Deciphering human emotion

Investigating Plant Electrical Response to Eurythmy

Agenda

01 Plants Literature

02 Plant Response to Eurythmy

03 Future Research

01

Plants Literature

What does a plant do?

Photosynthesis

Intelligence

Respiration

Nutrition

Transpiration

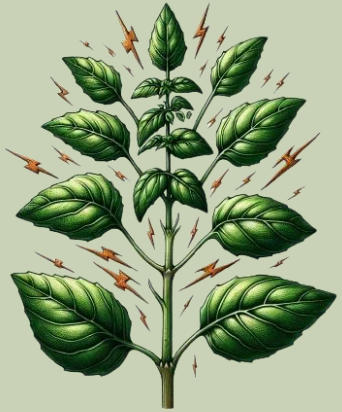
Tropisms

Dormancy

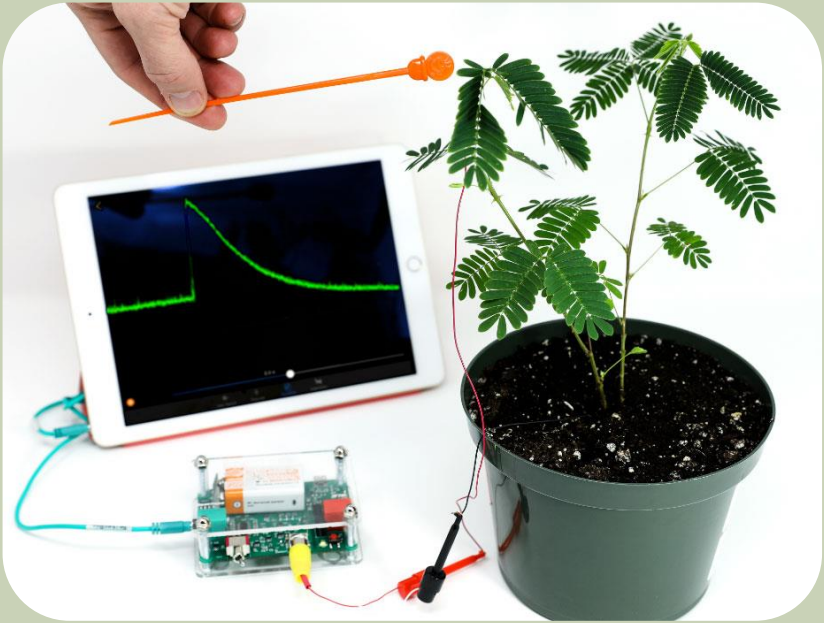
Electrophisiology

Electrical Responses

Sanderson, 1873
Pickard, 1973
Marzullo, 2012



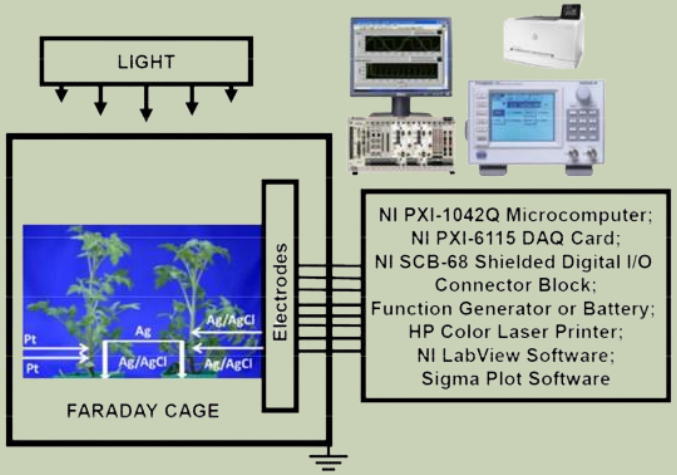
Plant Spikerbox



Communication

Volkov et al, 2019

1. Volatile Organic Compounds (chemicals)
2. Mycorrhizal Networks (fungi)
3. Rhizosphere (chemical)
4. Natural Grafting (merge roots)
5. Electrostatic or Electromagnetic
6. Acoustic
7. **Electrical Signal through the Soil**



Light Stimulus

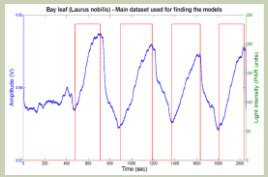
Prediction from Electrophysiological Response

Chatterjee et al, 2014

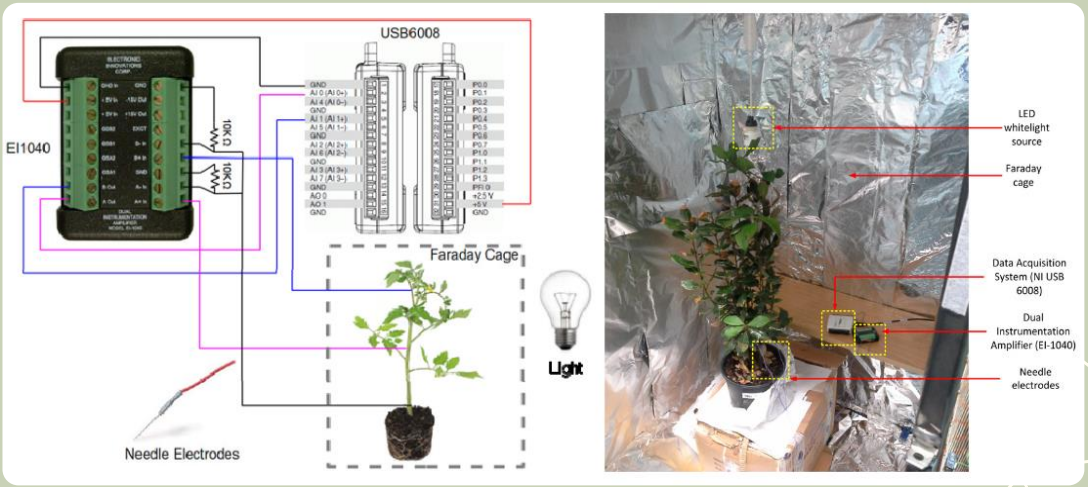
bay leaf

cucumber

zanzibar



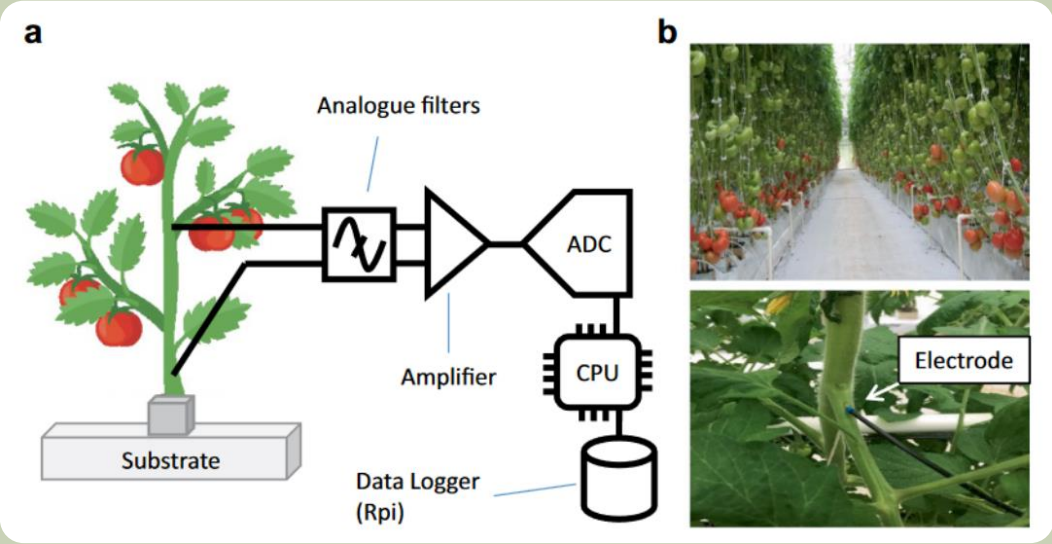
Photon Flux Density



Water status

By electrophysiological assessment

Tran et al, Nature 2019



Monitoring
2 weeks

Output
Water Deficit

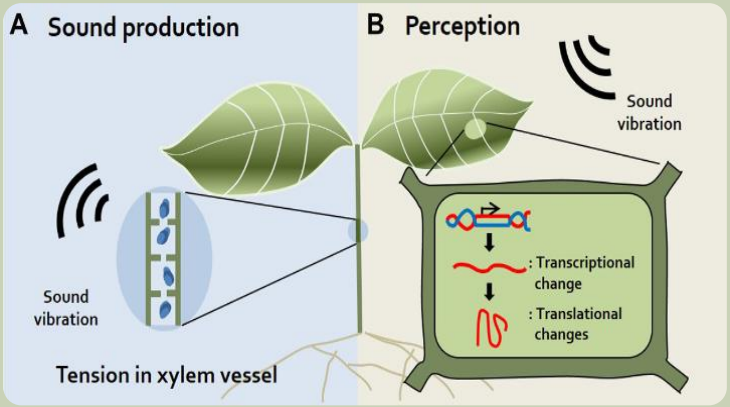
Acuracy
0.98

Sound

Production

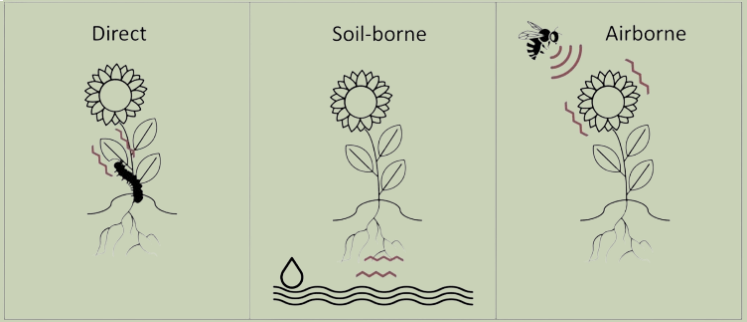
Jung et al, 2018

- Spontaneous sounds
- Gas bubbles in xylem vessels
- Audible and ultrasonic (20-105kHz)

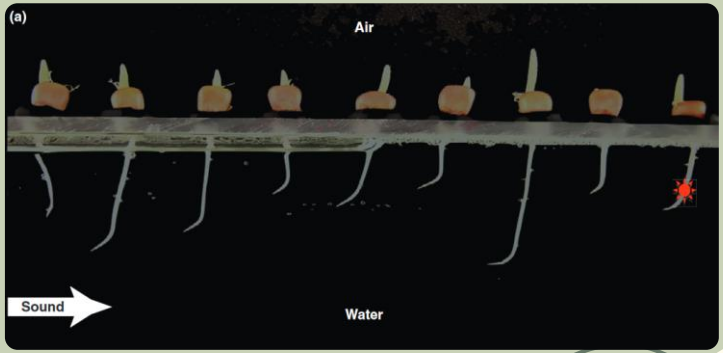


Perception

Khait et al, 2019

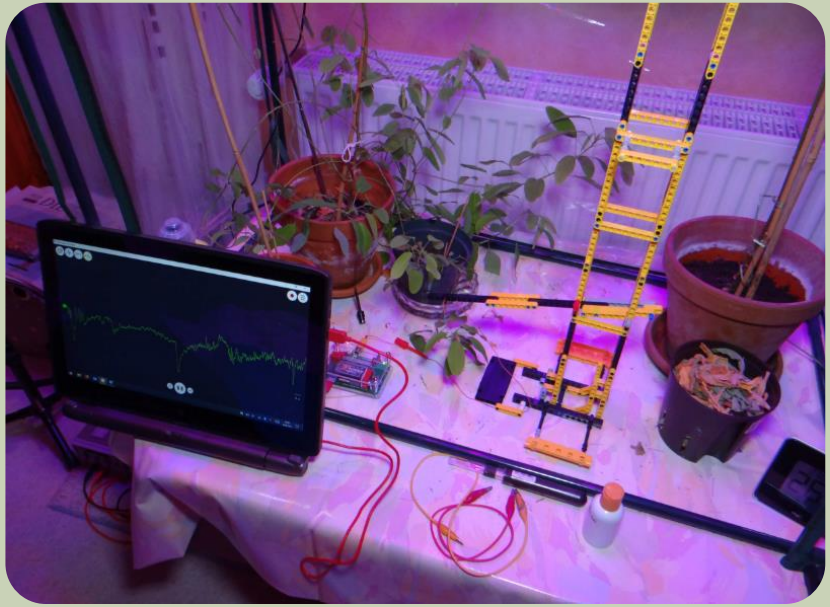


Gagliano et al, 2012



Music

Peter & Gloor, 2021



Location
Indoor greenhouse

Species
Dancing plant

Output
Control | 200 Hz | 600 Hz

Accuracy
0.72

02

Plant Response to Eurythmy

Eurythmy

- **Expressive movement art**
- Originated by **Rudolf Steiner**
- Used in education, anthroposophic medicine, and in **Biodynamic agriculture**
- The melody is conveyed through expressing the **arm gestures** of the actual letters

How to Measure

Extracellular Recording

- Surface measurements (EEG)
- Total sum of bioelectrical activity in large groups of cells
- Placement of electrodes on the plant surface and soil

https://backyardbrains.com/products/plantspikerbox

Measurements

Salad

A-G-D

Tomato

A-G-D-O

Basil

A-G-D-L

Eurythmy Gestures

(4x times each)

Procedure

Eurythmy

The voltage of 3 plants is measured while an expert performs the eurythmy gestures on them

Control

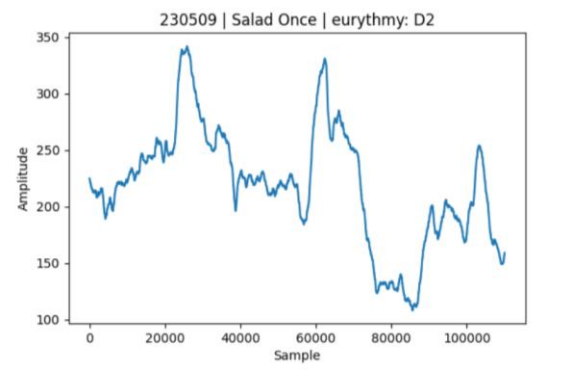
The tension of 3 plants far away from the expert but in the same orchard is measured

Data

108 eurythmy performances

(Apr 29 – Sep 30)

Wav



The Wav files are datapoints and represent the plant voltage over time

41 hours

Mp4

The Mp4 files help us to detect the gesture and timing of eurythmy

7 hours

Research Questions

01 Do plants react to eurythmy?

02 Do plants react differently to Eurythmy for the first time than when they are used to it?

03 Do plants react differently between several eurythmy movements in a row?

04 Do plants react differently between different eurythmy gestures?

Data Preparation

Labelling

EDA

Cleaning

Input Approaches

01

Features

- Statistical
- Temporal
- Frequency

02

MFCCs

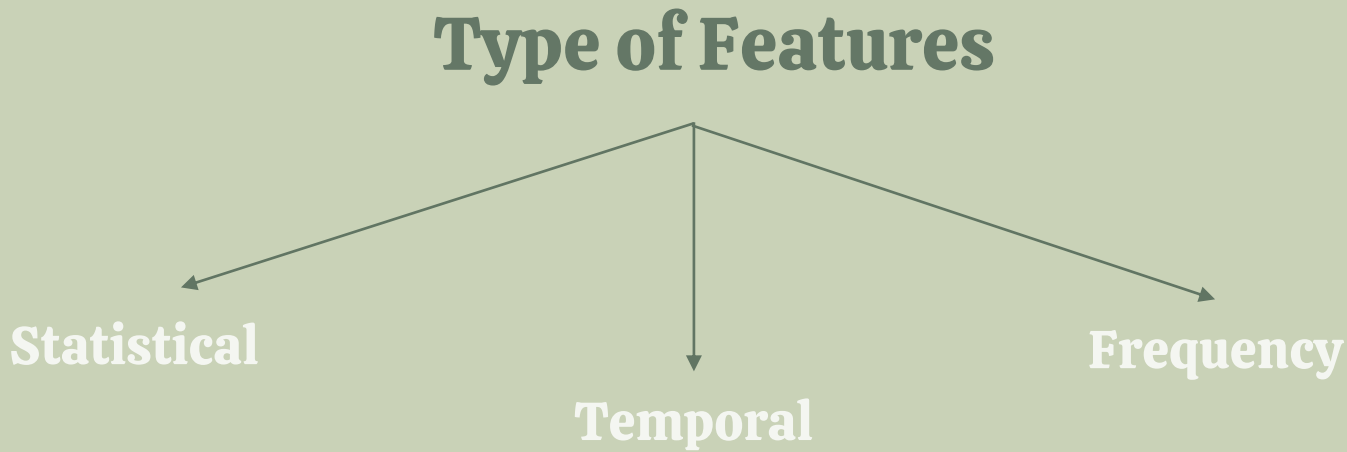
- FCNN
- CNN

03

Signal

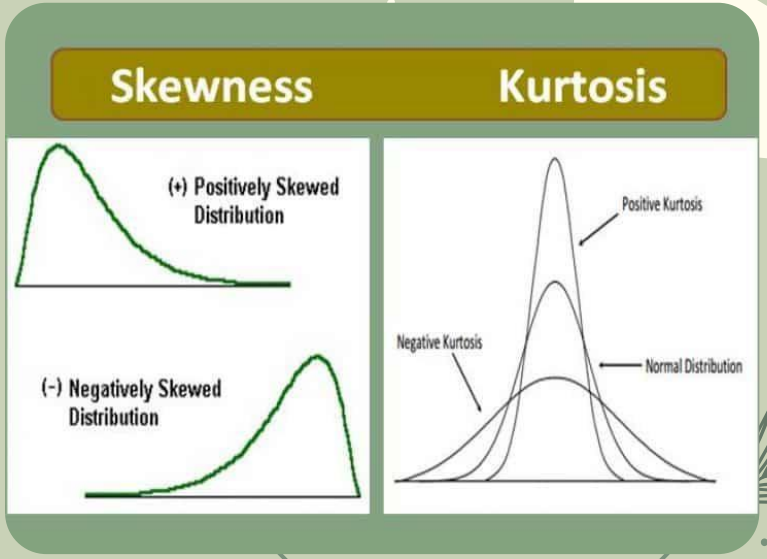
- Dense Classifier
- LSTM Classifier

Featurization



Statistical Features

- Variance
- Standard Deviation
- Interquartile Range
- Skewness
- Kurtosis
- Hjorth mobility
- Hjorth Complexity
- DFA
- Hurst

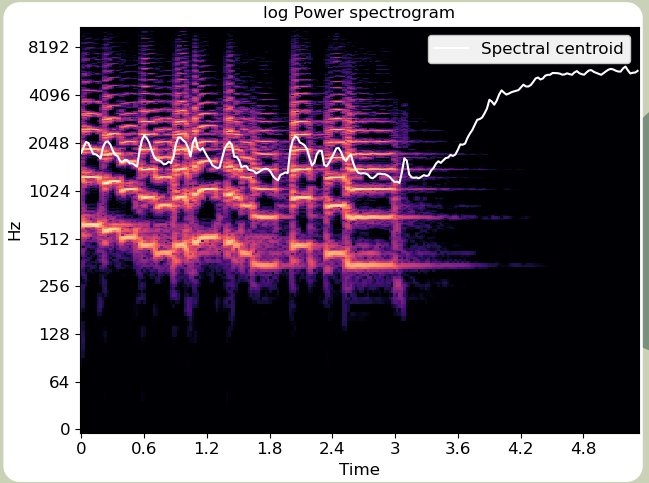


Temporal Features

- Zero-Crossing Rate
- Root Mean Square Energy
- Slope Sign Changes Ratio

Frequency Features

- MFCCs
- delta_MFCCs
- delta2_MFCCs
- Spectral Centroid
- Bandwith



Frequency Processing

01 Fast Fourier Transformation

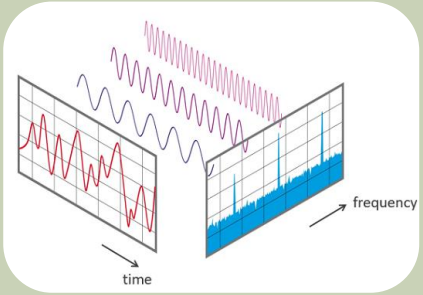
02 Spectrogram

03 Mel Spectrogram

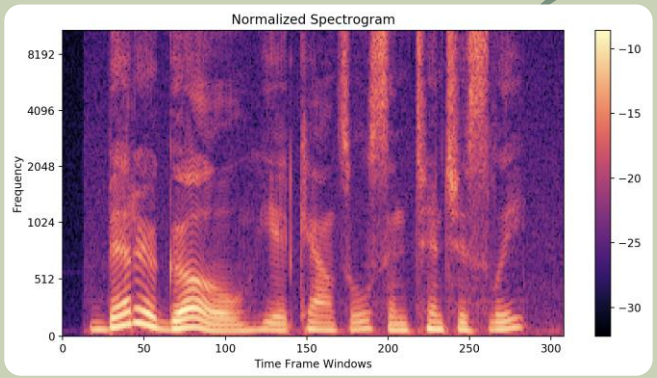
04 Mel-Frequency Cepstral Coefficients

Processing Steps

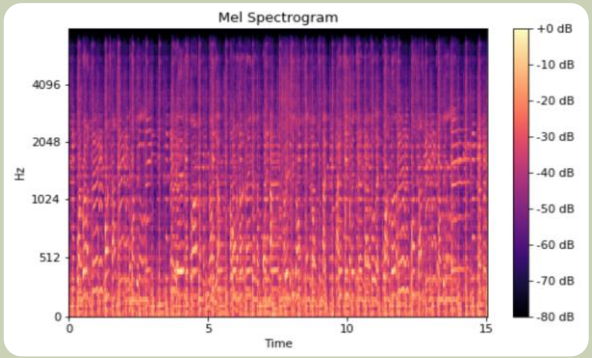
FFT



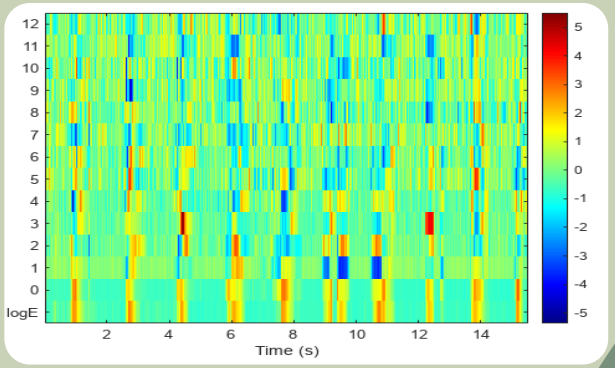
Spectrogram



Mel Spectrogram



MFCC



ML Results

Eurythmy Detection (y/n)

Model

Random Forest

CV Accuracy: 0.7

Test Accuracy: 0.69

Precision: 0.63

Recall: 0.77

F1-Score: 0.69

T-test

features	mean_kontrol	mean_eurythmy	p_value
mfcc_1_std	2.058381e+01	2.732229e+01	1.330005e-191
mfcc_2_std	6.970364e-01	9.135830e-01	2.894829e-184
mfcc_4_std	1.573539e-01	1.873600e-01	2.891658e-167
delta mfcc_1_std	2.041327e+01	2.604781e+01	1.499101e-155
mfcc_2_mean	1.845533e+00	1.518966e+00	1.345694e-151
delta mfcc_2_std	7.132347e-01	8.871280e-01	2.218756e-146
mfcc_1_mean	-4.407104e+01	-5.346663e+01	1.102917e-145
mfcc_3_mean	2.308727e-01	1.909942e-01	1.831672e-144
mfcc_8_mean	8.540016e-02	7.053349e-02	6.175182e-140
mfcc_7_mean	8.408431e-02	6.917139e-02	2.856566e-139
mfcc_4_mean	3.265205e-01	2.714686e-01	3.828610e-138
mfcc_6_mean	1.561676e-01	1.298179e-01	1.751355e-136
mfcc_5_mean	1.482412e-01	1.230739e-01	3.118636e-136
mfcc_10_mean	5.659019e-02	4.699163e-02	3.313550e-128
mfcc_3_std	1.345109e-01	1.533055e-01	4.007569e-127
mfcc_9_mean	5.136776e-02	4.252517e-02	1.517383e-125
mfcc_12_mean	4.085781e-02	3.401768e-02	8.305825e-120
mfcc_11_mean	3.839020e-02	3.175306e-02	1.656019e-116
spectral_spread_mean	1.195303e-01	9.912436e-02	6.631478e-108
mfcc_13_mean	2.916533e-02	2.390266e-02	1.257625e-102
mfcc_6_std	1.098918e-01	1.199409e-01	1.293550e-93
delta mfcc_4_std	1.823252e-01	2.031845e-01	3.436077e-91
spectral_spread_std	6.564381e-02	7.294716e-02	1.471261e-83
mfcc_5_std	1.065880e-01	1.152874e-01	4.812216e-81
spectral_centroid_mean	4.955959e-02	4.125566e-02	2.368041e-63
delta spectral_spread_std	5.239278e-02	6.099878e-02	2.169113e-62
slope_sign_changes_ratio	2.477535e-02	8.678106e-03	4.878300e-60
dfa	1.681960e+00	1.633993e+00	2.640268e-52
delta mfcc_3_std	1.647343e-01	1.777800e-01	9.146572e-51
chroma_7_std	5.195644e-02	4.500658e-02	9.849618e-48

Window Size: 0.05s | Hop Length: 0.5ws

ML Results

Eurythmy Detection by Plant (y/n)

Salad

Accuracy 0.67

Tomato

Accuracy 0.72

Basil

Accuracy 0.74

03

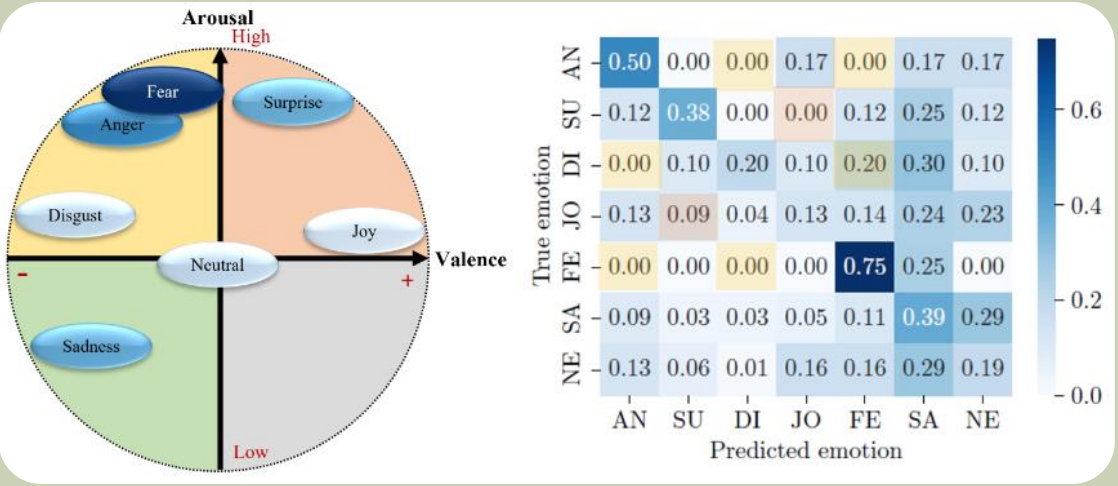
Future Research

Human emotion

Kruse et al, 2023

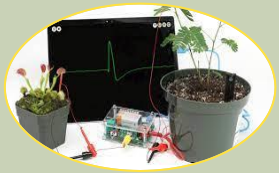
Species	Output	Accuracy
Basil	7 emotions	0.32

Model	Test set Accuracy	Test set Recall
MLP	0.399	0.220
biLSTM	0.260	0.351
MFCC-CNN	0.377	0.275
MFCC-RestNet	0.318	**0.324**



Vision

Bio-Lingo



Elings, 2016

Effects of plants on People

physical

1. Stress and mental fatigue relief
2. Treatment of mental health issues
3. Lower blood pressure and heart rate
4. Faser recovery from stress
5. Reduction in risk factors for diseases

mental

6. Improved self-steem and responsibility
7. Enhanced tranquility and enjoyment
8. Promotion of relaxation and reflection
9. Positive correlation with well-being

social

10. Stimulation of social cohesión
11. Enhanced social interaction
12. Reduction in lonileness

Thanks!

Do you have any questions?

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