Early detection of abiotic stress of strawberry leaves using variable-length time-series hyperspectral imaging

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INTRODUCTION

- The climate abnormality caused by global warming negatively impacts plants, reducing growth and ultimately yields, limiting the availability of food.
- Early detection and managing abiotic stress of plants could be one of the possible solutions to overcome this challenge.
- Hyperspectral imaging, which is frequently used recently, has showed the feasibility of non-destructive analysis of physiological, biochemical and morphological properties of plants.
- Since near-infrared hyperspectral imaging has a tendency to concentrate exclusively on spectral features, understanding the variation of plants health status over time could be challenging.
- Depending on the plant's stress resistance and environment, growth changes due to high temperature, moisture, and complex stress are different. Based on this, changing spectral information was monitored to detect stress before symptoms appeared.

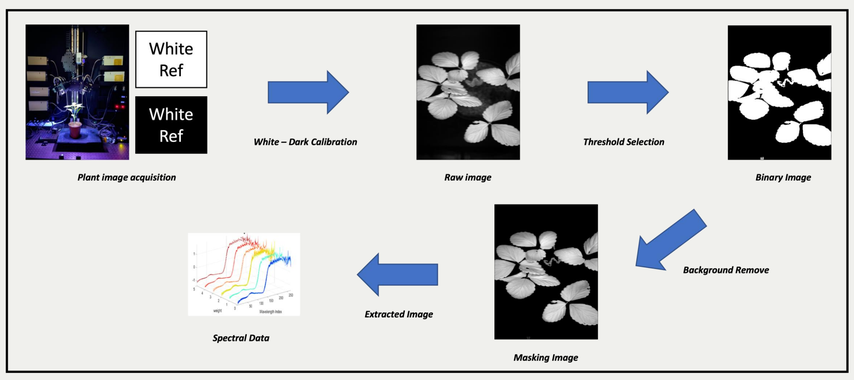
MATERIALS

- In this study, spectral information of control and stressed strawberry leaves were collected using visible near-infrared (400-1000nm) and short-wave infrared (1000-1700nm) hyperspectral imaging systems.

- For the abiotic stress experiment, the plants were divided into the 4 groups
  → Control, Drought stress, Heat stress, Heat & Drought combination stress

- To investigate the spectral and time features of the stressed plant, time-series spectral data were measured in every 2-day intervals for 12 days after exposure to heat and drought stress for 2 days.

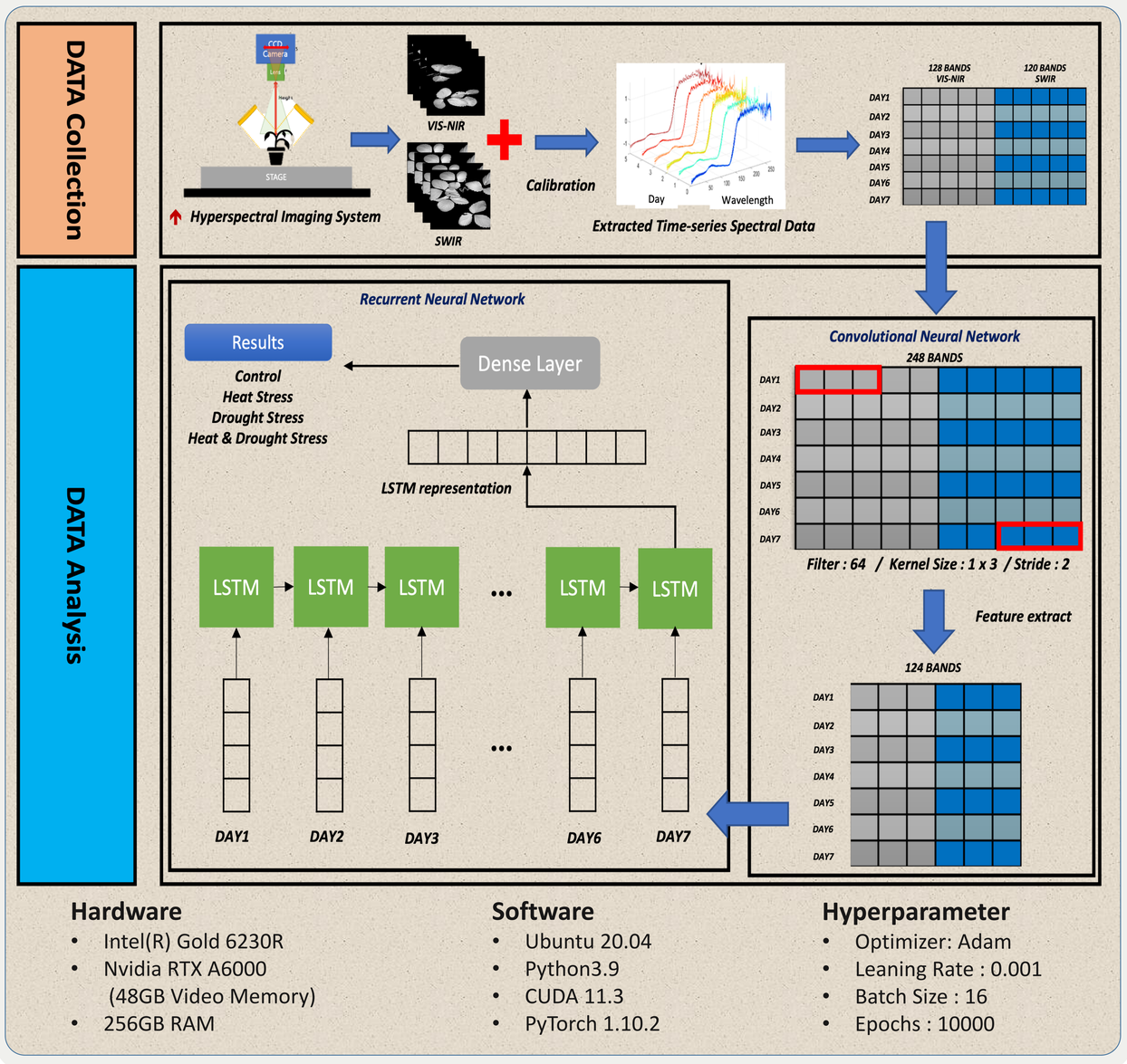
↑ *Plant Growth Chamber*



↑ *Hyperspectral image acquisition & Image processing*

METHODS

- The total time series data with 30 samples each of control and complex abiotic stress are summed up to 120, and the ratio of the train and test set is 6: 4
- A classification model was constructed using a hybrid approach that combines variable-length multivariate time-series hyperspectral data in conjugation with convolutional neural network (CNN) and long-short-term memory (LSTM) for early detection of abiotic stresses of strawberry.
- Time-series hyperspectral data of plants from day 1 to day 7 are trained through CNN-LSTM model.



Hardware
- Intel(R) Gold 6230R
- Nvidia RTX A6000 (48GB Video Memory)
- 256GB RAM

Software
- Ubuntu 20.04
- Python3.9
- CUDA 11.3
- PyTorch 1.10.2

Hyperparameter
- Optimizer: Adam
- Leaning Rate : 0.001
- Batch Size : 16
- Epochs : 10000

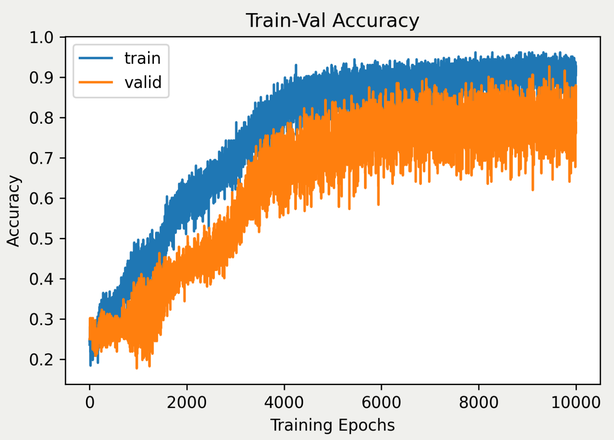
Result & Discussion

- To validate the developed variable-length time-series hyperspectral data analysis model of strawberry leaves, data from day 1 to day 4, day 1 to day 5, and day 1 to day 6 were tested.

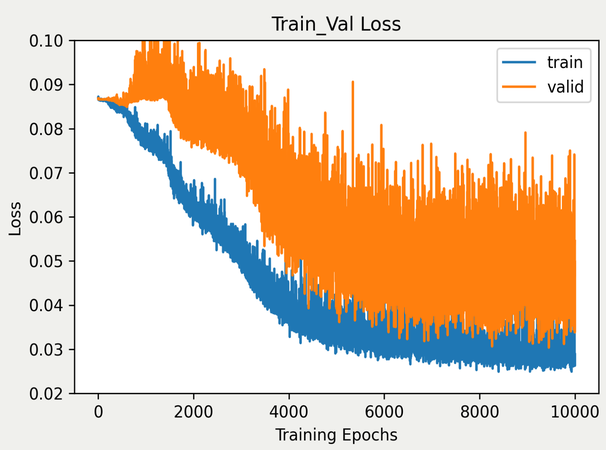
- The learning time took about 75 minutes, and the weight was saved when the loss was the lowest during training.

	Day up to 4	Day up to 5	Day up to 6	Day up to 7
Accuracy	89.6%	89.6%	93.6%	97.9%
Loss	0.0372	0.0372	0.0256	0.0212

↑ *Result of Test Accuracy & Loss*



↑ *Test Accuracy*



↑ *Test Loss*

Conclusion

- As a result of the experiment, an early detection model for abiotic stress in plants using time-series VIS-NIR and SWIR spectral data was developed.
- The CNN-LSTM model was trained with spectral data from day 1 to day 7, and the test result shows 97.9%.
- In order to verify the early detection of abiotic stress before symptoms appeared, a test with variable length time-series data showed the possibility.
- It can be applied to other plants in the future, and it is expected to be able to detect plant abiotic stress early with better performance through a lot of data, hyperparameter and model optimization, and Pre-Preprocessing