3D plant morphology in the field: experiments with a consumer LiDAR device

Dewi Endah Kharismawati*, **Chimdi Walter Ndubuisi**, and **Toni Kazic**

Dept. of Electrical Engineering and Computer Science, University of Missouri, Columbia, USA
Missouri Maize Center
Interdisciplinary Plant Group
Plant Science Foundry

Keywords: 3D reconstruction, plant morphology, plant phenotyping, LiDAR, field crops

Abstract: Agricultural 3D reconstruction is often achieved by using Structure from Motion of high resolution RGB imagery from UAV or hand held cameras (Che et al., 2020; Guo et al., 2021). Light Detector and Ranging (LiDAR) is a depth sensor-based device that uses a pulsed laser to measure distances to the surfaces of objects. It is less sensitive to lighting conditions than RGB imagery, making it a good candidate for agricultural and outdoor applications. Morphological phenotypes, such as plant height, leaf pathologies and dimensions, and the status of reproductive organs are important to assess as the plant develops for research in genetics and crop improvement and for managing production fields (Kelly et al., 2016). In principle, LiDAR data could provide detailed morphological information for a variety of crops, and the dimensions obtained from LiDAR-based morphological models could be used to correct morphological models built from other data. However, reflections from beneath the canopy, for example for stems and lower leaves, are currently difficult to resolve underneath the complex occlusions. The recent availability of consumer-grade LiDAR devices on Apple iPhones and iPads might provide a way to collect higher resolution data close to the plant, rather than imaging through the canopy. Gollob *et alia* compared data on the diameter of trees at breast height (dbh, a standard forestry measure) collected with a 2020 iPad Pro to standard methods and found remarkably good agreement (Gollob et al., 2021).

We explored the use of a 2021 Apple iPad Pro, different methods of data collection, and different free apps on maize, soybeans, and common field weeds late in the 2021 field season. These plants have very different architectures: maize is tall, with relatively few, large, fairly thick, and quite narrow leaves; soybeans are short and bushy, with many small, thin, roughly circular leaves. Cocklebur, a common field weed, is intermediate: taller than most soybean varieties, with much larger circular and thicker leaves, and a more open, branching stem. The two best apps we found were Scaniverse and 3D Scanner App. For 3D Scanner App, the best settings were high resolution (5mm), maximum depth 5m, confidence level high or medium (depending on the plants), and masking set to off. For Scaniverse, the only settable parameter was the maximum depth, which we set to 5m, and we have no information on the app's default point cloud resolution. We scanned isolated maize plants from the ground to the tassel, walking around the plant to capture data at different heights and distances from the culm. For soybeans and cocklebur, we scanned from the top of the canopy downwards, circling around the plant. We imaged these at distances ranging from 5cm – 1m, while we imaged maize at about 3m from the culm. All scans used an oblique angle and included the soil for ample ground reflections.

Scans of cocklebur and soybeans show their canopies reflect the LiDAR well, but the lower leaves and the stems were invisible to LiDAR. When set to high confidence, 3D Scanner App returned fewer features than at medium confidence; conversely, its 3D reconstruction was better at the higher confidence. Scaniverse's default higher confidence level detects fewer features, producing a poorer 3D reconstruction than 3D Scanner App. In contrast, maize was scanned better with Scaniverse than with 3D Scanner App. Plant features more

proximal to the culm, such as the ear and the leaf sheath, were reconstructed better than more distal portions of the leaves. Senesced maize — culms, ears, and leaves — reflected better compared to younger, greener leaves and tassels. These results are consistent with prior observations: thicker, denser plant structures reflect better than thinner, less dense ones. As maize senesces, it dries and shrinks, likely increasing the density of the plant material. For the bushier plants, we could partially compensate for the canopy occluding the laser by scanning alongside the plant at close range, but this strategy failed with maize. Reconstruction may be better with better instrumentation, but it seems likely that better models of plant reflectances, gap probabilities, and leaves will be needed for each crop species of interest.

References

Che, Y., Q. Wang, Z. Xie, L. Zhou, S. Li, F. Hui, X. Wang, B. Li, and Y. Ma (2020). Estimation of maize plant height and leaf area index dynamics using an unmanned aerial vehicle with oblique and nadir photography. *Ann. Bot. 126*(4), 765–773.

Gollob, C., T. Ritter, R. Kraßnitzer, A. Tockner, and A. Nothdurft (2021). Measurement of forest inventory parameters with Apple iPad Pro and integrated LiDAR technology. *Remote Sens. 13*(16), 3129.

Guo, Y., H. Wang, Q. Hu, H. Liu, L. Liu, and M. Bennamoun (2021). Deep learning for 3D point clouds: a survey. *ieeepami 43*(12), 4338–4364.

Kelly, D., A. Vatsa, W. Mayham, L. Ngô, A. Thompson, and T. Kazic (2016). An opinion on imaging challenges in phenotyping field crops. *Mach. Vision Appl. 27*, 681–694.

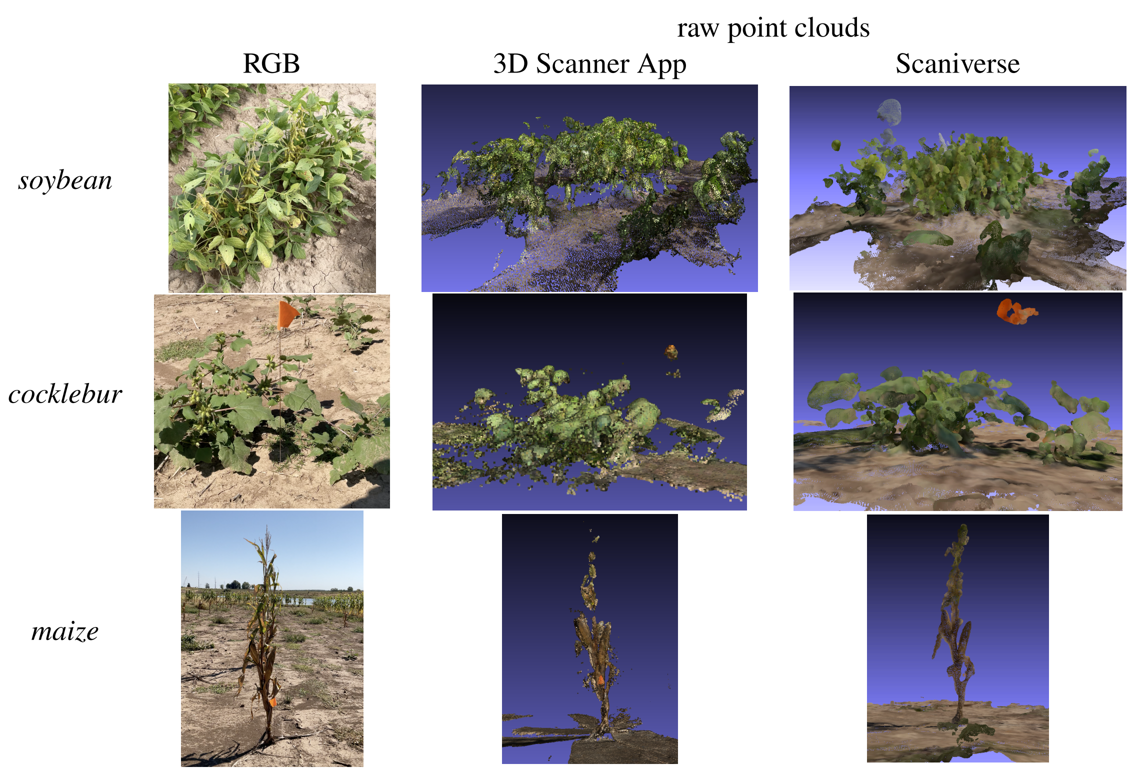

Figure 1: RGB images from the video and raw point clouds from the two apps. Orange marking flags are visible in the cocklebur and the RGB and 3D Scanner App maize panels.