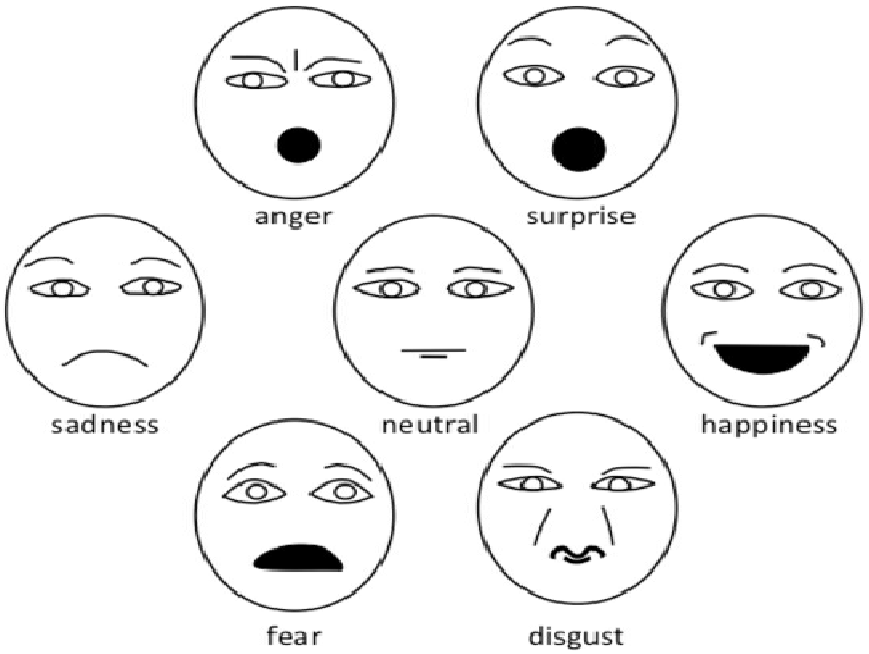
Mimicking or Replicating the Human Facial Expressions on Prof. Einstein's Robot

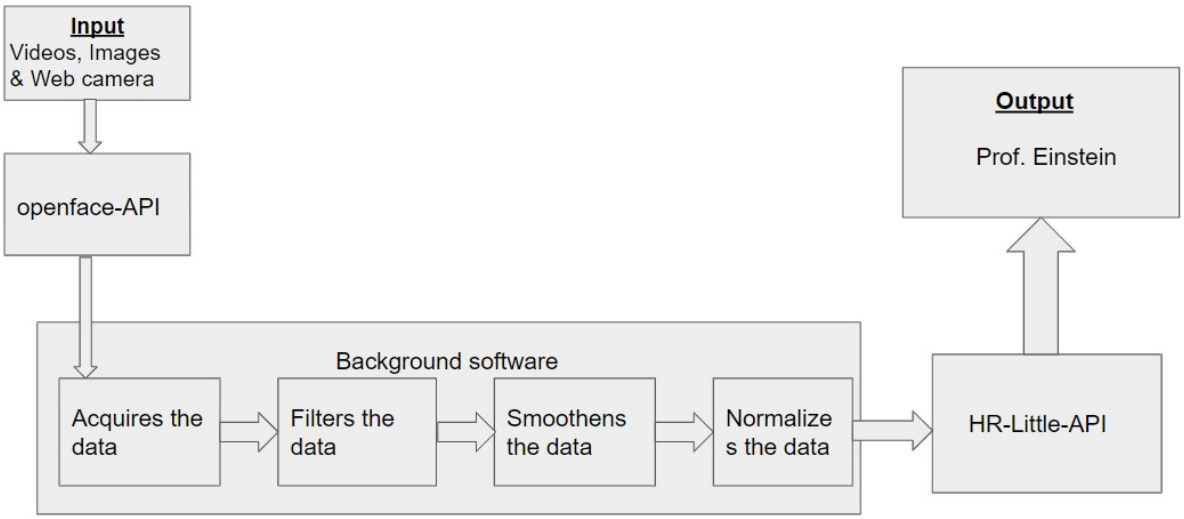
The main aim of this research is to build a software system which is capable of mimicking the facial expressions of a human on a Humanoid Robot (Prof. Einstein Robot)

Facial Expressions and Emotions

A facial expression is one or more motions or positions of the muscles beneath the skin of the face. These movements convey the emotional state of an individual to observers. Facial expressions are a form of nonverbal communication.
Some of the common facial expressions are anger, surprise, sadness, neutral, happiness, fear & disgust.



The Software Architecture of the Face Mimicking system



This is the basic block diagram of how this system functions to take the human face or expressions as the input and replicate it on the Prof. Einstein robot.

The basic functioning blocks of this system are

Input: Here we can give facial expressions of a human in various forms such as Images, Videos, and through the live web camera.

Openface API: This is a state-of-the-art tool that is intended for facial landmark detection & facial action unit recognition(FAU's).

Background Software: This block is intended for data acquisition, filtering, processing, and visualization.

HR-Little-API: This is a tool used to control the movements of the Professor Einstein Robot.

Professor Einstein Robot: This is the hardware, where we can see the replica of our facial expressions.

Professor Einstein Robot

The hardware of the EINSTEIN ROBOT

- The main computer board uses an ARM7 processor;
- Two NiMH rechargeable batteries hide inside the feet, allowing the robot to run for 3 hours;
- The main audio input is a microphone on its chest; two additional mics on the sides of the head help with sound direction location;
- Infrared sensors on the bottom of the shoes prevent the robot from walking off of a table;
- For movement, the robot uses nine coreless DC motors with custom gearboxes. Motors on the legs and feet allow it to walk.

Motors controlling the Head and Facial Expressions of the Robot

The Facial expressions of the robot can be controlled by four motors

- Eyebrows
- Eyelids
- Mouth
- Lip-corners

The head Movement of the robot can be controlled by two motors

- Head turn
- Head pitch

Position of Motors - This is used to move a motor, to a certain position between 0.0 and 1.0

Delay of the Motors- This is the time in seconds that the motor can take to move to the desired position, between 0.0 and 1.0.

HR Little API
This is the tool used to program and control Prof. Einstein's robot.

To install the HR Little API:

Use the link and make use of the Github repository
https://github.com/hansonrobotics/hr-little-api
or
To install hr-little-api from PyPI, with the command line using pip:
`pip install hr-little-api`

Important Classes and Functions to control the robot:

Robot class: This has a number of methods to control the actions to the robot.
robot = Robot(): To Instantiate a Robot object:
robot.do(): we can create actions by calling functions that represent the action we want the robot to make, and then pass the action through this function.
motor(self, motor_id: MotorId, position: float, seconds: float): This is a very important function to move the robot to a particular position within a certain time.
motor_id: the ID of the motor.
position: the position to move the motor to, between 0.0 and 1.0.
seconds: the time in seconds that the motor should take to move to the desired position, between 0.0 and 1.0

How to detect Faces and the position of each individual facial movements

Facial Action Units

Facial Action Coding System (FACS) is a system to taxonomize human facial movements by their appearance on the face. Movements of individual facial muscles

are encoded by FACS from slight different instant changes in facial appearance. Using FACS it is possible to code nearly any anatomically possible facial expression, deconstructing it into the specific Action Units (AU) that produced the expression. It is a common standard to objectively describe facial expressions.

Upper Face Action Units					
AU 1	AU 2	AU 4	AU 5	AU 6	AU 7
					
Inner Brow Raiser	Outer Brow Raiser	Brow Lowerer	Upper Lid Raiser	Cheek Raiser	Lid Tightener
*AU 41	*AU 42	*AU 43	AU 44	AU 45	AU 46
					
Lid Droop	Slit	Eyes Closed	Squint	Blink	Wink
Lower Face Action Units					
AU 9	AU 10	AU 11	AU 12	AU 13	AU 14
					
Nose Wrinkler	Upper Lip Raiser	Nasolabial Deepener	Lip Corner Puller	Cheek Puffer	Dimpler
AU 15	AU 16	AU 17	AU 18	AU 20	AU 22
					
Lip Corner Depressor	Lower Lip Depressor	Chin Raiser	Lip Puckerer	Lip Stretcher	Lip Funneler
AU 23	AU 24	*AU 25	*AU 26	*AU 27	AU 28
					
Lip Tightener	Lip Pressor	Lips Part	Jaw Drop	Mouth Stretch	Lip Suck

Available tools for Facial Action Units(FAU) Recognition and why choose open-face

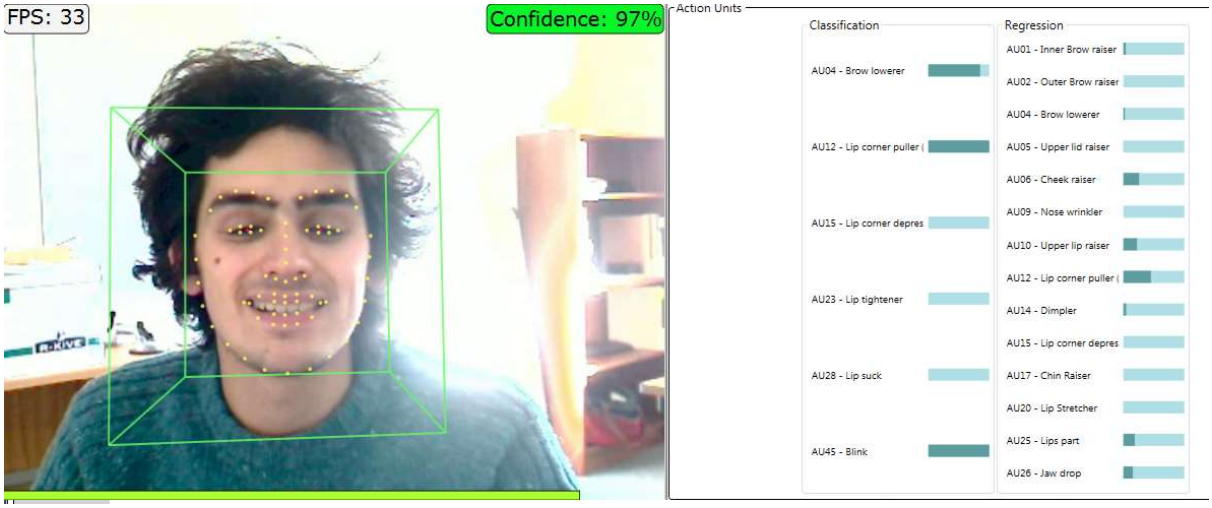
There are very few freely available tools for action unit recognition. There are a number of commercial systems that can perform Action Unit Recognition like

- iMotions
- Affectiva
- Noldus FaceReacer

Drawbacks

- The cost of these systems is very high.
- The algorithms and the training data used are mostly unknown
- Some tools are restricted to single machine use.
- The commercial product may be discontinued leading it impossible to reproduce the results due to a lack of product transparency.

open face tool is free to use and most importantly it covers most of the discussed drawbacks of the above mentioned alternative commercial products.



AU's available on openface

OpenFace is able to recognize a subset of AUs, specifically: 1, 2, 4, 5, 6, 7, 9, 10, 12, 14, 15, 17, 20, 23, 25, 26, 28, and 45.

AU's that can be mapped with the Einstein's robot

AU	Description	Example image
1	Inner Brow Raiser	

2	Outer Brow Raiser	
4	Brow Lowerer	
5	Upper Lid Raiser	
7	Lid Tightener	
10	Upper Lip Raiser	
12	Lip Corner Puller	
15	Lip Corner Depressor	
25	Lips part	

Data Collection

The face has four motors Eyebrows(AU01,AU04), Eyelids(AU05,AU07), Lipcorners(AU12,AU15) and Mouth(AU25). Collect the data using the openface from multiple users. For example Set the timer to 30 sec, start with the eyebrows, raise the eyebrows to the maximum value and hold on to it for 5 seconds and after 5 seconds frown the eyebrow to the least possible minimum value repeat these for 30 seconds and do the same exercise for each of the eyelids, lipcorners and mouth. Save all these data and perform the analysis.

Data Analysis

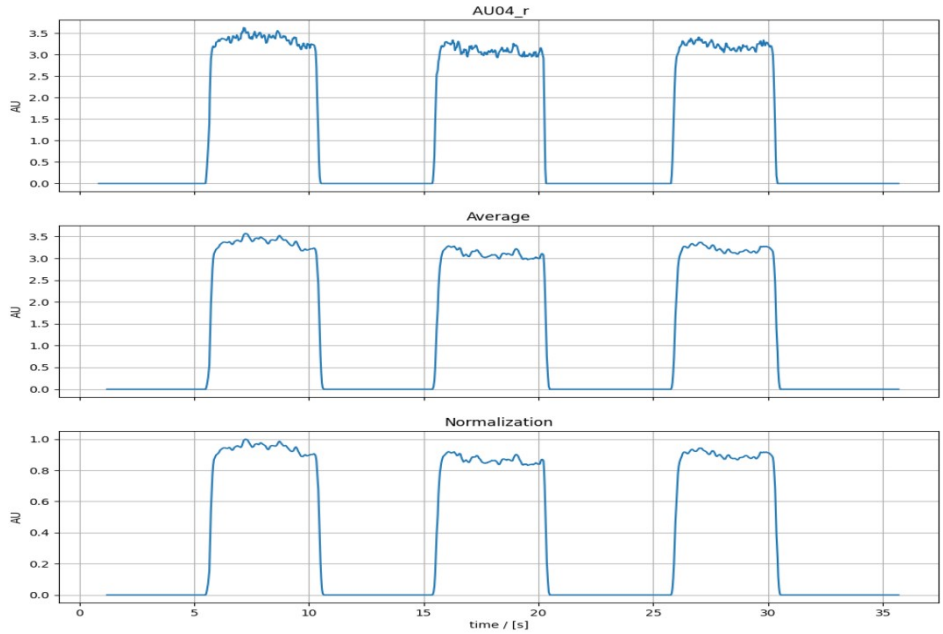
Data analysis is a very crucial step for the system. The data is obtained in the form of a CSV file.

1. From the obtained data extract only the required set of Action Units(AU) information and filter the remaining data. The obtained data will have a lot of noise and disturbances.
2. To over come the noise we have to smoothen the data, for this task we can take the moving average of the data, so the curve will be smoothed.
3. Normalize the moving average - to match the robot motor inputs for the range (0.0 to 1.0)

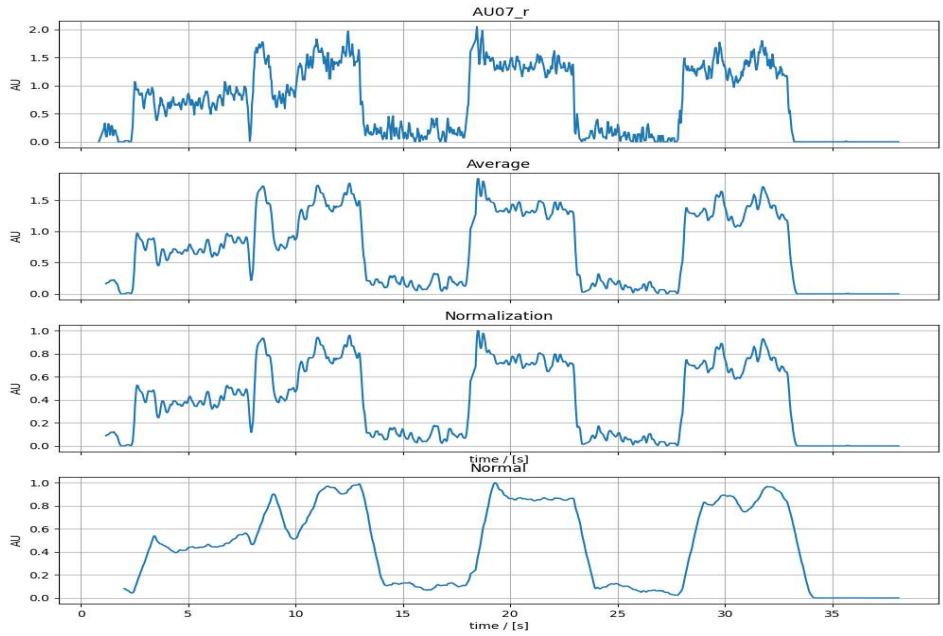
Plotting graphs

Plot all the required graphs and compare the output between plotted graph results from data analysis and execute the data on the robot.

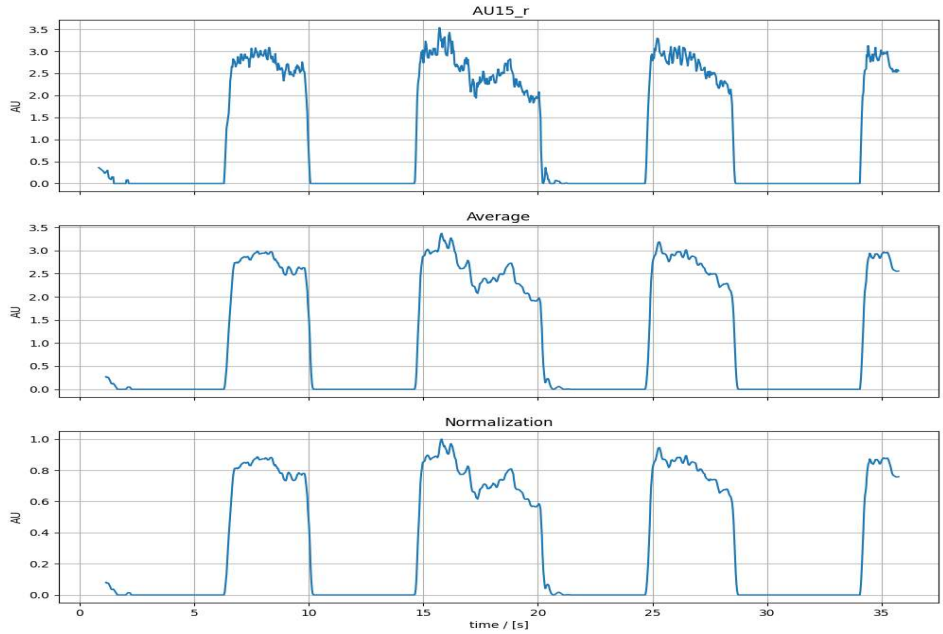
Eyebrows



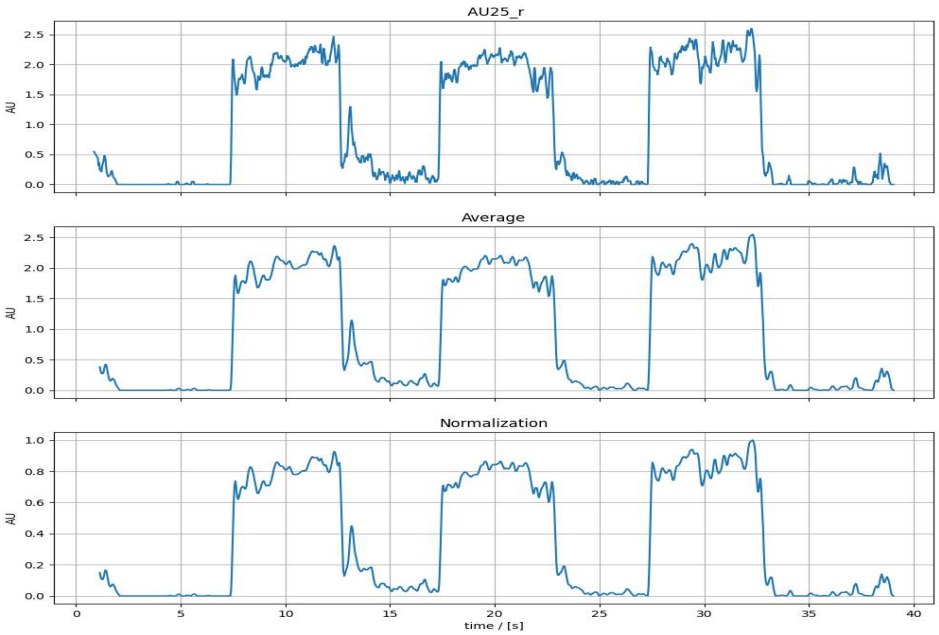
Eyelids



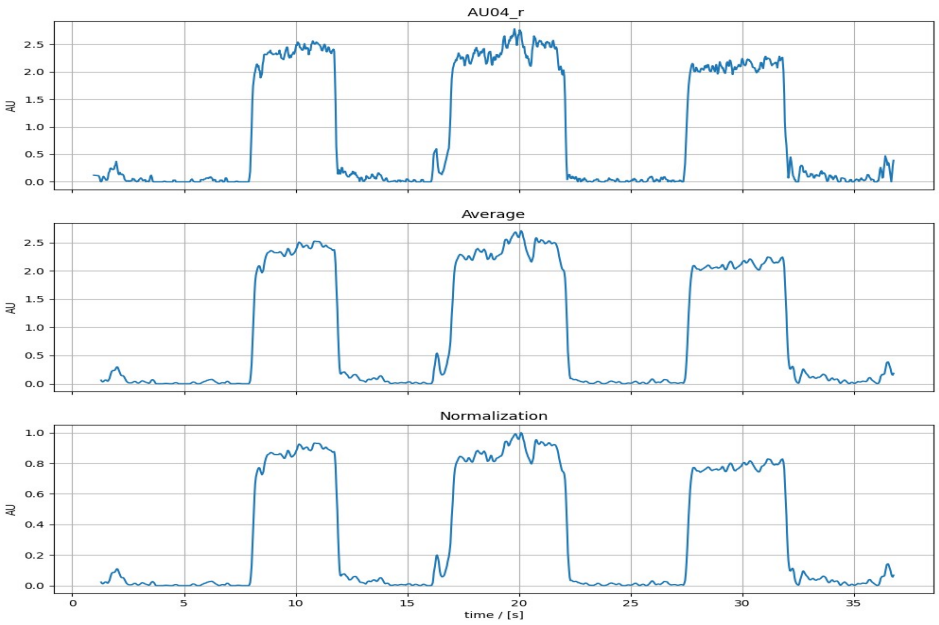
Lipcorners



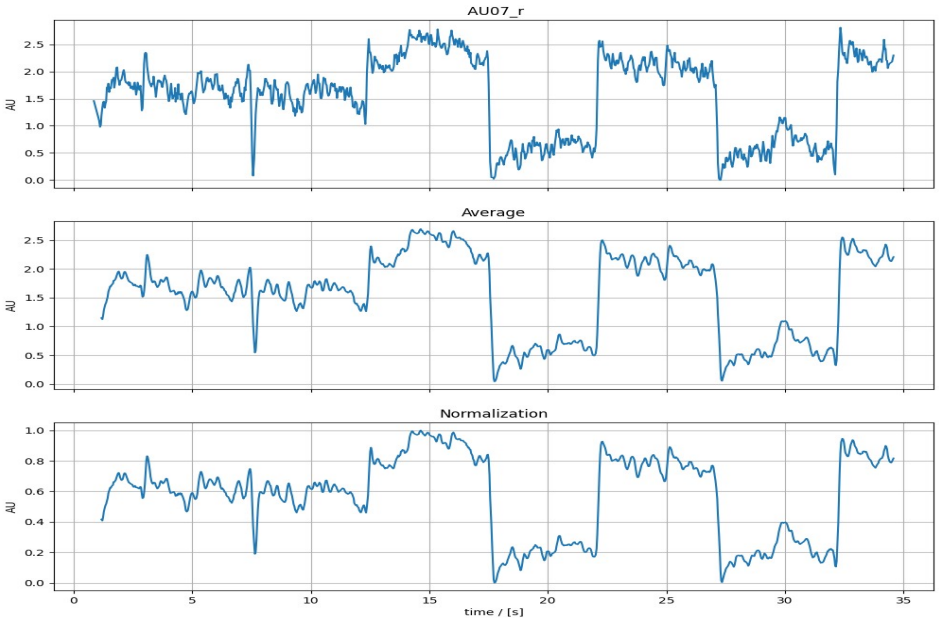
Mouth



Eyebrows


AU04_r
Average
Normalization
AU
time / [s]

Eyelids


AU07_r
Average
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AU
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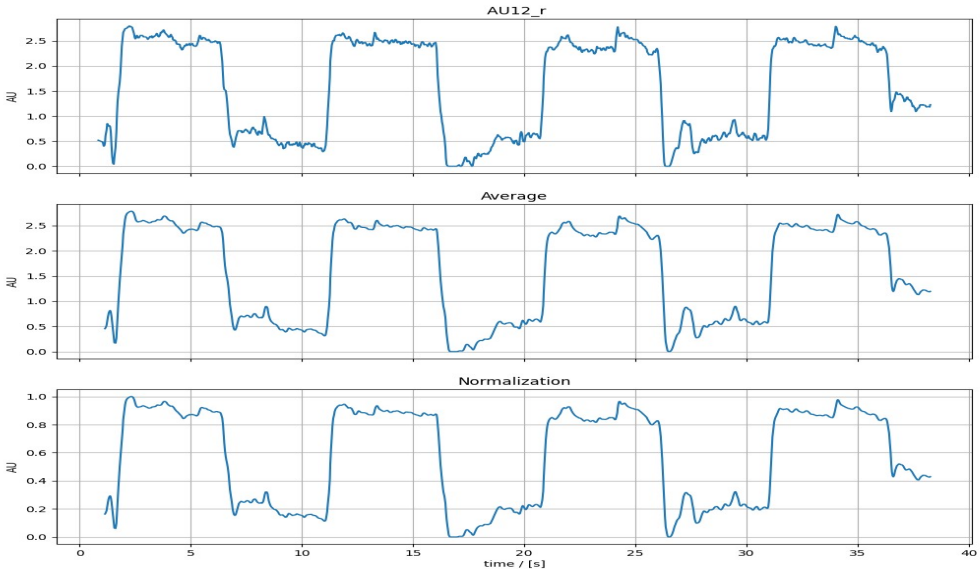
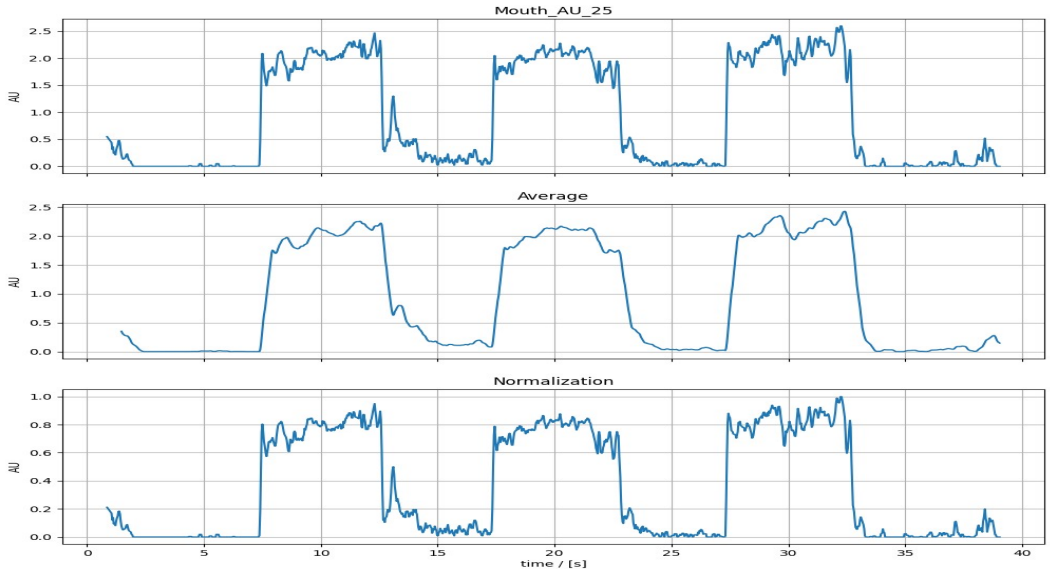
Lipcorners



Mouth



Final Step - Mimicking

1. Activate the camera and connect the Einstein robot
2. The user faces the camera connected to the robot.
3. The software detects the Facial action units and automatically creates a CSV file live with constantly updating the Action unit values.
4. Import the data from the CSV file into the software script.
5. Since the min and max values were already recorded and given in the script.
6. The final output of the facial expressions is replicated on the robot.