FruitPhenoNet: Fruit Detection From Hyperspectral Imagery Using Deep Neural Networks For Temporal Plant Phenotyping Analysis

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Motivation

This research aims to detect fruits that aren't discernable in RGB images and compute fruit-based phenotypes. Specifically, the efficacy of hyperspectral imagery is examined. These images capture a broad range of wavelengths at narrow intervals. A plant phenotype is an observable characteristic resulting from the interaction between a plant's genetic makeup and its environment. Findings show that detecting green fruits in RGB images can be challenging. However, these same fruits are clearly visible at specific wavelengths in hyperspectral images (Fig. 2).

Research Contributions

- A novel fruit detection algorithm using hyperspectral imagery
- A set of new fruit-based phenotypes and the demonstration of their efficacy in response to stress: yield, size, shape, location, and growth rate
- FruitPheno Dataset: A public image dataset that captures their growth, including vegetative and reproductive stages, and a set of over 500 labeled pepper images to spur research advancement through new algorithm development

FruitPheno Dataset

This dataset includes 500+ labeled images from 14 pepper plants of the *Fooled You* cultivar at three different side-views over the course of its growing period. Seven plants are in the drought-stressed treatment group, and seven plants are in the well-watered treatment group. The hyperspectral images capture the electromagnetic spectrum at wavelengths between 546 *nm* and 1700 *nm* at 4.7 *nm* wavelength intervals.

FruitPhenoNet: Steps

- Identify wavelengths where fruits are clearly separable in the hyperspectral images
- Retrieve the images at these wavelengths from the hyperspectral images for analysis
- Create a training set by labeling fruit with bounding boxes
- Train FruitPhenoNet: a deep learning-based object detector (e.g. YOLO) using the labeled fruit images
- Use FruitPhenoNet to identify fruits in a given hyperspectral image
- Perform non-maximum suppression to choose the optimal bounding boxes
- Remove mislabeled bounding boxes that don't contain a fruit
- Calculate phenotypes from the identified fruits in the inputted images

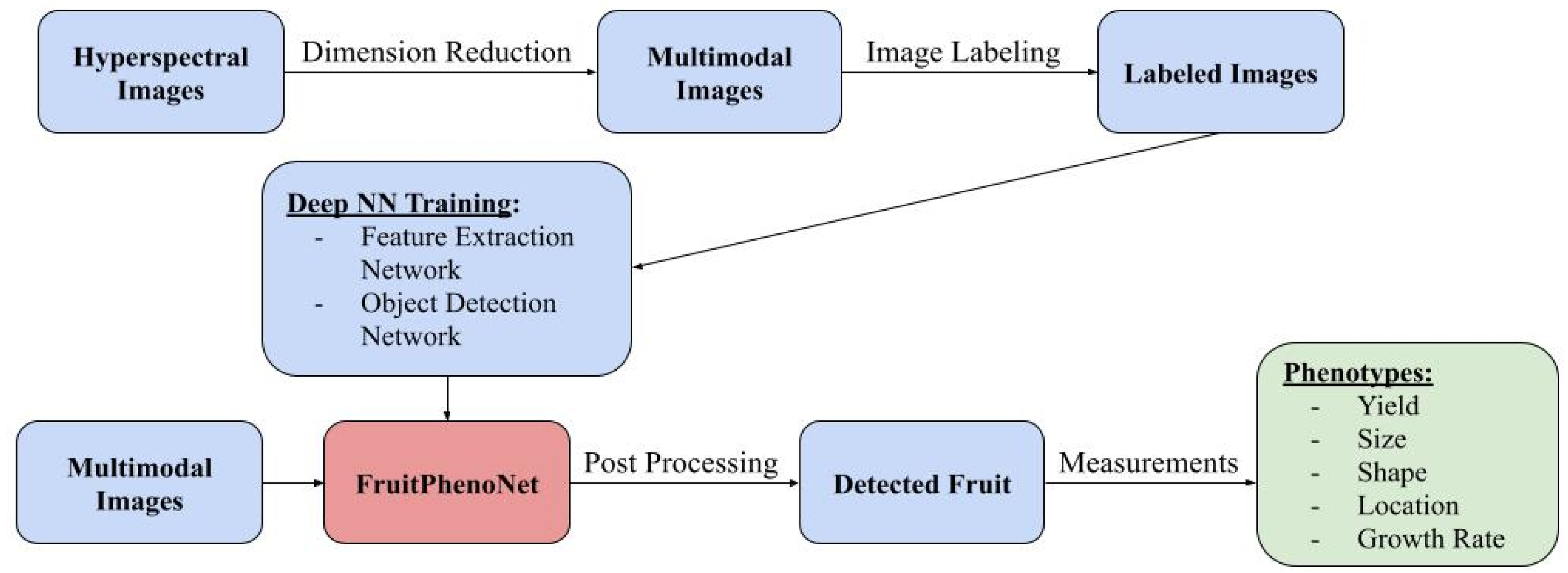

Fig. 1: Block diagram of FruitPhenoNet.

Fig. 2: (Left) RGB image of a pepper plant. (Right) Hyperspectral band at wavelength 1333 *nm* of same plant.

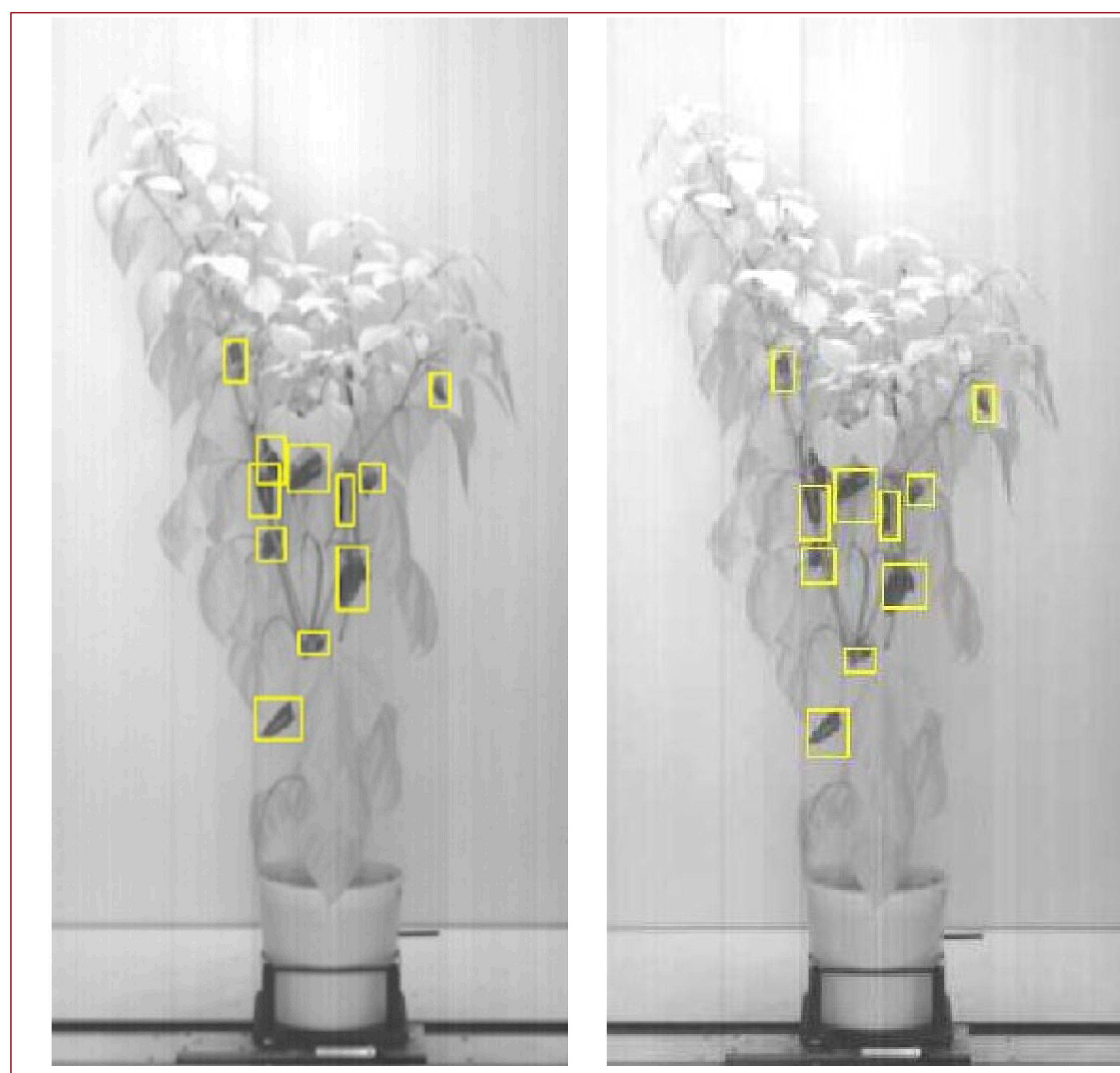

Fig. 3: (Left) Labeled pepper training image. (Right) Detected pepper fruit results from FruitPhenoNet.

Results

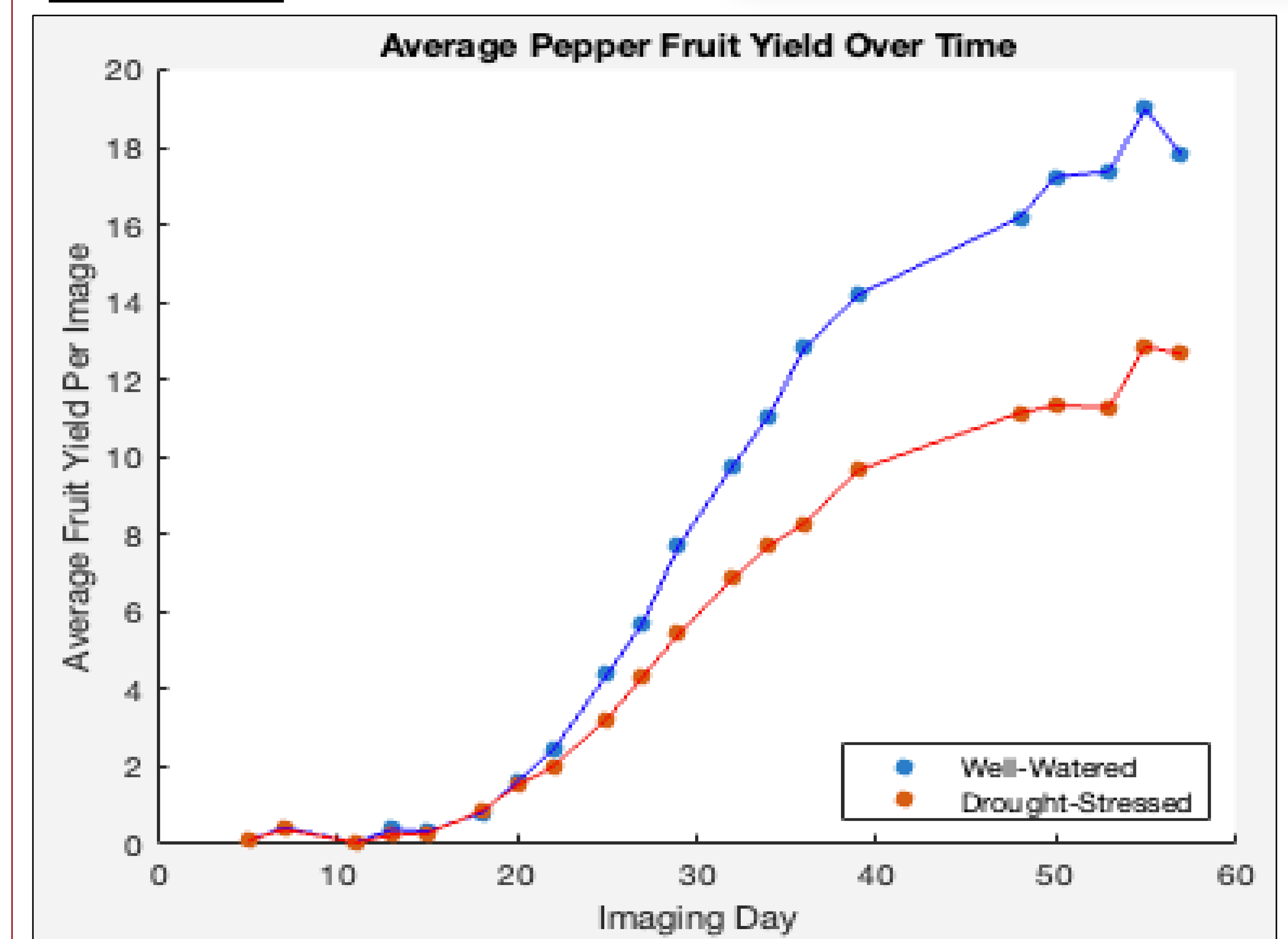

Fig. 4: Fruit yield for *Fooled You* jalapeño cultivar under two treatment conditions.

FruitPhenoNet demonstrates the efficacy of using hyperspectral images to detect and measure fruit phenotypes. Further, the fruit-based phenotypes, i.e., plant yield, size, and growth rate, show statistically significant differences between drought-stressed and well-watered conditions.

Future Work

- Create a generalizable detection and phenotyping algorithm for any fruit
- Create a model to predict phenotypes of partially occluded fruit
- Train a model that incorporates multiple modalities: visible, hyperspectral, IR, etc.
- Develop a detection algorithm to determine the location and timing of fruit emergence

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