3D Reconstruction of Plant/Tree Canopy from Multiple Views Using Stereo Cameras

Zhijiang Ni, Thomas F. Burks
Agricultural & Biological Engineering

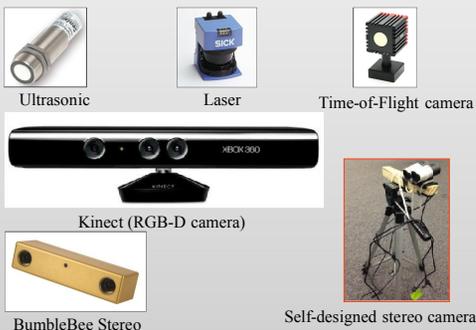UF|IFAS
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MOTIVATION & OBJECTIVES

Motivation
- Tree canopy measurements, including height, width, and volume
- Modeling of tree profile
- 3D reconstruction and Visualization of agricultural crops
- Plant Phenotyping

Objectives
- World coordinate system setup for stereo cameras
- Metric 3D reconstruction and visualization of plant/tree canopy
- Canopy volume calculation based on 3D reconstruction

AVAILABLE TOOLS

Ultrasonic | Laser | Time-of-Flight camera

Kinect (RGB-D camera)

BumbleBee Stereo | Self-designed stereo camera

Comparisons among these tools

	Ultrasonic Laser ToF camera	Kinect	BumbleBee	Self-designed camera
Detection	Distance	Distance + color	Distance + color	Distance + color
Price	Expensive	Cheap	Expensive	Cheap
Usage environment	Indoor + outdoor	indoor	Indoor + outdoor	Indoor + outdoor

MATERIALS

Tools & Materials
- Self-designed stereo cameras & Laptop
- One hexagon box, three plants: croton plant (big leaves), jalapeno pepper plant (median leaves), and lemon tree (small leaves)
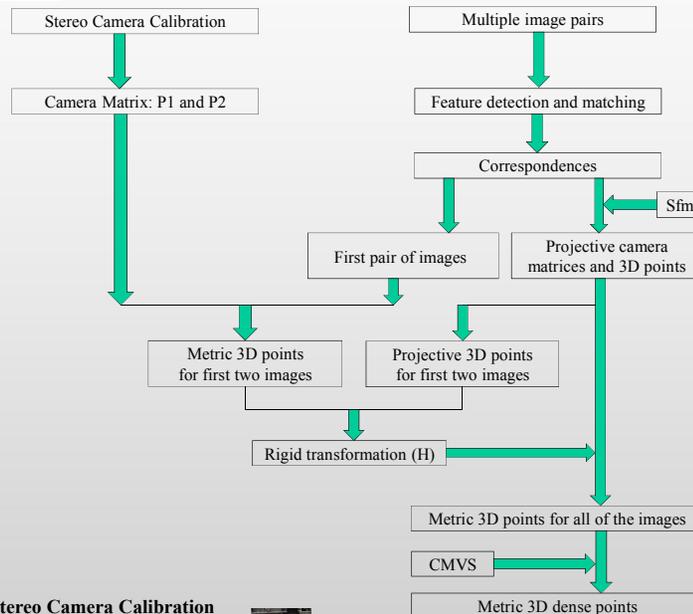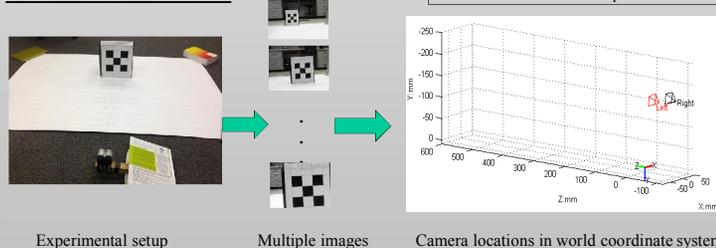

Image Acquisition
Use self-designed stereo cameras to take the images around the target. Adjacent images should have overlap.
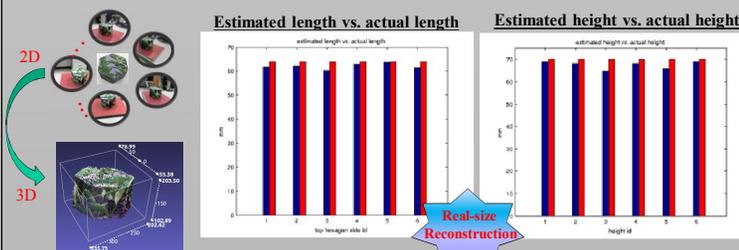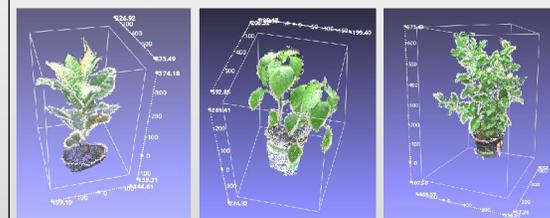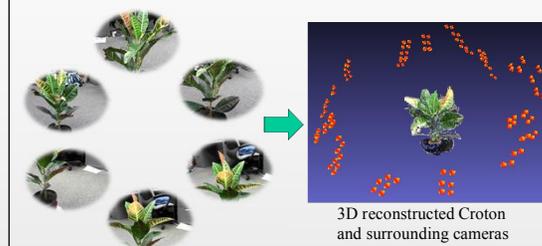
METHODS

Methods

Stereo Camera Calibration → Camera Matrix: P1 and P2

Multiple image pairs → Feature detection and matching → Correspondences ← Sfm

First pair of images | Projective camera matrices and 3D points

Metric 3D points for first two images | Projective 3D points for first two images

Rigid transformation (H)

Metric 3D points for all of the images

CMVS

Metric 3D dense points

Stereo Camera Calibration

Experimental setup | Multiple images | Camera locations in world coordinate system

CONTROL TEST RESULT

2D → 3D

Real-size Reconstruction

Estimated length vs. actual length

Estimated height vs. actual height

EXPERIMENTAL TEST RESULTS

3D Reconstruction and Visualization

3D reconstructed Croton and surrounding cameras

Reconstructed Croton with bounding box | Reconstructed Pepper with bounding box | Reconstructed Lemon with bounding box

Discussion
From reconstruction results of these three plants, we can see that all leaves of the croton were fully reconstructed due to its big leave size and its sparseness. The leaves of pepper plant is also well reconstructed due to median leaf size and its sparseness. But for the lemon tree, some leaves were not reconstructed due to the leaves' density. But for all these three targets, the reconstruction is real size. The texture were also well presented.

Volume Calculation
Method to calculate the volume of complicated plant/tree canopy: Divide the bounding box into small voxels, if there is one or more than one 3D points in a voxel, keep it; otherwise delete this voxel.

Original bounding box with all voxels | Voxels after deletion

Volume of these three plants

	# of Voxel hits / # of total 3D points	Voxel size (mm³)	Volume (mm³)
Croton	16156/19579	28.46	1.23×10^6
Pepper	28591/38773	12.61	3.61×10^5
Lemon	48609/96680	3.76	1.83×10^5

CONCLUSIONS

✓ Stereo cameras calibration in world coordinate system
✓ Metric (real size) 3D reconstruction from multiple images
✓ Canopy volume calculation using voxel