PlotWorkspace: An Interactive Visual Analytics Tool for Field Phenotyping Data

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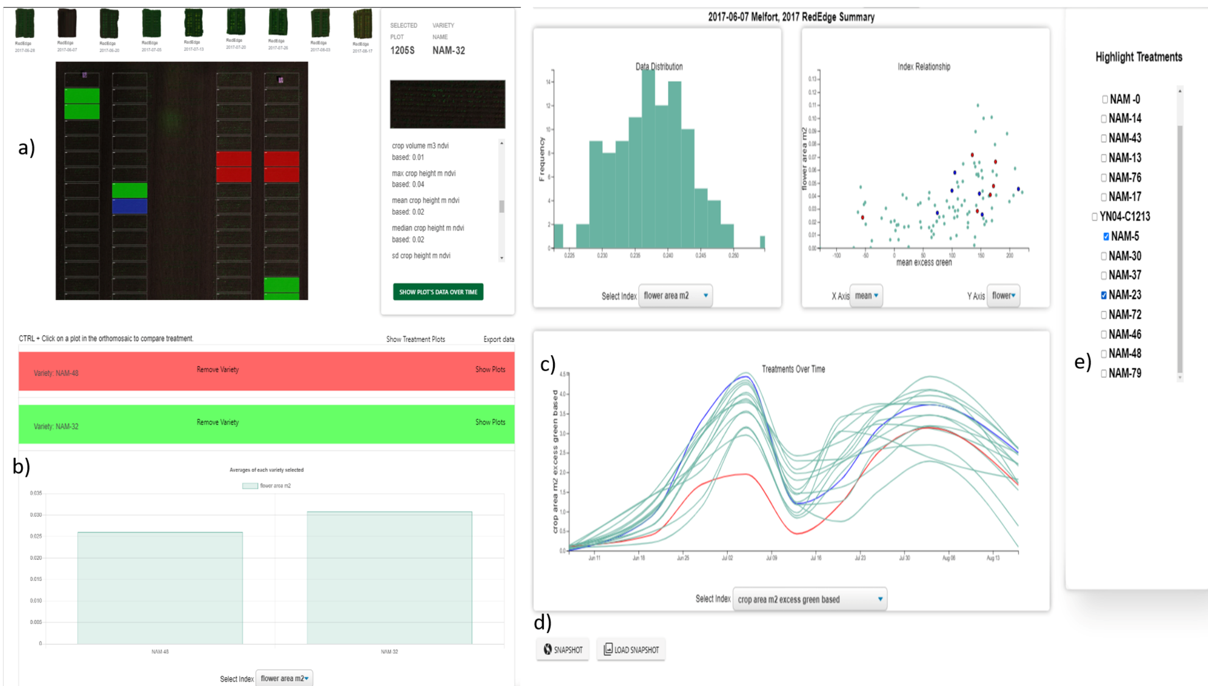

Figure 1: Different views and features of our visual platform: a) Users can select specific plots for easy access to data values. b) Data comparisons between plots or replications c) Visualization of data values across a growing season d) Snapshot feature to store and share visualization states. e) Filter panel to refine the visualizations in real time.

Abstract

Plant and soil science researchers seek to answer questions about crops by analyzing field data collected over growing seasons. High-throughput UAV image-based methods have increased the availability of image-based phenotyping data. Current tools for visualizing and exploring data gathered about a field trial, however, have not kept with pace with the increasing availability of high-resolution imagery, and are limited in their capacity. We present PlotWorkspace, an interactive visualization tool with support for image retrieval and viewing, simple access to data values for selected plots over time, comparison and visualization of data values between plots or replications, visualization of data across a growing season, and support for collaboration.

Index Terms: H.5.2 [User Interfaces]: User Interfaces—Graphical user interfaces (GUI); H.5.m [Information Interfaces and Presentation]: Miscellaneous

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1 Introduction

Over the past decade, plant phenotyping – the study of an organism's traits and how these interact with its environment – has gained considerable attention, which has resulted in an increased requirement for reliable and timely data analysis platforms to support crop phenotyping programs [2,6]. Traditional methods of measuring crop phenotypic characteristics are based on visual ratings or manual assessments, which are time consuming, labour intensive, and prone to human error [3]. Recent high-throughput phenotyping platforms such as unmanned aerial vehicles (UAVs) paired with image detection and segmentation techniques offer a low-cost alternative capable of extracting plant phenotype information from individual breeding or research plots with greater operational flexibility [1,3,5].

High-throughput UAV image-based methods have resulted in an increased availability of high-resolution image-based phenotyping data. While some aspects of phenotyping data comparisons are computational and can be automated, expert human judgement is vital for comparative analysis and hypothesis generation, and visualization tools can assist researchers in these tasks. Complex analytical tasks mean that researchers need access to systems that can support a wide variety of exploration, interaction, and collaboration activities. However, current tools for visualizing and exploring data gathered about a field trial are limited in their capacity and do not offer the ability to compare data across treatments, varieties, or locations.

To address this gap, we have been working with a group of crop researchers to understand the interactive and visual requirements needed to support their crop phenotyping activities. In collaboration with these experts, we identified requirements for interactive phenotyping visualizations that are not supported by current visualization tools. Based on these requirements, we developed the PlotWorkspace tool, which offers support for image retrieval and viewing, easy access to temporal crop data, comparison and visualization of data values between plots or replications, visualization of data values within or across growing seasons, and scoring and annotation tools that add information about plots with support for collaboration and sharing of information.

Our tool enables these activities through the interactive exploration of a trial's imagery data by letting users explore an interactive overview of the field, allowing users to select plots (for easy access to specific data values) or groups of plots (to compare treatment results). Comparison of results is available through histograms, scatterplots, and time series visualizations. PlotWorkspace has been used by our collaborators (as well as by numerous other researchers around the world) as part of a larger image-processing pipeline for field data. We carried out initial real-world evaluations of our tool to assess its success in meeting the visualization and interaction requirements of expert users. Our experiences with the visualization system and its initial evaluation provide several contributions that can be valuable for other interactive phenotyping visualizations systems.

2 Requirements for Phenotyping Exploration

To gather real-world design requirements, we have been working closely with a team of researchers from a crop breeding program. We initially informed our design through interviews with this group to understand their tasks and refine interaction requirements. To improve our design, over the past year, one of the visualization researchers in the group undertook a *design by immersion* approach [4], primarily through observations of domain experts in their day-to-day visualization and analysis tasks. An important requirement of the initial observation period was that we did not alter their normal data analysis process in any way. After the initial period, however, the visualization researchers were involved in collaborative data analysis through the development of a visual platform that assists researchers in deriving results through hypothesis testing. Our discussions and collaborations with the research team led to the following major requirements for interactive visualization systems for phenotyping data:

R_1 **Image retrieval and per-plot viewing:** Traditional methods of measuring crop phenotypic characteristics are based on visual ratings or manual assessments. Researchers need to be able to access their field images and visually inspect individual plots.

R_2 **Easy access to data values:** Insights about a crop's performance can be gained from data values generated from computer vision analyses. These results must be easily accessible in data analysis platforms.

R_3 **Dynamic comparison and visualization of data values between plots or replications:** Field studies involve complex trial designs and field layouts. Researchers must be able to compare results between plots, replications and locations.

R_4 **Hypothesis testing through temporal visualizations:** Field studies are conducted across a growing season, spanning multiple months. Monitoring crop growth and the ability to track key temporal events such as flowering in a growing season is essential. Systems should then support the visualization of data values within or across growing seasons.

R_5 **Link to external analyses through data download:** To support researcher's activities, platforms should link to external analysis tools with downloadable charts and data for use in publications and offline analyses.

R_6 **Annotation and Collaboration support:** Analysis of field trials require scientists to explore several scenarios and results through the analysis tool. Fields can be very large, with many involving hundreds of individual plots and multiple treatments. Analysis tools therefore need to include a permanent record of explorations to enable communication between collaborators and to enable revisitation of potentially-interesting locations and results during exploration.

3 Implementation and Initial User Evaluation

PlotWorkspace is an interactive web tool that has been operational for approximately one year as part of a larger image analysis pipeline for crop data. Our main collaborators have used it to visually inspect their field imagery, and we have observed interactions such as selecting specific plots for viewing and zooming into the image to visually inspect a crop's properties (e.g., looking for pre-emergence early in a season, or assessing crop damage in a field trial that tests herbicide resistance). Other initial uses include inspecting crop metrics for outliers, comparing the results of two treatments (Fig 1 b) and storing a visualization state for future reference.

4 Conclusion and Future Work

Plant and soil science researchers seek to answer questions about crops by analyzing field data collected over growing seasons by comparing data from plots, treatments, replications, and locations of field trials. PlotWorkspace has shown the possibility of a cohesive system that offers dynamic visualizations and simple interactive methods to access and compare data values from high-resolution image-based phenotyping data emerging captured through high-throughput UAV methods. As a venture into the space of collaborative data analysis and visualizations, PlotWorkspace has made it easy to share insights and data exploration actions. We are encouraged by the intial adoption of PlotWorkspace, and we plan on conducting a more extensive analysis of PlotWorkspace's use 'in the wild' and plan to open source the tool beyond our internal analysis pipeline.

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