From Motion software such as Agisoft Metashape.

Note

There are many options for SFM software. We have evaluated a few. The protocol described here has been sucessfully used with Agisoft Metashape. First we describe some of the other software that we evaluated:

In reviewing our options for capturing 3D models of objects, we found there were two major strategies in the field of photogrammetry: structure from motion (SFM), and structured light scanning (SLS). Structure from motion allows the production of 3D models using any off-the-shelf digital camera. It takes a set of photographs that capture the object from many angles and detects features common to multiple pictures, determines how they distort from one image to another, and builds a 3D model based on how the image of the object changes from picture to picture. Structured light scanning employs a more rigid setup of a camera and projector. A known image (typically black and white line patterns) is projected onto the object to be scanned, and software calculates how that projected image is distorted by the object it's projected on to.

Some software products based on structure form motion include Autodesk 123D Catch, Agisoft, Bundler, VisualSFM, and Sure. Products that employ structured light scanning include the Microsoft Kinect (and various software interfaces, including ReconstructMe and Skanect), DAVID 3D Scanner (projector and software package), and a script produced by the MIT Center for Bits and Atoms called Three Phase.

We've tested the Kinect with ReconstructMe, and captured several models with 123D Catch and Agisoft.

Kinect based 3D imaging. We first tested a Kinect camera connected to ReconstructMe software using OpenNI drivers. We had promising initial results - with very little setup, it took seconds to produce a mesh that represented our young soy plant. We were able to save this file as a ASCII (plain text) .ply file of 60 MB (Figure **2**a) In subsequent attempts, however, we realized that our first scan likely hit the limit of the detail this particular device (the Kinect) could provide. It's only a 640x320 resolution camera, and its focal length is designed to capture a person standing several feet away from the video game console, not to get detailed close-ups of an object. Using it to capture 3D models is already a stretch for the technology, it was designed to capture human gestures: gross motor movements, not detailed 3D models. Note: the PrimseSense camera has identical tech specs and capabilities.

123D Catch is a freemium (free downloads up to a certain point) cloud service from Adobe Autodesk accessible using a browser and with an iPad app. The iPad app allows user to collect a set of images, which are then stiched together in the cloud (Figure **2**b). This software offers convenience and ease of use (you can log in from any computer to download the resulting models, and view the models on any computer that runs OpenGL in the browser), but has arbitrary limits imposed by Autodesk: maximum 70 photographs, and fixed size of texture map: limited amount of detail to lessen the computational burden on Autodesk's end (since the 3D model is being generated "in the cloud" i.e. on Autodesk's dime.) The results of 123D Catch is a binary .obj or .stl, so it takes further processing to convert into a plain text file that can be processed by custom scripts. This page contains some examples of 123D Catch output http://ebimodeling.github.io/3dmodeling.html

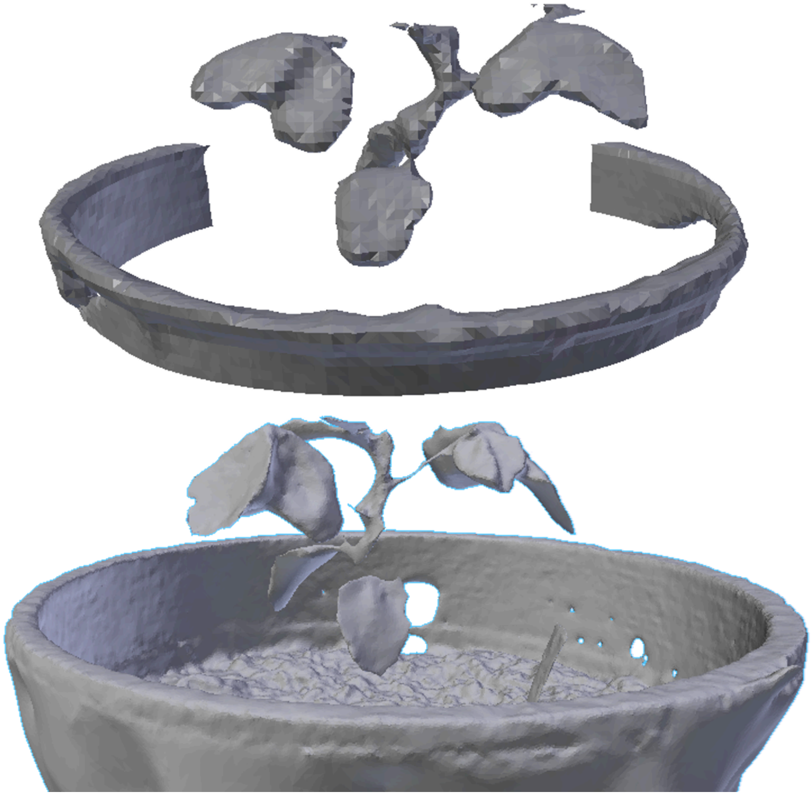

Image taken with Kinect Camera (above) and reconstructed with images takein on an iphone with Adobe's 123D Catch (below) .

Agisoft is software that can be purchased and run locally, allowing us to use our own computational resources (instead of waiting for 'the cloud' to process the result) and giving us much more control of the level of detail we want to capture. There is also no artificially imposed limit on number of photographs, though the more photographs that are processed, the longer the process takes - and it should be noted that this technology is very computationally demanding. Without adaquate processiing power and memory, generating a model will take many, many hours. The software will take advantage of as many processing cores and as much RAM as you can provide it. It can, however, be used on modern consumer machines (high detail models took about 2 hours to produce on my computer equipped with an i7 processor and 8 gigabytes of RAM). The workflow is very simple, and the resulting file can be exported with a variety of options. Most useful is that it can be saved directly as an ASCII (plain text) file with each line simply corresponding to x,y,z coordinates and r g b color values, ready to be processed by custom-built programs.

Image Attribution

Davis, Sarah C., et al. "Toward systems-level analysis of agricultural production from crassulacean acid metabolism (CAM): scaling from cell to commercial production." New Phytologist 208.1 (2015): 66-72.

Materials

- **RGB camera** Agisoft suggests >= 5MP; 123D Catch works with the iPad 3MP camera
- **Old newspaper**, blanket or sheets with designs to provide the software with lines and shapes to use as reference when reconstructing the scene.
- **Weights** or stakes to keep newspaper in place during an outdoor shoot
- Pen or paint to mark North (if preparing for a ray-tracing simulation)
- A method of transfering files such as Box or Google Drive

Troubleshooting

1 place sheets of newspaper, sheets, or other material on the ground around the base of the plant, and in the background. It is most important to obscure other plants.

2 take a photograph from eye level in which the plant takes up most of the frame.

3 move approximately 20 degrees (two steps to the side) around the plant and take another photograph.

4 repeat 1-2 18 times until you have gone in a circle.

5 repeat 1-3, but taking from the ground looking up at the plant

6 repeat 1-3 but from an angle looking down at the plant

7 download the images to a computer and share using Box. Here is a collection of images from a photo shoot in December 2014 https://uofi.box.com/v/dec2014agave