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# High-throughput robotic plant phenotyping using 3D machine vision and deep neural networks

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## 1 Background

**Current major gap**

- Plant architectural traits play an important role in photosynthetic efficiency and plant productivity.
- The traditional way to quantify plant architecture is by manual measuring, which is labor-intensive, time-consuming, and inaccurate.



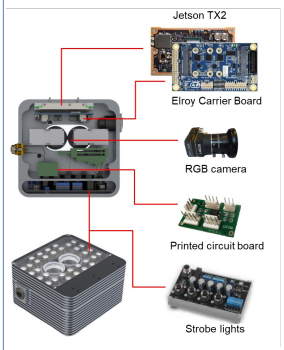

## 2 Development of PhenoStereo

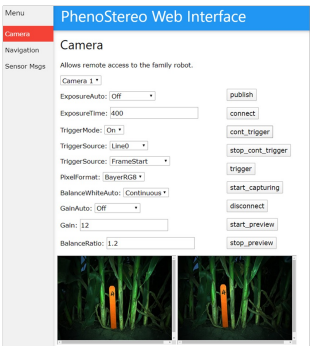
**Challenges for imaging**

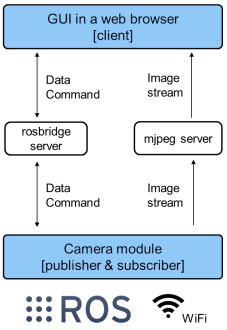
- Short working distance (~20”)
- Varying illumination conditions
- Wind conditions
- Canopy overlapping and occlusions
- Complex background

**Our solution**

**A custom-built stereo imaging module with strobe lighting**



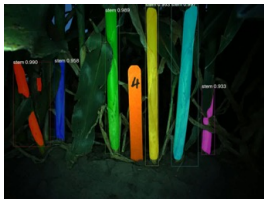




## 3 Measurement of Stem Diameter

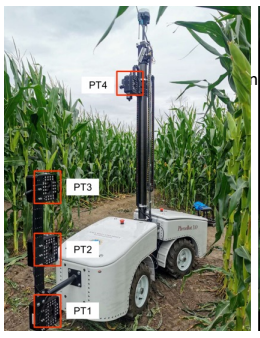
**Key features**

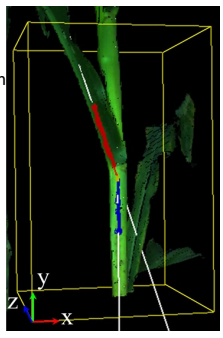
- Wireless control: ROS - based
- Onboard storage
- High shutter speed: 0.3 ms
- High frame rate: 3.2 MP, 14 FPS
- Light illuminance: 31000 lux @ distance 0.5 m
- Millimeter-level accuracy

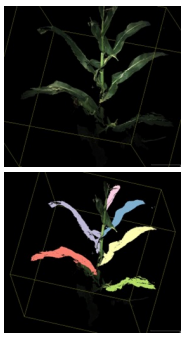



## 4 Phenotyping of Maize Plants

- PhenoBot3.0, equipped with multiple layers of PhenoStereo cameras, is capable of capturing high-quality stereo images of plants in the field.
- A series morphological traits were derived by 3D modeling process and deep neural networks.







## 5 Final Remark(s)

❑ Customized a high-throughput stereo system for field-based plant phenotyping.
- High-quality, high-sharpness stereoscopic images.
- Robust to various environmental conditions.

❑ Developed a series of automated image processing pipelines to characterize organ-level phenotypic traits of sorghum & maize plants in the field. The image-derived traits were highly correlated with ground truth.
- Node height: $r > 0.992$, MAE < 3.5 $cm$
- Leaf angle: $r > 0.876$, MAE < 5º
- Leaf area: $r = 0.846$, MAE = 114.868 $cm^2$
- Leaf length: $r = 0.838$, MAE = 9.675 $cm$