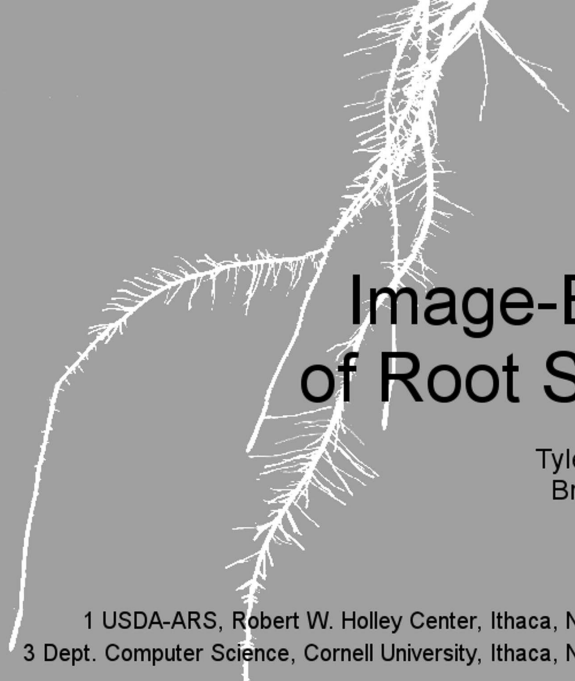
AGU Fall Meeting 2016
B54D: Revealing the Hidden Half:
Advances in Imaging and Quantification of
Plant Roots and Root-Soil Interactions II



Next Generation Image-Based Phenotyping of Root System Architecture

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"The spatial distribution of root systems within the soil can impact the efficiency for carrying out certain physiological functions" (Piñeros et al., 2016).

Understanding the role of root system architecture (RSA) in regards to:

- water and nutrient acquisition;
- stress tolerance;
- biological carbon sequestration

of crops and linking RSA traits to the underlying genetics that control them.

- Eight years of digitally imaging crop root systems have shown successful 2D and 3D RSA trait analysis (e.g., Clark et al., 2011; Hund et al., 2009)
- Numerous specialized image processing platforms exist for characterizing traits (e.g., www.plant-image-analysis.org; Lobet et al., 2013)

However ...

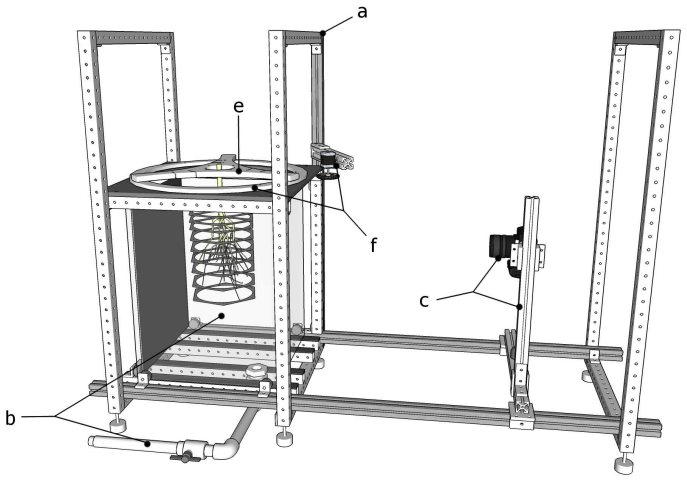
Few studies provide a means for data acquisition, storage and preservation.

We propose the Plant Root Imaging and Data Acquisition (PRIDA) framework.

- Facilitates the *acquisition*, *consolidation* and *preservation* of data with experimental procedures necessary for the reproducibility of results
- Enables the *accessibility* of these data including: image visualization, searchable metadata, attribute editing, and data extraction
- Affords a flexible design to meet various project requirements
- Consists of *imaging apparatus*, *control system*, and *interface* software with graphical user interface

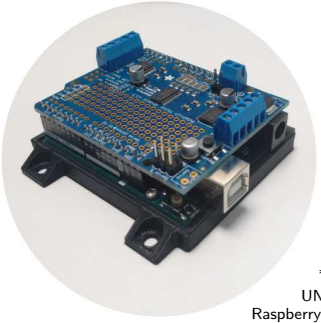
A prototype of the digital root imaging apparatus.

(a) Structural Framing
(b) Imaging Tank and Drain
(c) Camera and Mount
(d) Lighting (not pictured)
(e) Plant Support System
(f) Motor and Bearing



"High performance" and "high portability" controls for UNIX-like systems.

- High performance on PC
  - Arduino + Stepper Shield
  - Better throughput



- High portability on Raspberry Pi
  - Adafruit Stepper HAT
  - Low power and low cost

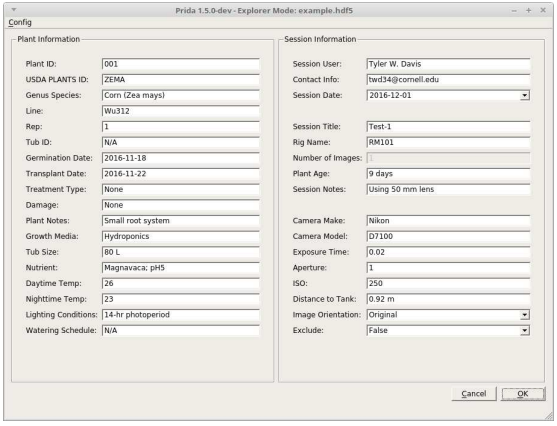
* Arduino is a trademark of Arduino LLC;
UNIX is a trademark of The Open Group; and
Raspberry Pi is a trademark of the Raspberry Pi Foundation

The Plant Root Imaging and Data Acquisition (PRIDA) Software
https://bitbucket.org/usda-ars/prida_one/

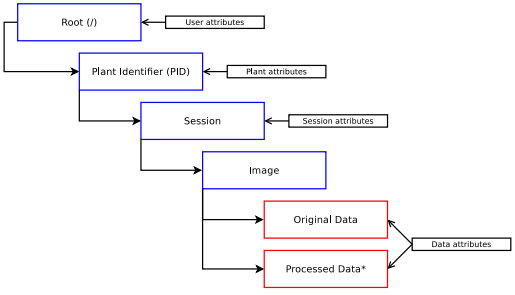
- Unified camera capture and motor control
- Self-contained images and experiment data (HDF5)
- Graphical user interface (Qt® version 5)
- Supports multiple image files
- Source code, user manual and developer guide
- Executable binaries and distributable virtual machine

*Qt is a registered trademark of The Qt Company Ltd. and its subsidiaries

- User input to software:



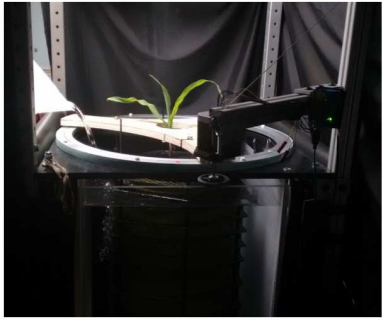
- How it is organized in HDF5:



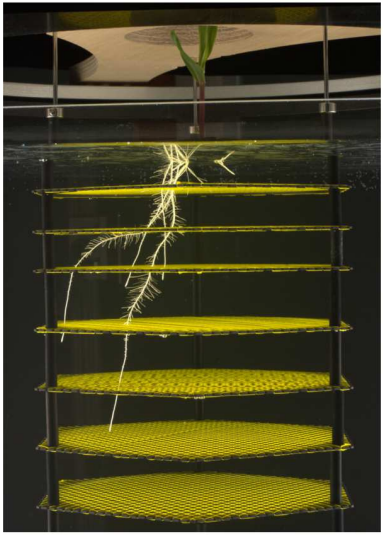
*For example, image thumbnails.

(a) Computer controls and imaging "darkroom"
(b) Topping off the water in the imaging tank
(c) Roots of nine-day old maize

(a)

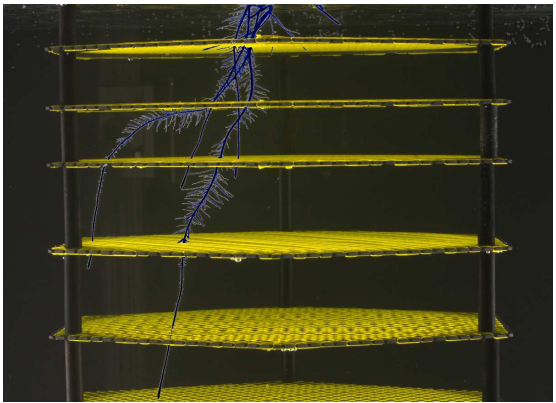


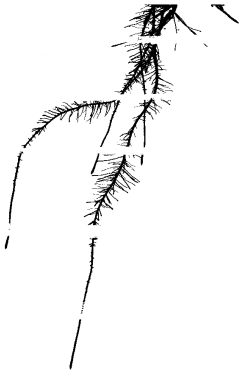
(b)



(c)

Root identification (i.e., mesh and background subtraction):





Software improvements:

- Analysis features (e.g., gap-filling, root skeletonization)
- Camera calibration
- Data portability
- Hardware controls (e.g., ramping motor speed, canceling image sequences)
- GUI features (e.g., improved metadata searching, on-the-fly configurations)

Hardware developments:

- Multiple imaging cameras (i.e., viewing through the mesh)
- Range finder (i.e., measuring distance between camera and tank)
- "Darkroom" fixtures

- Clark, R. T. et al. (2011). "Three-dimensional root phenotyping with a novel imaging and software platform". In: *Plant Physiol* 156.2, pp. 455–465.
- Hund, A., S. Trachsel, and P. Stamp (2009). "Growth of axile and lateral roots of maize: I development of a phenotyping platform". In: *Plant Soil* 325.1, pp. 335–349.
- Lobet, Guillaume, Xavier Draye, and Claire Périlleux (2013). "An online database for plant image analysis software tools". In: *Plant Methods* 9.1, p. 38.
- Piñeros, Miguel A. et al. (2016). "Evolving technologies for growing, imaging, and analyzing 3D root system architecture of crop plants". In: *J Integr Plant Biol* 58.3, pp. 230–241.

Thank you for your attention.

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