Smart Irrigation:
Big Data approach for accurate water stress detection and precision irrigation in fruit crops

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Challenges:

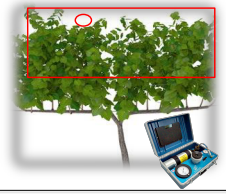
- Under and over irrigation of fruit crops (e.g. grapes) are both non-ideal for overall productivity and quality
- Plant and/or soil-based water stress sensing methods are labor intensive, and can be inaccurate
  - Current irrigation strategies rely on sparsely collected samples and can not control soil moisture at desired level
- Non-contact sensing of plant/vine water status could be faster and more comprehensive, but are currently limited to aerial studies and to a few leaf samples
- Ground-based spectral images of entire canopies could be useful to capture spatial and temporal variability in water stress and develop more precise irrigation scheduling techniques

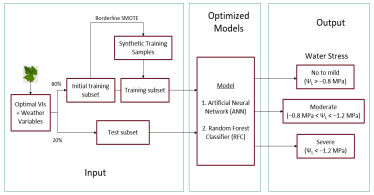
Scientific Impact:

- Within-vine spatial analysis of water stress in 3D canopy space, which helps minimize uncertainty and improve the reliability of irrigation scheduling techniques
- Classification of water stress into three practically important categories: High stress, medium stress and low stress
- A knowledge graph for data analytics over multi-dimensional factors, including soil moisture, leaf water potential, and weather conditions
- Accurate irrigation experiments (e.g. Deficit Irrigation) by precise control of soil moisture content

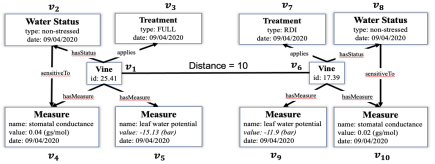
Solutions:

- Ground-based hyperspectral images collected, which allowed multiple readings within a given vine to account for spatial variability
- Two machine learning models, Random Forest Classifier and Artificial Neural Network, used to classify water stress levels in vines using spectral information

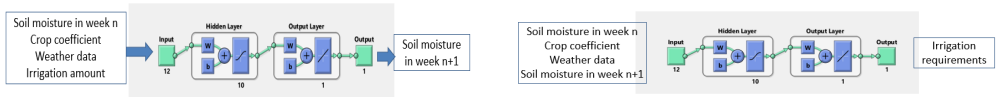




- Represented irrigation data as a spatiotemporal knowledge graph, augmented training data, and enhanced Graph neural networks (GNN) model by Few-shot Prediction to generalize from only a few examples
- Incorporated temporal-spatial features with GNN and learned graph representation ("embeddings") for prediction



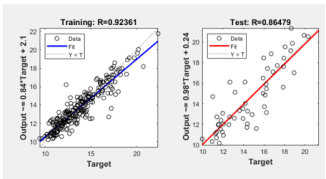
- Developed and validated a NN model to predict weekly soil moisture by learning the soil moisture dynamics in the soil-grapevine-atmosphere system from historical data
- Developed and validated a NN model to schedule weekly irrigation based on the soil moisture prediction model



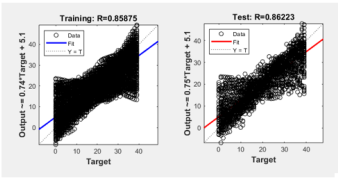
Results:

Ψ_t class	Precision	Recall	F1 score
Random Forest Classifier			
Mild	80%	63%	71%
Moderate	62%	79%	70%
Severe	89%	80%	84%
Artificial Neural Network			
Mild	93%	74%	82%
Moderate	69%	58%	63%
Severe	53%	90%	67%

Performance of water stress classification models

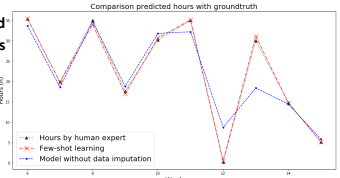


Performance of soil moisture content estimation model



Performance of irrigation estimation model

Comparison of model predicted and expert suggested irrigation hours



Method	RMSE	R^2
Few shot learning	0.5	0.99
Model without data imputation	3.92	0.93

Broader Impact

- Faster and easier data acquisition system that can be used in wider precision ag applications
- Irrigation water estimation tool applicable to other fruit crops
- Three female graduate students involved, one graduated
- Information disseminated through conferences and journal papers (in review)

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