Plants’ Bioelectrical Activity

Communication in Green Infrastructures & Lab Experience

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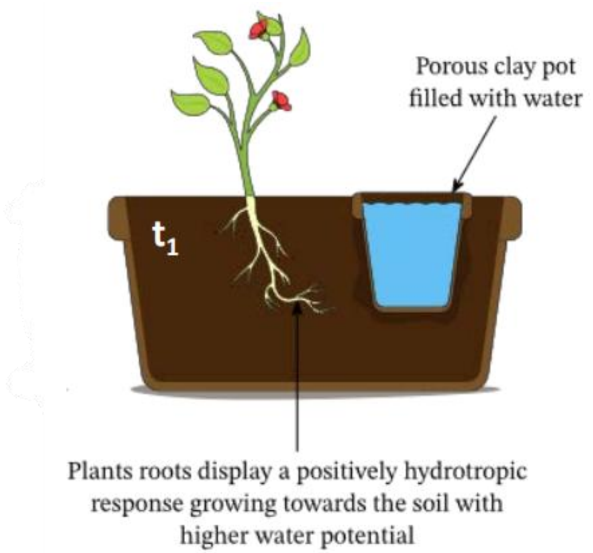
Work outline

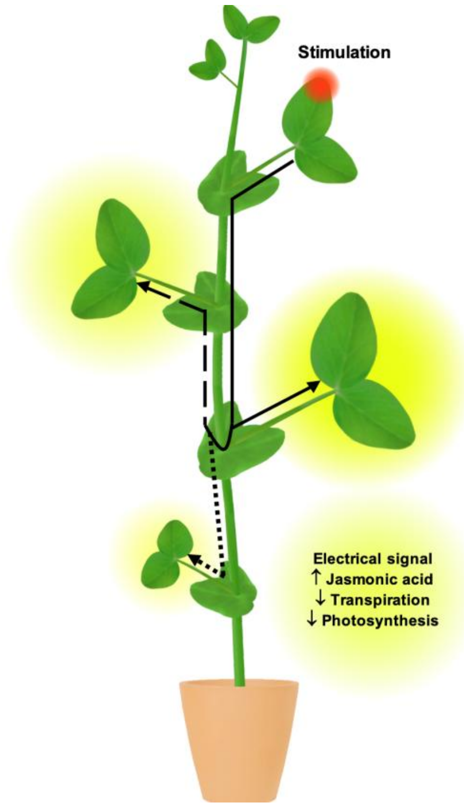
1. Introduction to Plant Bioelectrical Activity
2. Environmental Adaptation to Light Stimuli
3. Action Potentials in Plants
4. Literature Review
5. Data Analysis and Feature Analysis
6. Results and Conclusions

PLANTS' ADAPTABILITY

Plants are **sessile** organisms and so rely on their ability to **adapt** to the **environment** to survive.



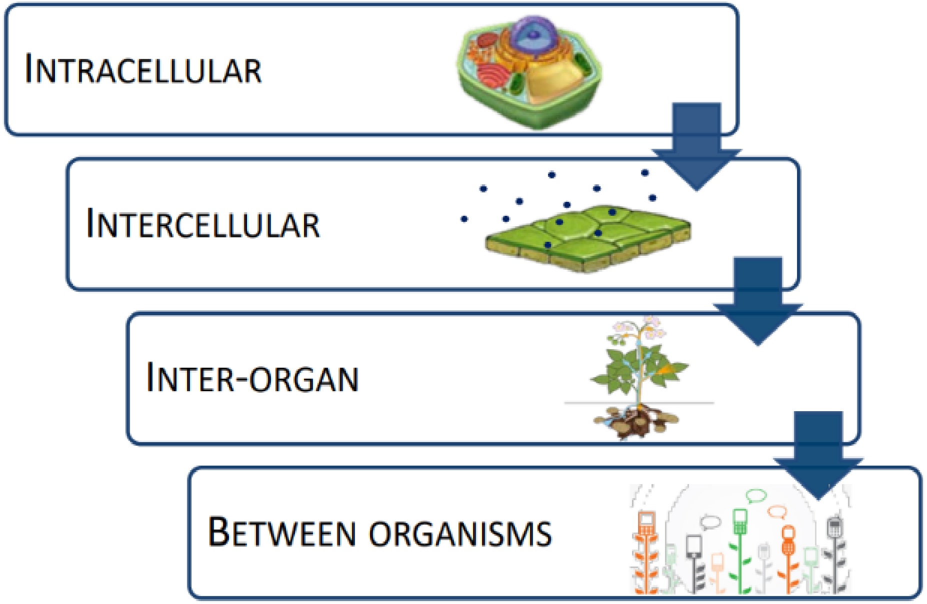
TROPISM

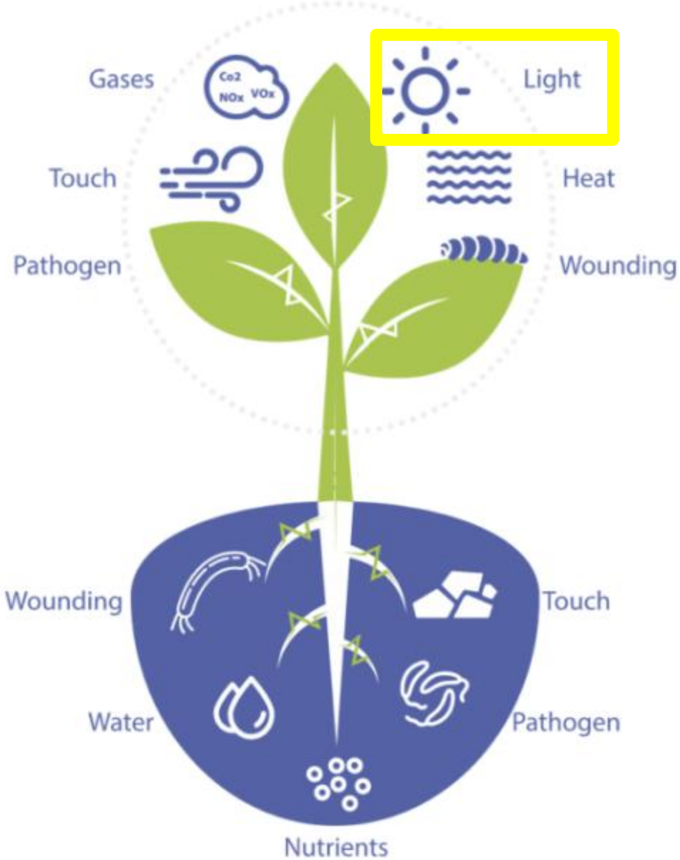


- **Electrical** signals
- **Chemical** signals
- Etc.

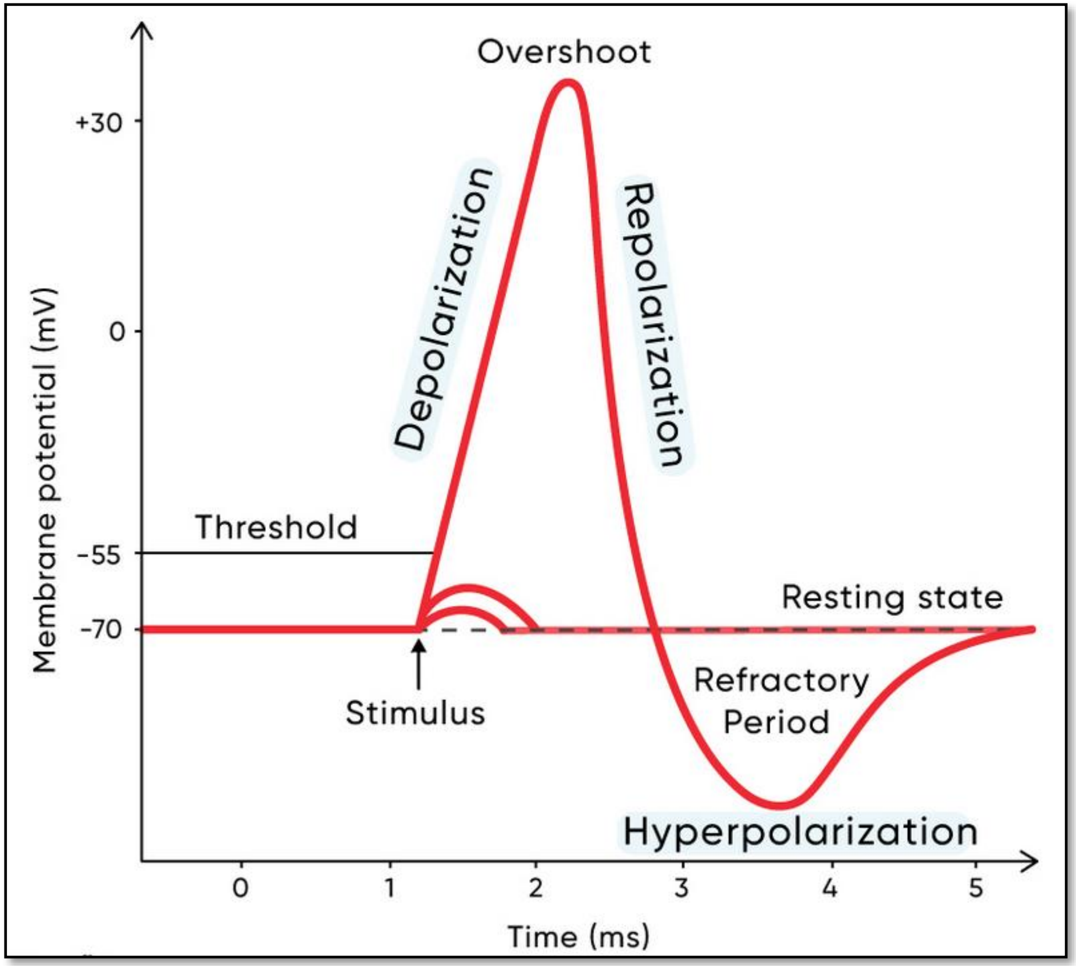
PLANTS' BIOELECTRICAL ACTIVITY

- **Action Potential** (APs)
- Variation Potential (VPs)
- Systemic Potential (SPs)





LIGHT-INDUCED APs



1. Resting State
2. Rising phase (Depolarization)
3. Falling phase (Repolarization)
4. Undershoot

SYSTEM MODEL

It's the experimental design as in «*Detecting Severe Plant Water Stress with Machine Learning in IoT-Enabled Chamber*».

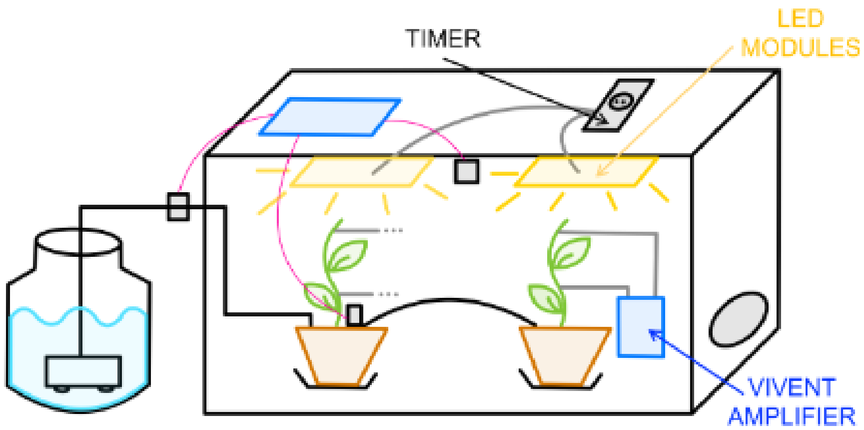


Fig. 3: Experimental set-up design scheme.

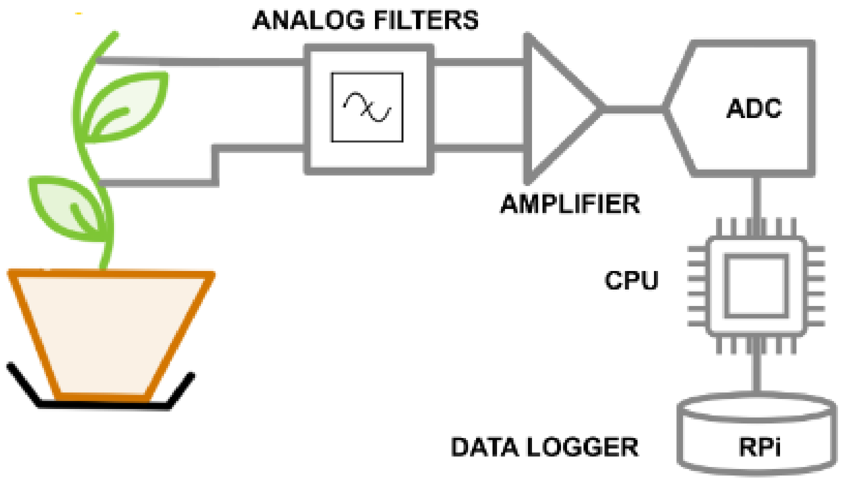
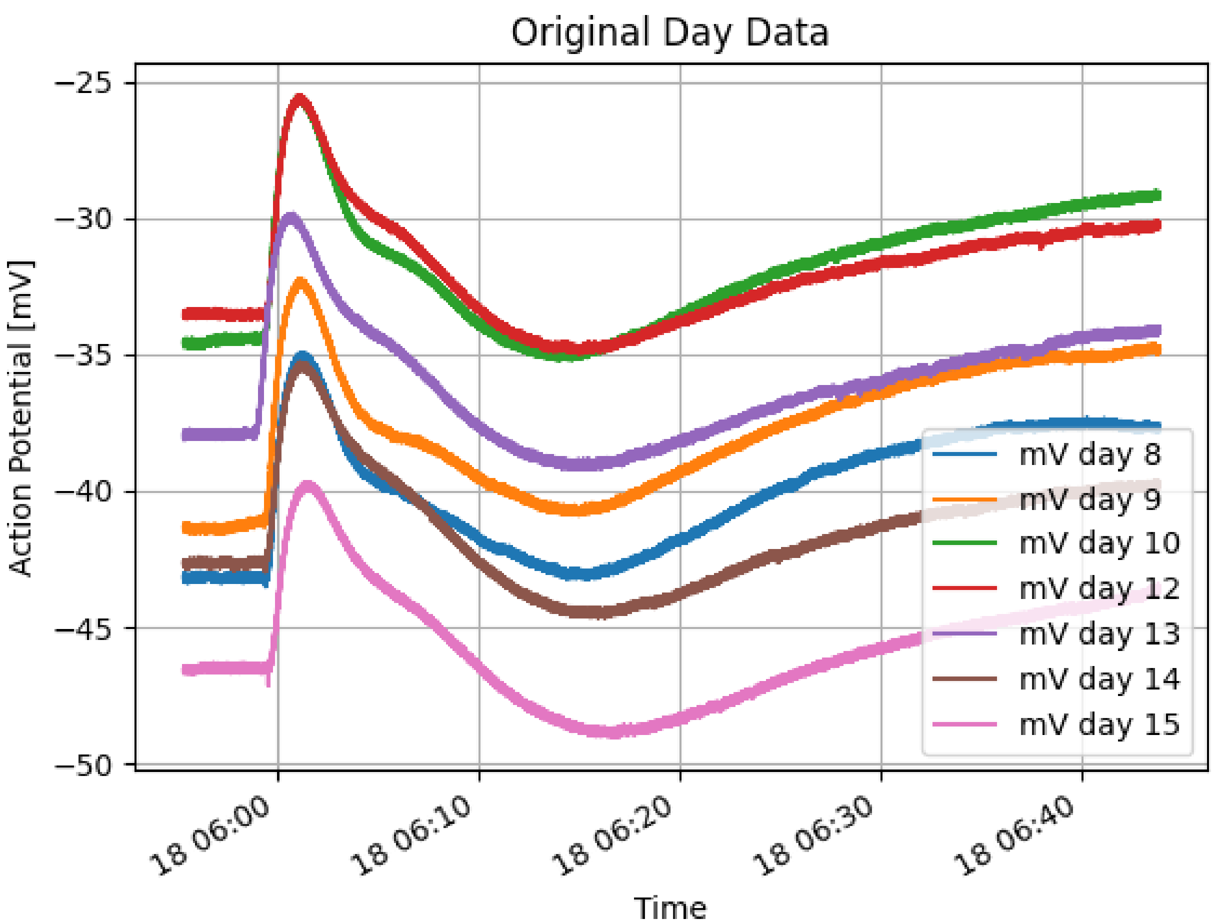
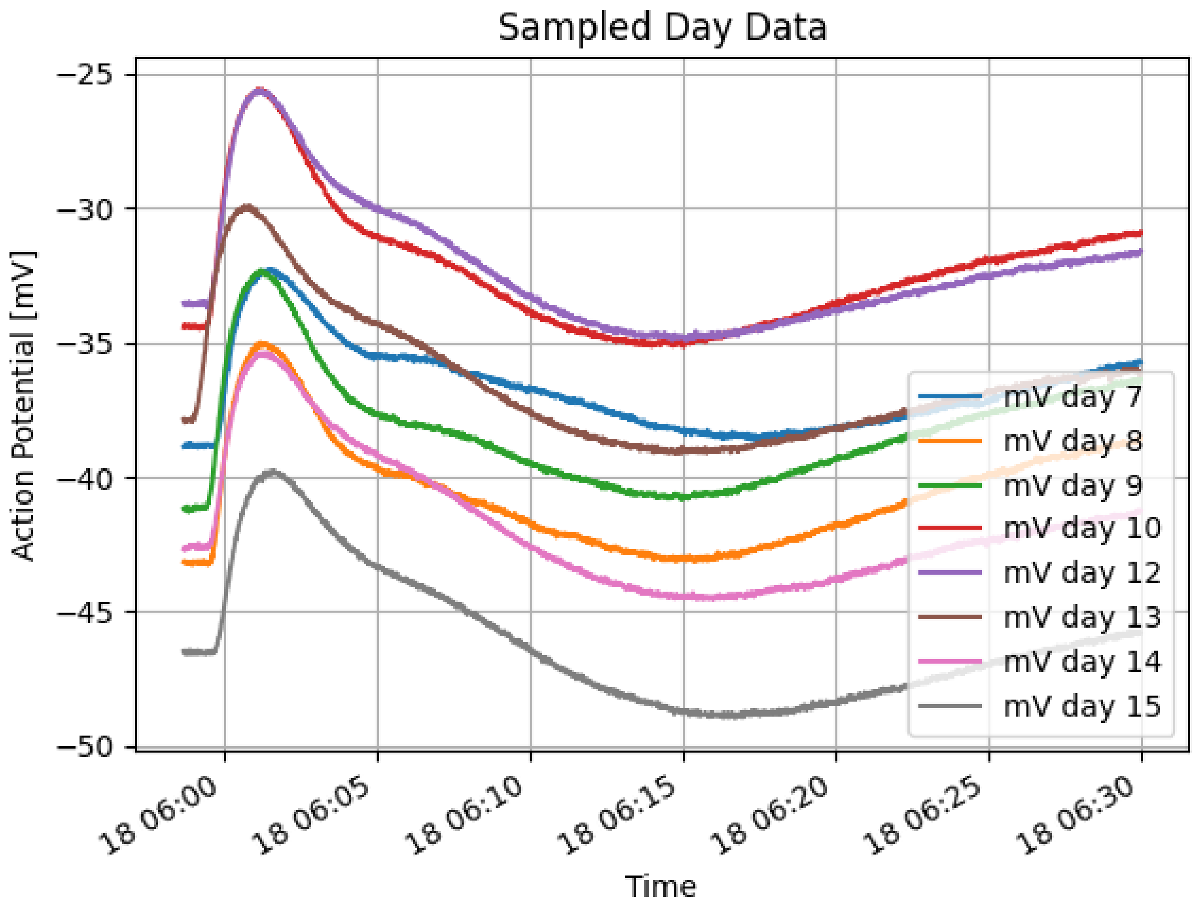


Fig. 4: Acquisition system.

RAW DATA – 256Hz



DOWN SAMPLE DATA – 1Hz



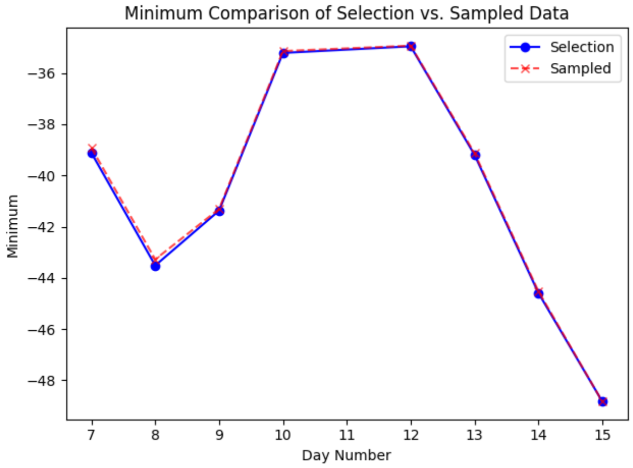
FEATURE EXTRACTION

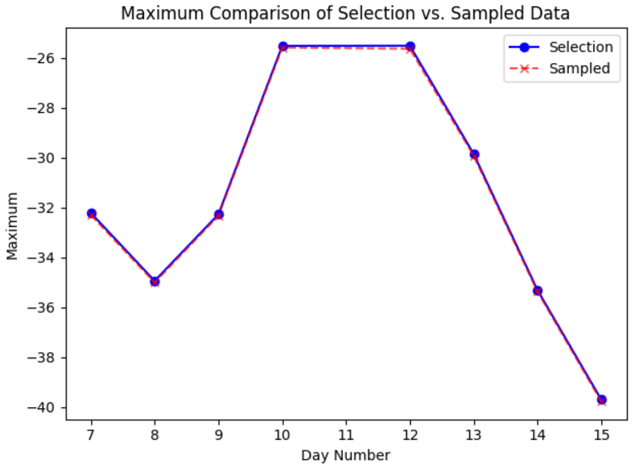
These indicators are computed over raw data and sampled set of AP values:

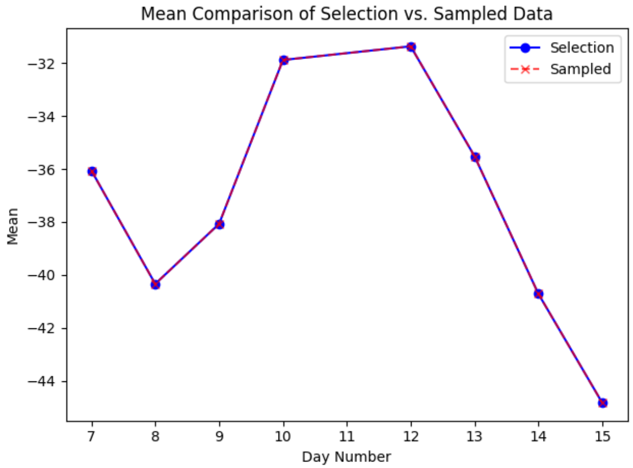
- **Minimum:** The smallest value
- **Maximum:**The largest value
- **Mean:** The average value $$\text{Mean} = \frac{\sum_{i=1}^{n} x_i}{n}$$
- **Variance:** Difference from the mean. $$(\sigma^2) = \frac{\sum_{i=1}^{N} (x_i - \mu)^2}{N}$$
- **Standard Deviation:** Amount of variation or spread. $$(\sigma) = \sqrt{\frac{\sum_{i=1}^{N} (x_i - \mu)^2}{N}}$$
- **Variation Index**: Relative variability.

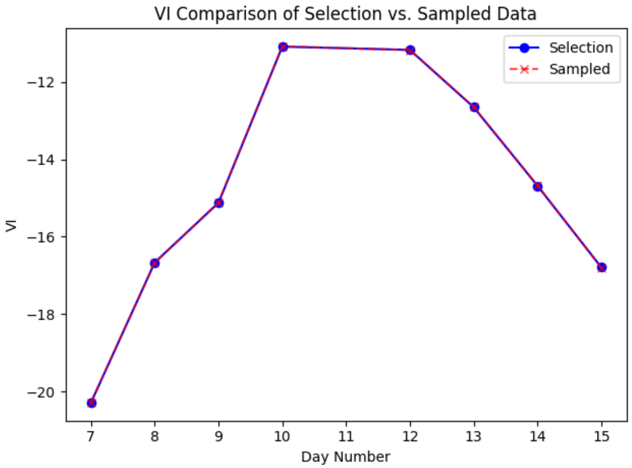
$$\text{VI} = \frac{\text{Standard Deviation}}{\text{Mean}}$$

RAW DATA VS. SAMPLED DATA

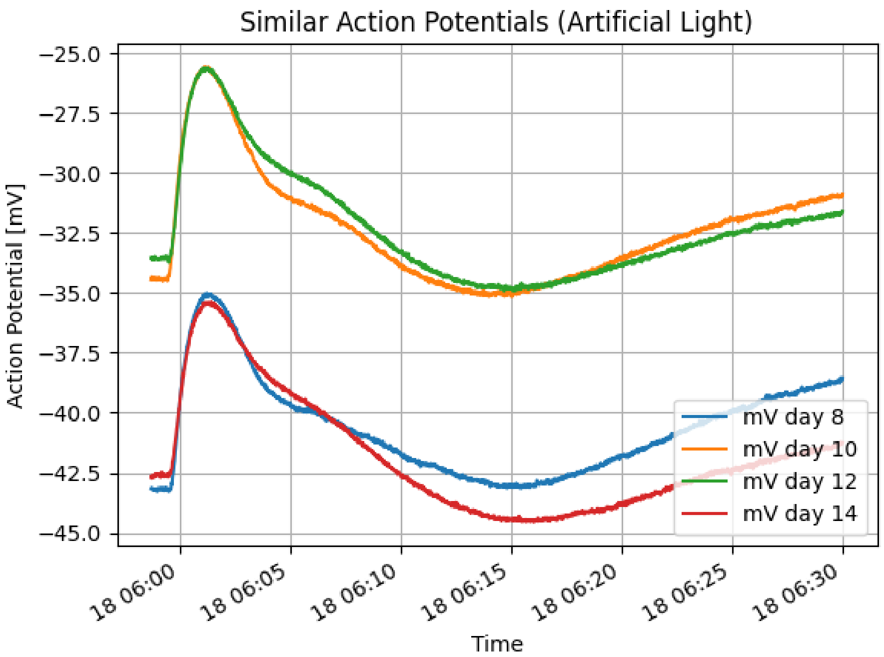


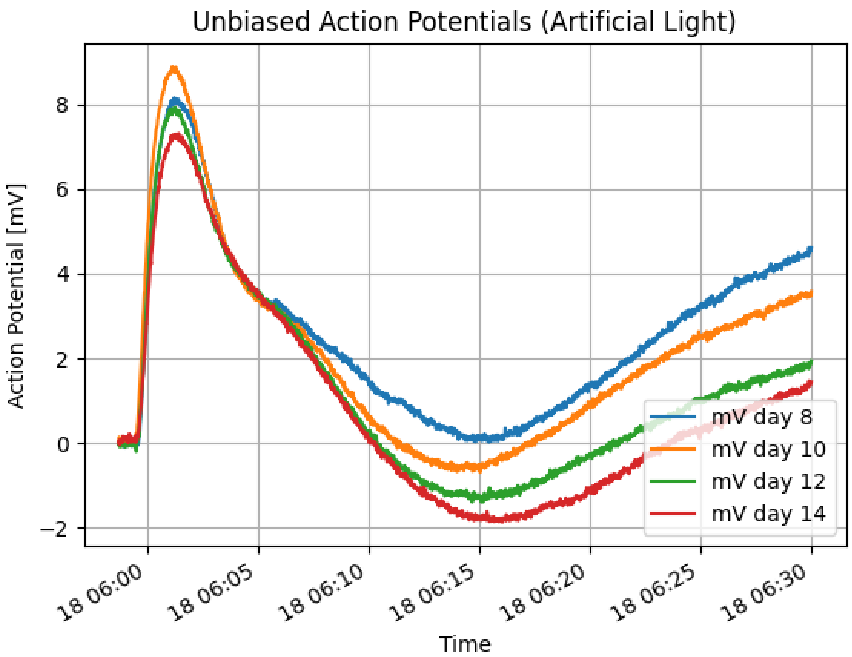




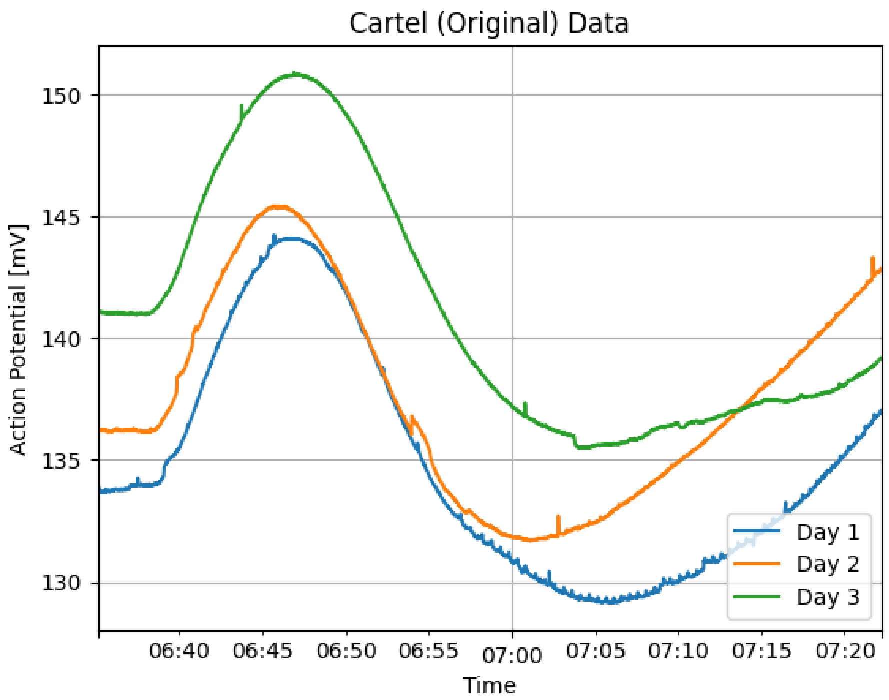


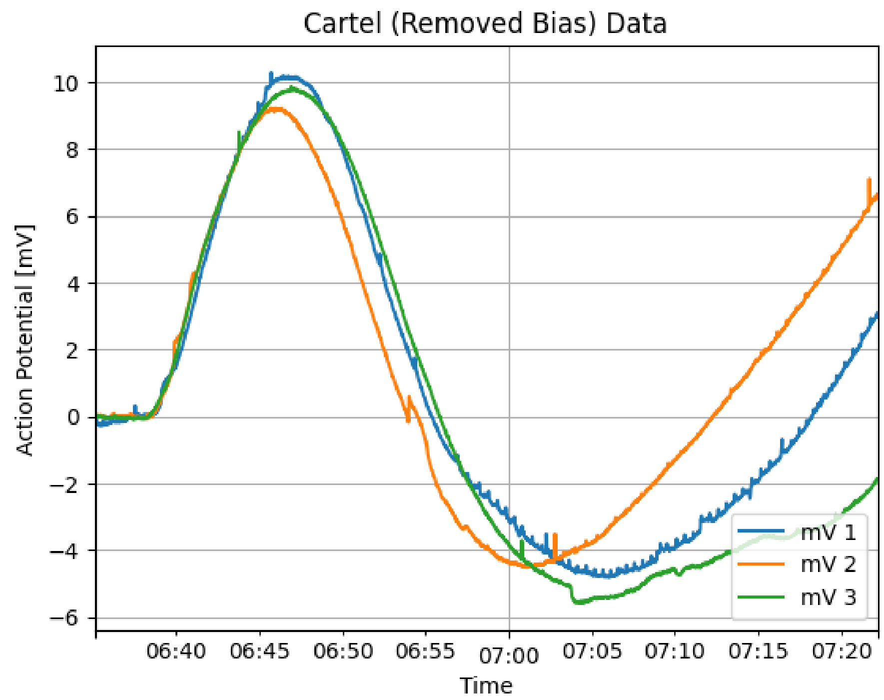
DATA NORMALIZATION





… AND IF THE LIGHT WAS NATURAL?

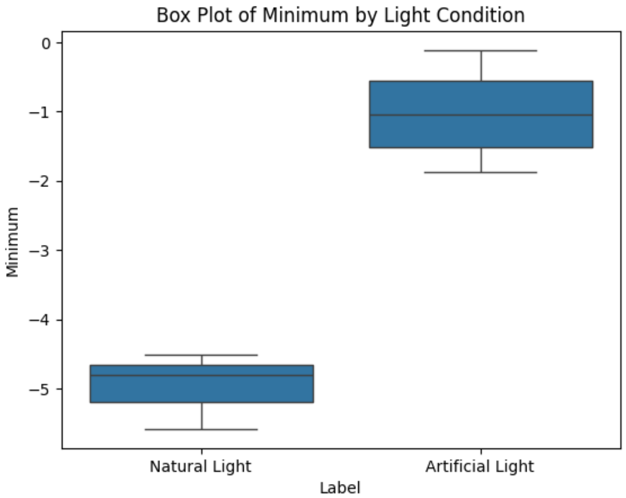


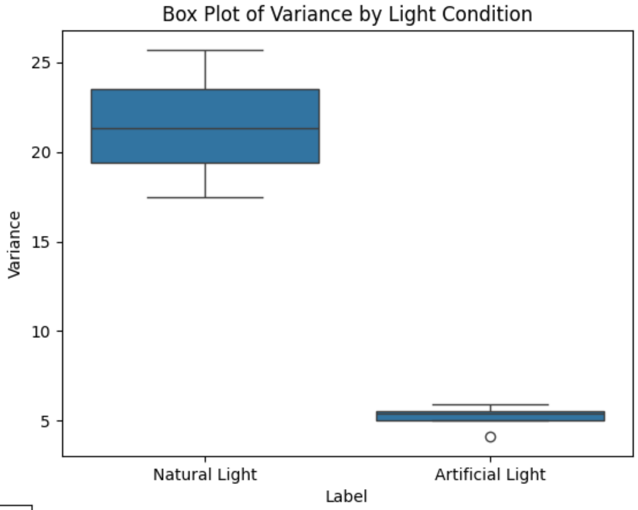


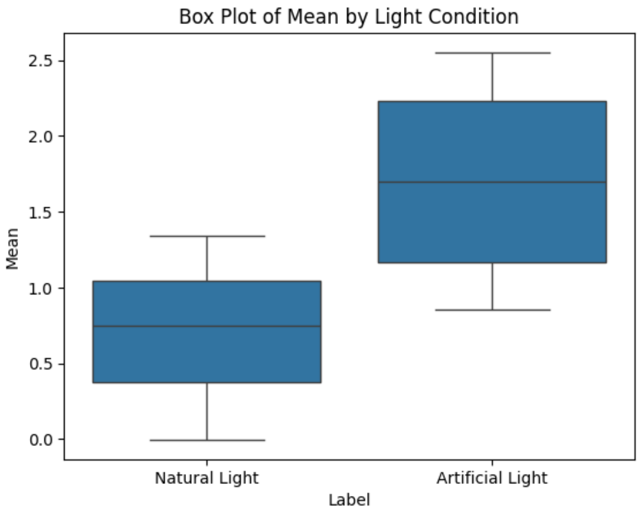
FEATURE ANALYSIS

	Day	Minimum	Maximum	Mean	Standard Deviation	VI	Variance	Label
0	1	-4.8107	10.2809	0.7491	4.6155	0.1623	21.3027	0
1	2	-4.5143	9.2124	1.3407	4.1809	0.3207	17.4800	0
2	3	-5.585	9.8577	-0.0035	5.0685	-0.0007	25.6902	0
0	8	-0.114	8.1573	2.5501	2.0318	1.2551	4.1283	1
1	10	-0.6936	8.8906	2.1187	2.308	0.918	5.3268	1
2	12	-1.3997	7.9071	1.2737	2.3353	0.5454	5.4536	1
3	14	-1.8759	7.3167	0.8559	2.4278	0.3526	5.8940	1

SPLITTER FEATURES



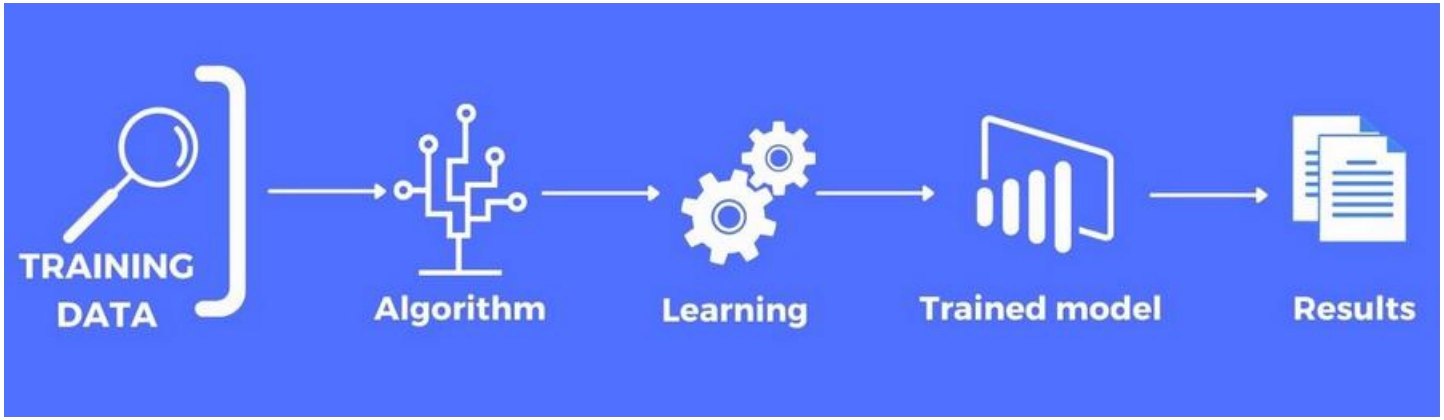




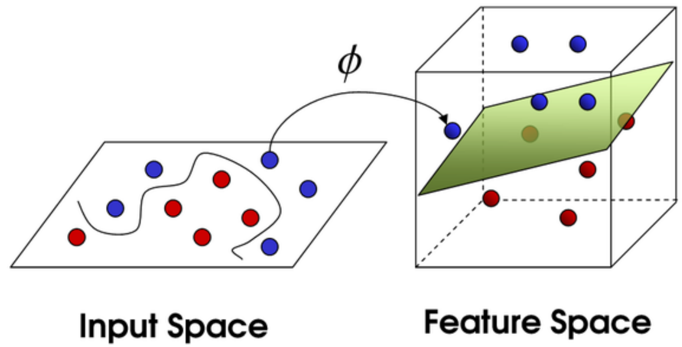
SOME EXPERIMENTS WE DID!

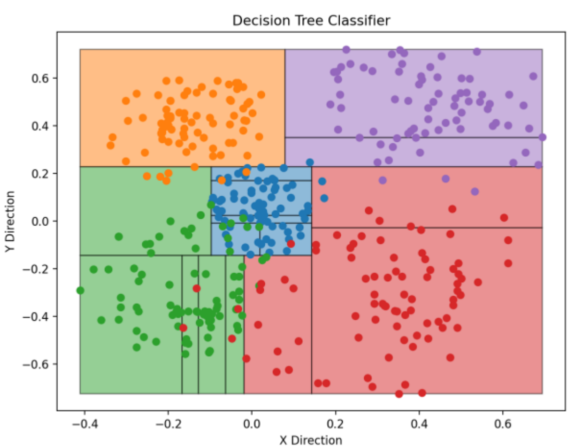
MACHINE LEARNING MODELS

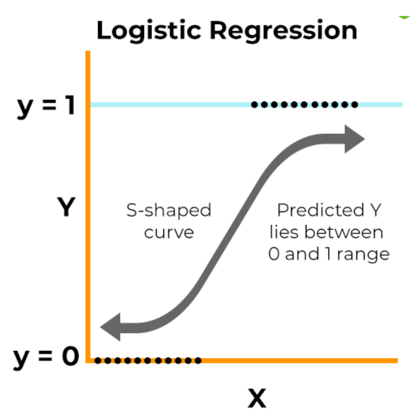
- Achieve real-time response detection to stimuli in plants
- Novel insights into the plant monitoring methodologies
- ML is a field of AI that enables algorithms to learn from data and make decisions.

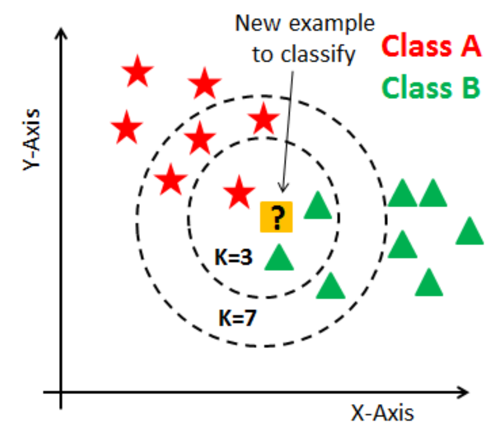


- Support Vector Machine
- K-Nearest Neighbors
- Logistic Regression
- Decision Trees









OUR FICTITIOUS RESULTS

ML Model	Accuracy
Logistic Regression	100%
KNN	100%
SVM	100%
Decision Trees	85.71%

	Day	Minimum	Maximum	Mean	Standard Deviation	VI	Variance	Label
0	1	-4.8107	10.2809	0.7491	4.6155	0.1623	21.3027	0
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Important Considerations:

1. There are only 7 samples and 6 features.
2. The features are highly based on each other.
3. The samples are significantly recognizable.
4. The models are trained and tested using Leave-One-Out Cross-Validation (LOOCV)

CONCLUSION

- The ML models were effective in distinguishing between the classes under study.
- Visual analysis of the signals revealed clear differences between artificial and natural light classes.
- The approach must be validated under true field conditions where unregulated factors could impact results.
- The obtained accuracy is not valid until we have more samples.


Thank
You

References

[1] Bekkari, I., Lombardo, S., Coviello, A., Magarini, M., and Wallbridge, N., Detecting Severe Plant Water Stress with Machine Learning in IoT-Enabled Chamber.

[2] Awan, H., Adve, R., Wallbridge, N., Plummer, C., and Eckford, A., Communication and information theory of single action potential signals in plants, IEEE Transactions on non-bioscience, Vol. 18, No. 1, 2019.

[3] Tran, D., Dutoit, F., Najdenovska, E. et al. Electrophysiological assessment of plant status outside a Faraday cage using supervised machine learning. Sci Rep 9, 17073 (2019).

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[7] Slide Sets and Recordings of Professor Maurizio Magarini provided for Communication in Green Infrastructures course in Politecnico di Milano, 2023.

[8] Slide Sets and Recordings of Professor Gabriele Candiani provided for Communication in Green Infrastructures course in Politecnico di Milano, 2023.

[9] https://byjus.com/biology/