SMART WEATHER STATION

Non-Mechanical Rain guage
Non-Mechanical Wind sensor

Date of Presentaion
DEC 15TH 2022

AI for good tinyML challenge

Presented By
DIYA U PRADEEP
RESEARCH ASSISTANT
ICFOSS

CENTER FOR DEVELOPMENT OF OPEN HARDWARE(CDOH)

Overview...

Introduction

Currently, weather elements wind and rain are monitored using mechanical instruments like tipping buckets and cup anemometer which require regular maintenence .

This project aims at producing locally maintainable weather stations at cheaper cost ,low power capabilities while ensuring accurate and dependable results using Machine Learcning(ML) at the Edge.

Why no mechanical moving parts for sensors measuring weather parameters???

- Inflexible rotation and stuck.
- Foreign stuffs like leaves in the gully,tipping bucket should be blocked at that time.
- Damaged filters, funnels, cracks or deformations on the tipping bucket, etc., will seriously affect the accuracy of the measurement.
- Induction of the read switch is not sensitive.

NO MECHANICAL MOVING PARTS

TINY ML MODEL ON EMBEDDED DEVICE

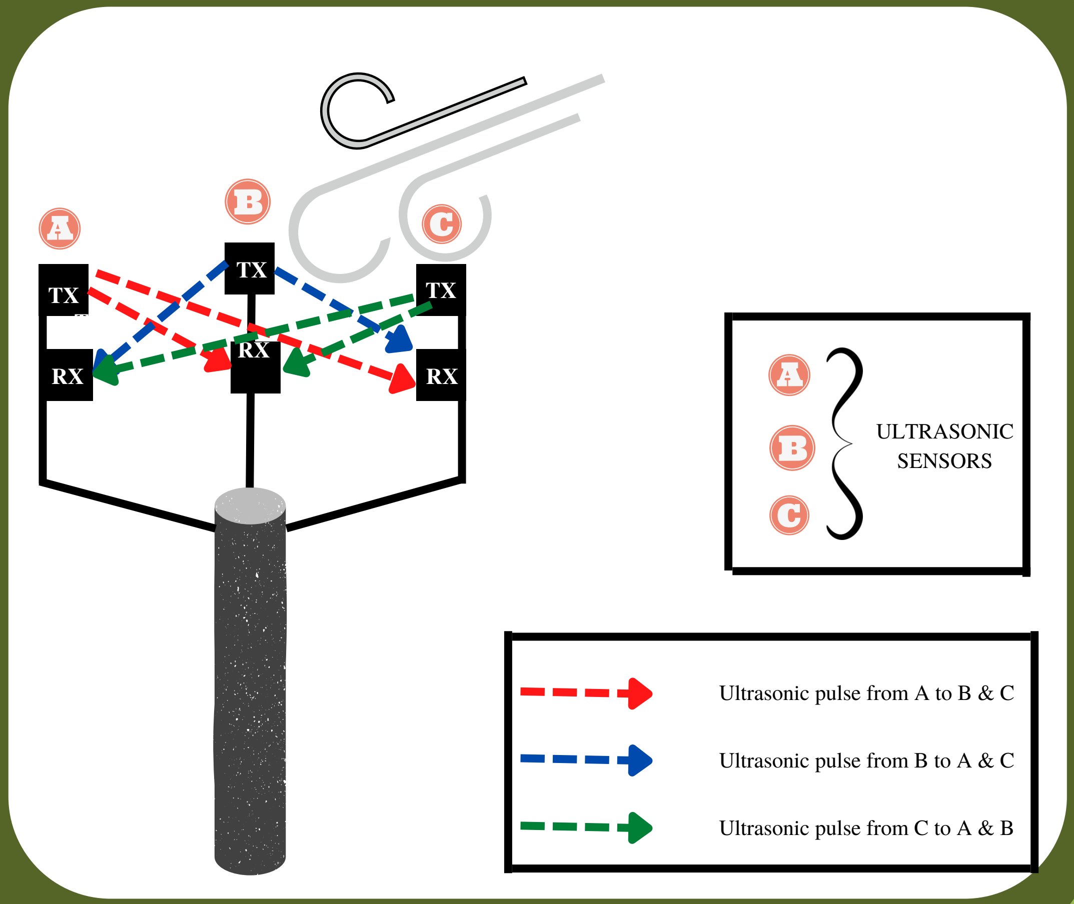
LOW COST

LOW POWER

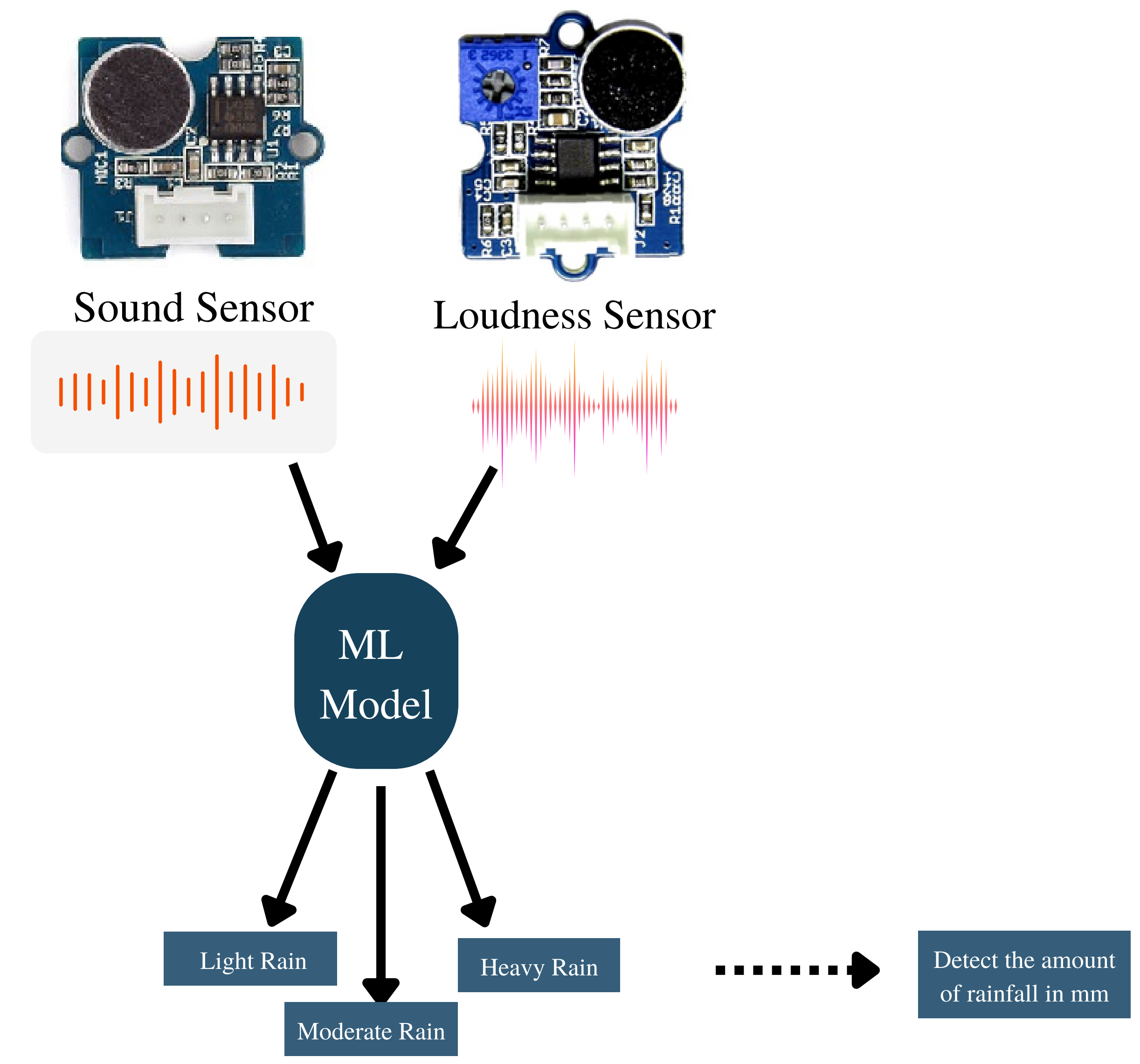
Proposed System

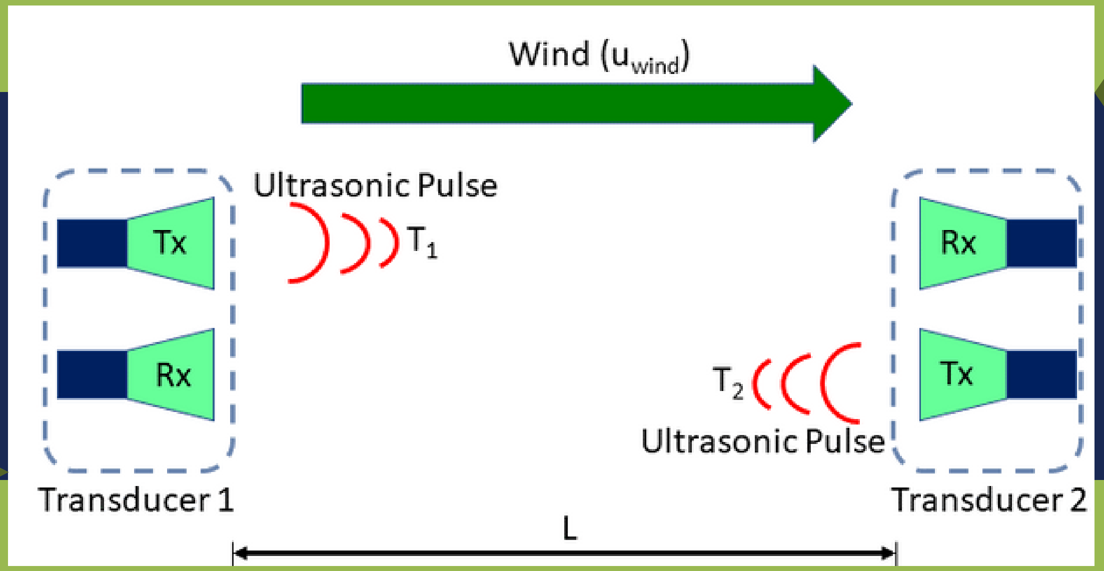
WIND

RAIN



Speed of the ultrasonic pulse is increased by the wind speed in the direction that wind is blowing.Ultrasonic pulses are transmitted between sensors A,B,and C. Ultrasonic pulse transmitted from sensor A and measure the speed of pulses fron sensor B and C. Similar for sensor B and C.thus a total of six measurements are taken to determine wind speed and direction.





Identify the sound and loudness of rain using ML algorithm for classification and Quantized to get amount of rainfall in mm.

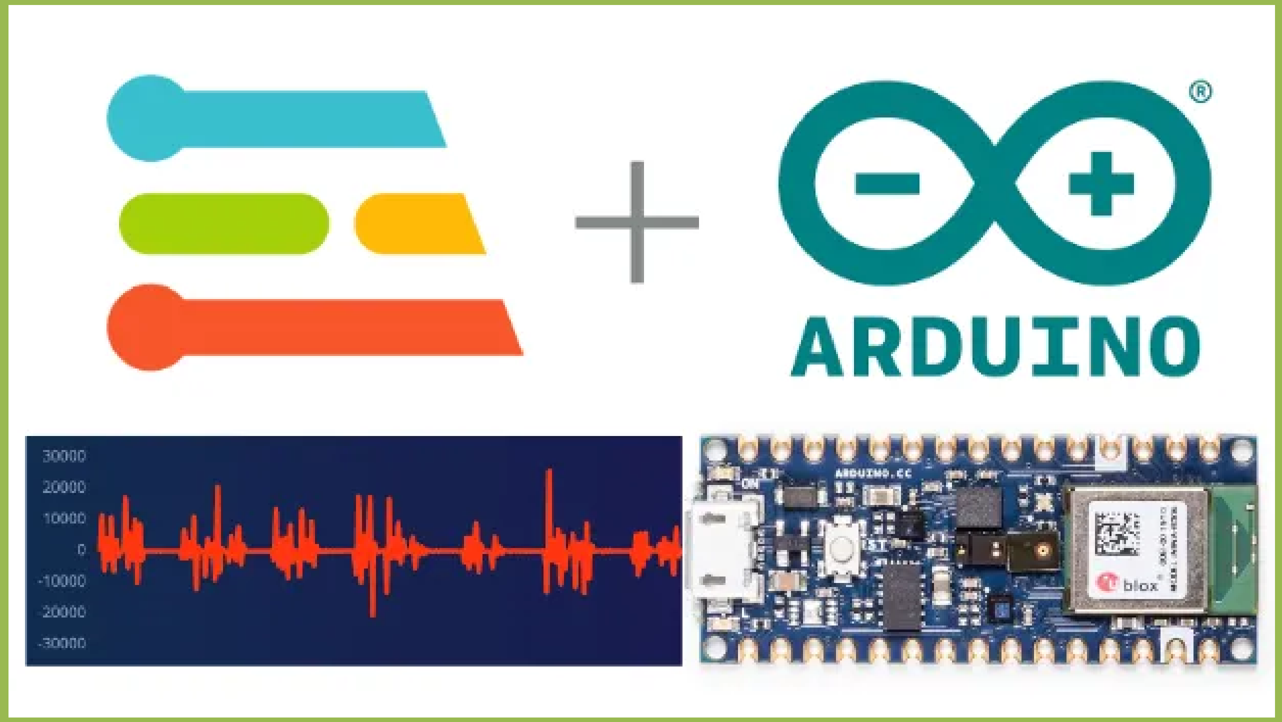
With no mechanical moving parts

Ultrasonic sensors are used for the determination of wind direction and wind speed

Sound and Loudness Sensor are used to Collect local rain acoustics.

Resources

- Use Edge Impulse Software for tiny ML model to derive rain and wind values.
- Use Arduino Nano BLE Sense board for the deployment



Wind - Device Concept and Design

Why ultrasonic sensor HC-SR04 prefered?

Ultrasonic sensor

Specifications

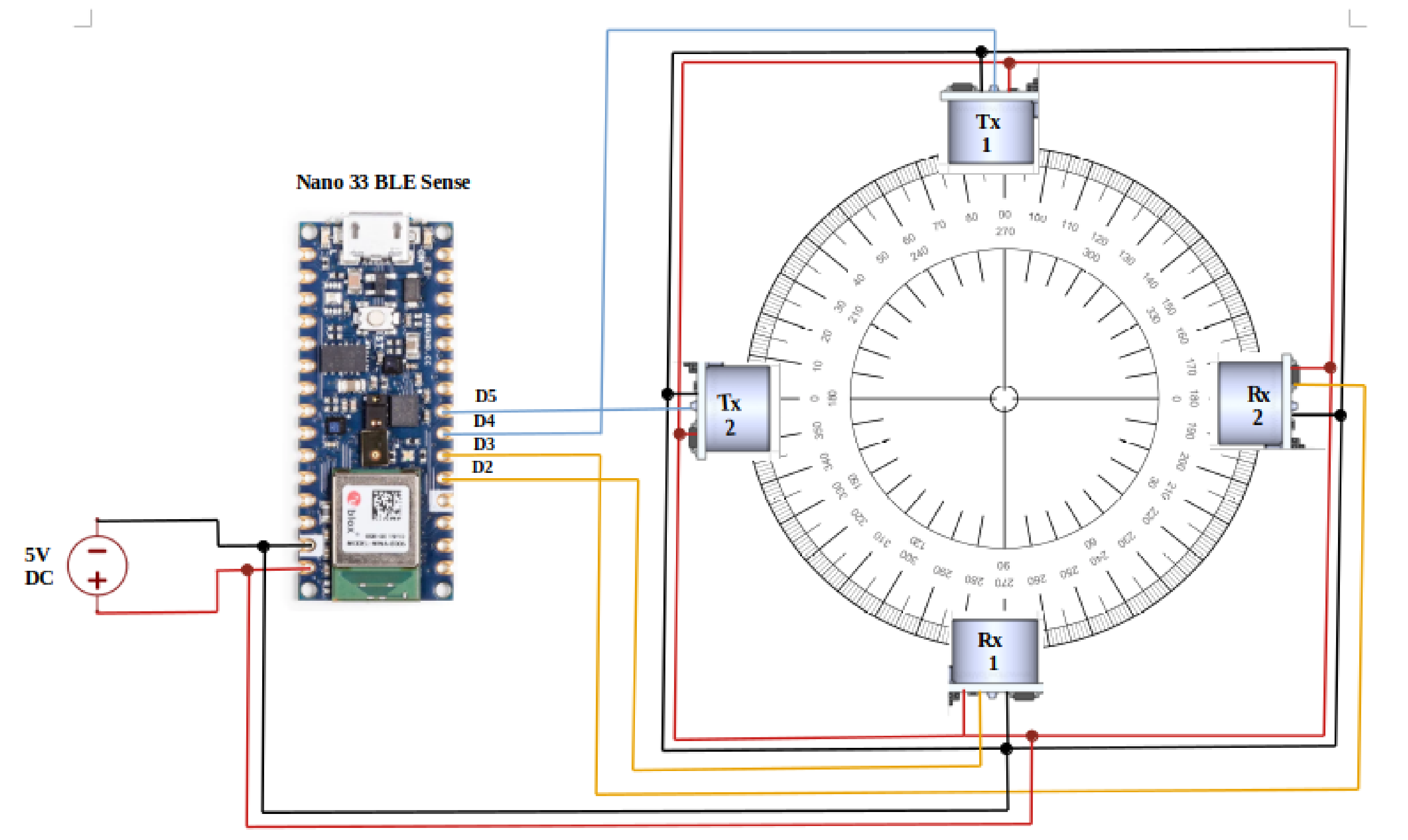
Electrical Parameters	HC-SR04 Ultrasonic Module
Operating Voltage	DC-5V
Operating Current	15mA
Operating Frequency	40KHZ
Farthest Range	4m
Nearest Range	2cm
Measuring Angle	15 Degree
Input Trigger Signal	10us TTL pulse
Output Echo Signal	Output TTL level signal, proportional with range
Dimensions	45*20*15mm

Data Collection Module

Components

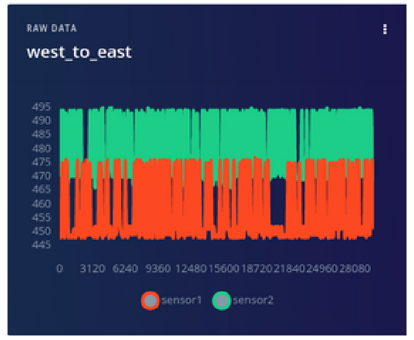
- HC-SR04 Ultrasonic sensor-2 Nos

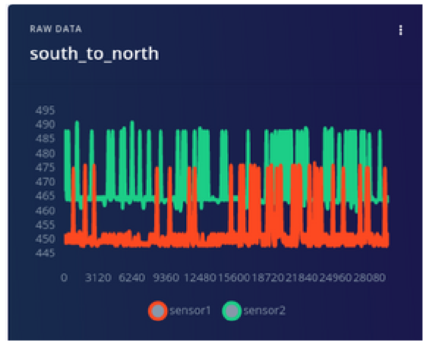
Circuit Setup

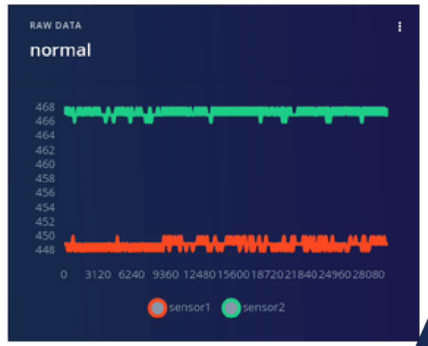


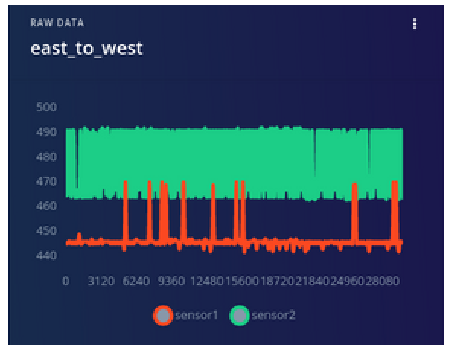
Dataset Creation

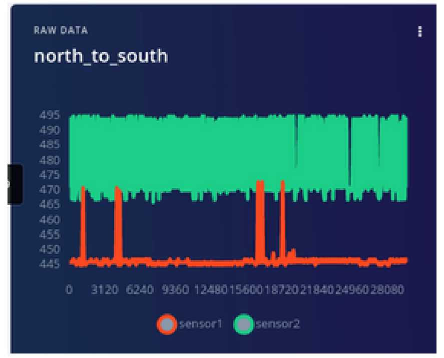
Dataset were created with the help of table fan and recorded the duration ultrasonic sound transmission and reception and labelled the data as **normal, north-south, south-north, east-west, west-east.**



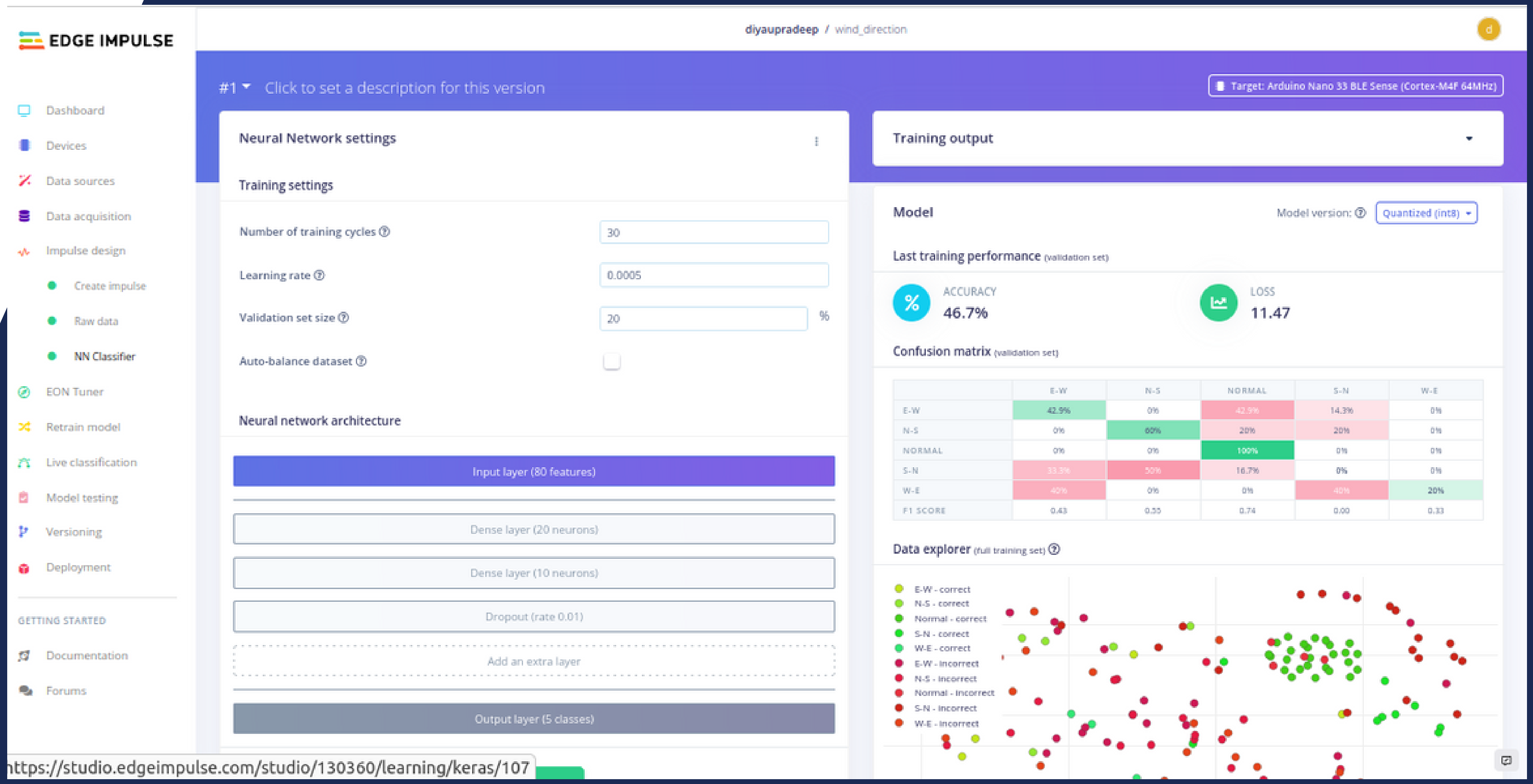








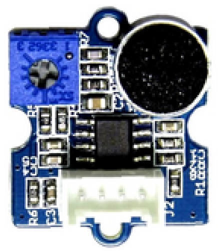
Model Creation and Performance Analysis.



- Accuracy:46.74%
- loss:11.47
- Learningrate:0.0005
- no:of epoch:30

Rain - Device Concept and Design

Why loudness sensor and sound sensor preferred for Acoustic data aquisition ?



Loudness Sensor

Sound Sensor

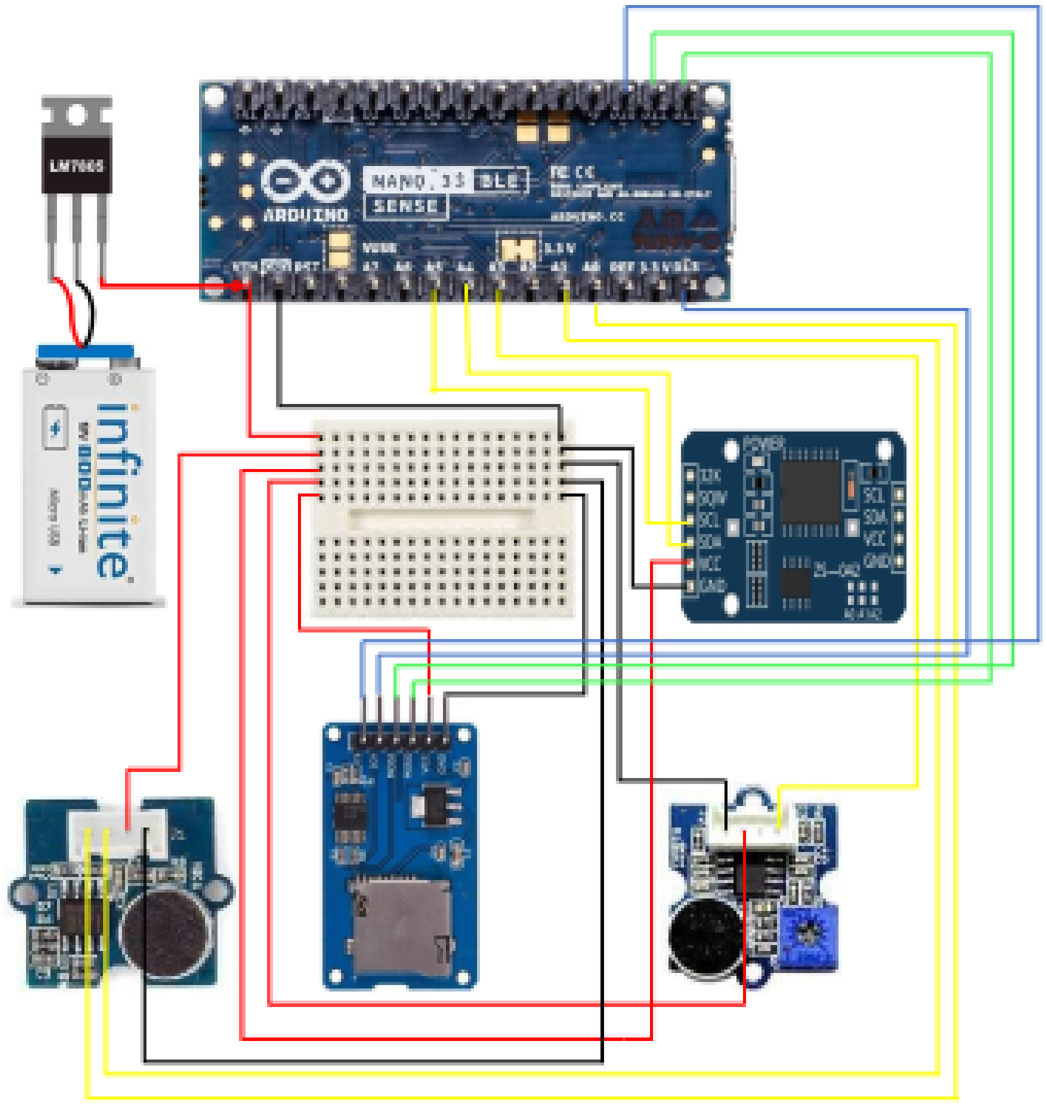
Specifications

Parameter	Value/Range
Voltage	3.5~10 VDC
Working Frequency	5~2000 Hz
Sensitivity	-60~-56dBV/Pa
Signal-to-noise Ratio	>58 dB
Output Signal range	Analog Signal (0-1023)

Specifications

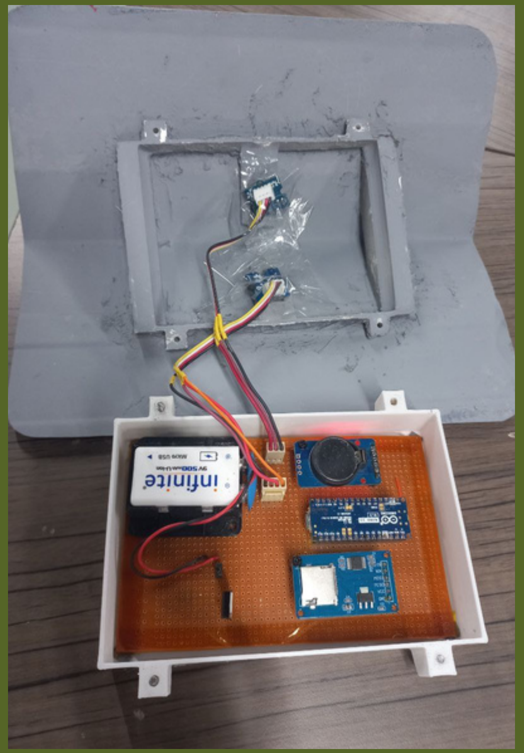
Item	Value
Operating Voltage Range	5 V
Operating Current(Vcc=5V)	4~5 mA
Voltage Gain(V=6V, f=1kHz)	26 dB
Microphone sensitivity(1kHz)	-60~-56dBV/Pa
Microphone Impedance	2.2k Ohm
Microphone Frequency	16-20 kHz
Microphone S/N Radio	54 dB

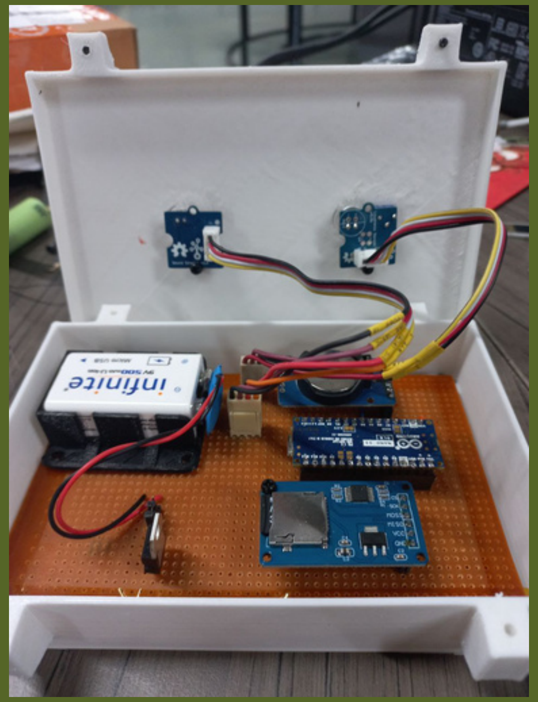
Circuit Setup



Components

- Groove sound sensor module
- Groove loudness sensor module
- RTC
- Micro SD Adapter
- memory card
- Battery 500 mAh 9V
- Metallic sheet
- 3D printed enclosure





Data Collection setup was implemented as shown here, where an aluminum sheet is placed to fix the sound and loudness sensor to collect the acoustics of local rain.

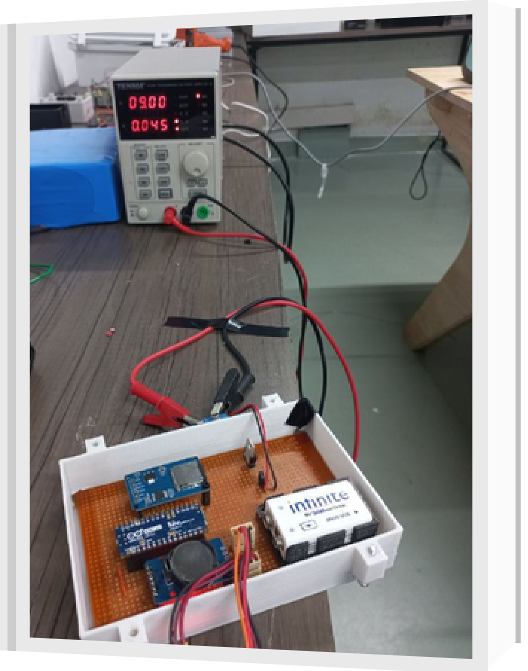
Power Analysis

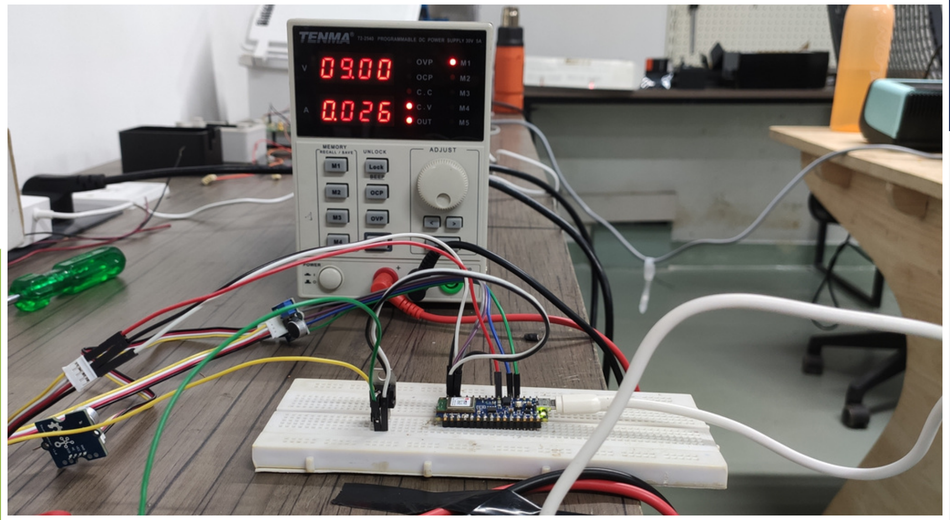
1.RTC MODULE

Operating Voltage= 3.63 V - 5.5 V
Current Requirement= 200 μA - 300 μA
Power = V*I
Minimum Power= 3.63*200*10^-6 = 0.000726 W
Maximum Power= 5.5*300*10^-6= 0.00165 W

2.MICRO SD ADAPTER

Operating Voltage= 4.5 V - 5.5 V
Current Requirement= 0.2 mA - 200 mA
Minimum Power=4.5*0.2*10^-3= 0.0009 W
Maximum Power= 5.5*200*10^-3 = 1.1W





3.SOUND SENSOR

Operating Voltage= 5 V
Current Requirement= 4 mA ~ 5 mA
Minimum Power=5*4*10^-3= 0.02W
Maximum Power= 5*5*10^-3 = 0.025W

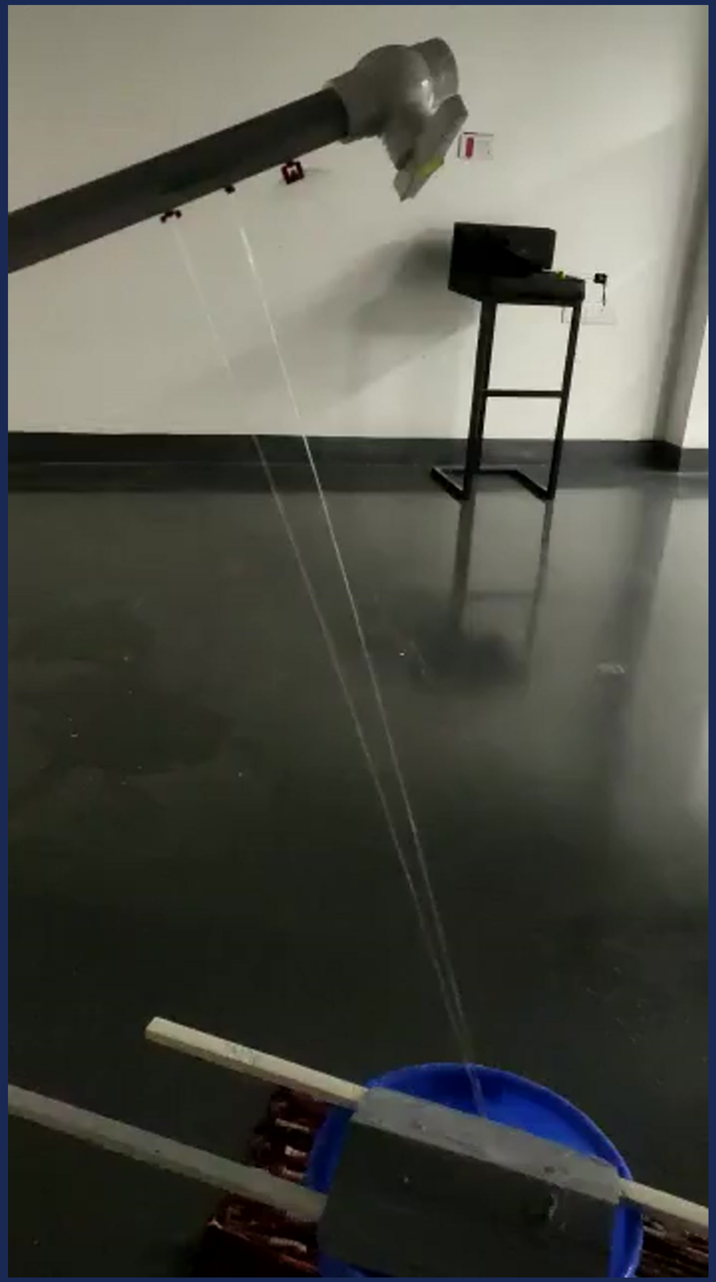
4.LOUDNESS SENSOR

Operating Voltage=3.5 V ~ 10 V
Power Rating Minimum= 0.0009+0.000726+0.020= 0.021626 Watts
Power Rating Maximum= 1.1+0.00165+0.025 =1.12665 Watts
Average Power Rating is 0.5 Watts

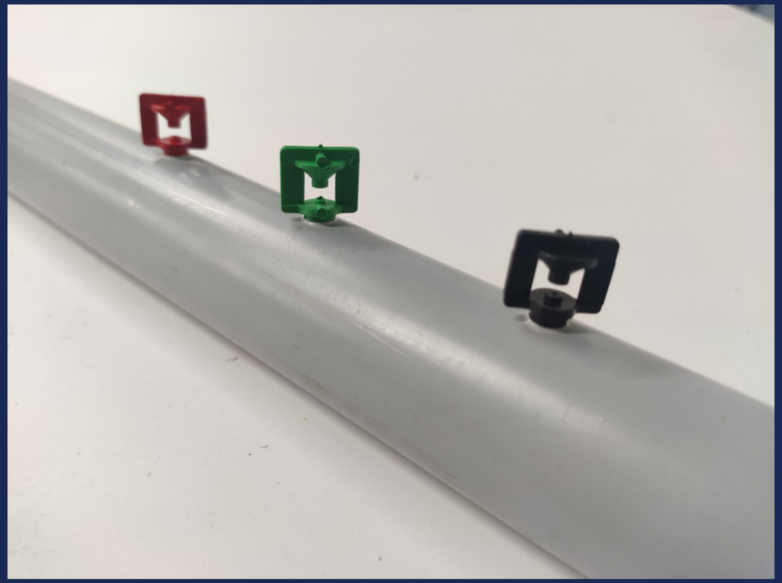
Overall power consumption for Data Collection setup (Arduino Nano BLE,Sound sensor,Loudness sensor,7805 voltage regulator,microSD adapter, RTC)= 0.405 Watts

Experimental Lab Setup

The first phase of experiments was setup using mist irrigation nozzles. and data collected with time duration of 45 minutes.



Testbench using Mist Irrigation Nozzles



Arrangements

Dataset Creation

Time	Sound	Loudness
12:07:07	659	260
12:08:07	20	271
12:09:08	620	273
12:10:08	486	238
12:11:08	521	258
12:12:08	200	254
12:13:09	491	91

Set up 1
Settings used for creating this condition:

Tap was almost closed.

Time	Sound	Loudness
12:15:09	447	277
12:16:09	280	255
12:17:10	308	224
12:18:10	472	260
12:19:10	383	287
12:20:10	12	139

Setup 2
Settings used for creating this condition:

Tap was more closed than the previous set

Time	Sound	Loudness
12:21:11	39	141
12:22:11	26	131
12:23:11	137	141
12:24:12	254	165
12:25:12	130	136
12:26:12	19	102

Setup 3
Settings used for creating this condition:

*Tap was more open than **setup 1***

Time	Sound	Loudness
12:32:14	90	172
12:33:14	447	275
12:34:14	665	240
12:35:15	563	251

Setup 4
Settings used for creating this condition:

The Mist Nozzle was cut.
Tap was partially open.

Modified Nozzle (ii)

Time	Sound	Loudness
12:37:15	848	383
12:38:16	676	373
12:39:16	377	378
12:40:16	362	328
12:41:17	469	372
12:42:17	56	120

Setup 5
Settings used for creating this condition:

The Mist Nozzle was cut.
Tap was more open than previous setup.

Fan jet Nozzle

Time	Sound	Loudness
12:43:17	79	139
12:44:18	615	338
12:45:18	79	126

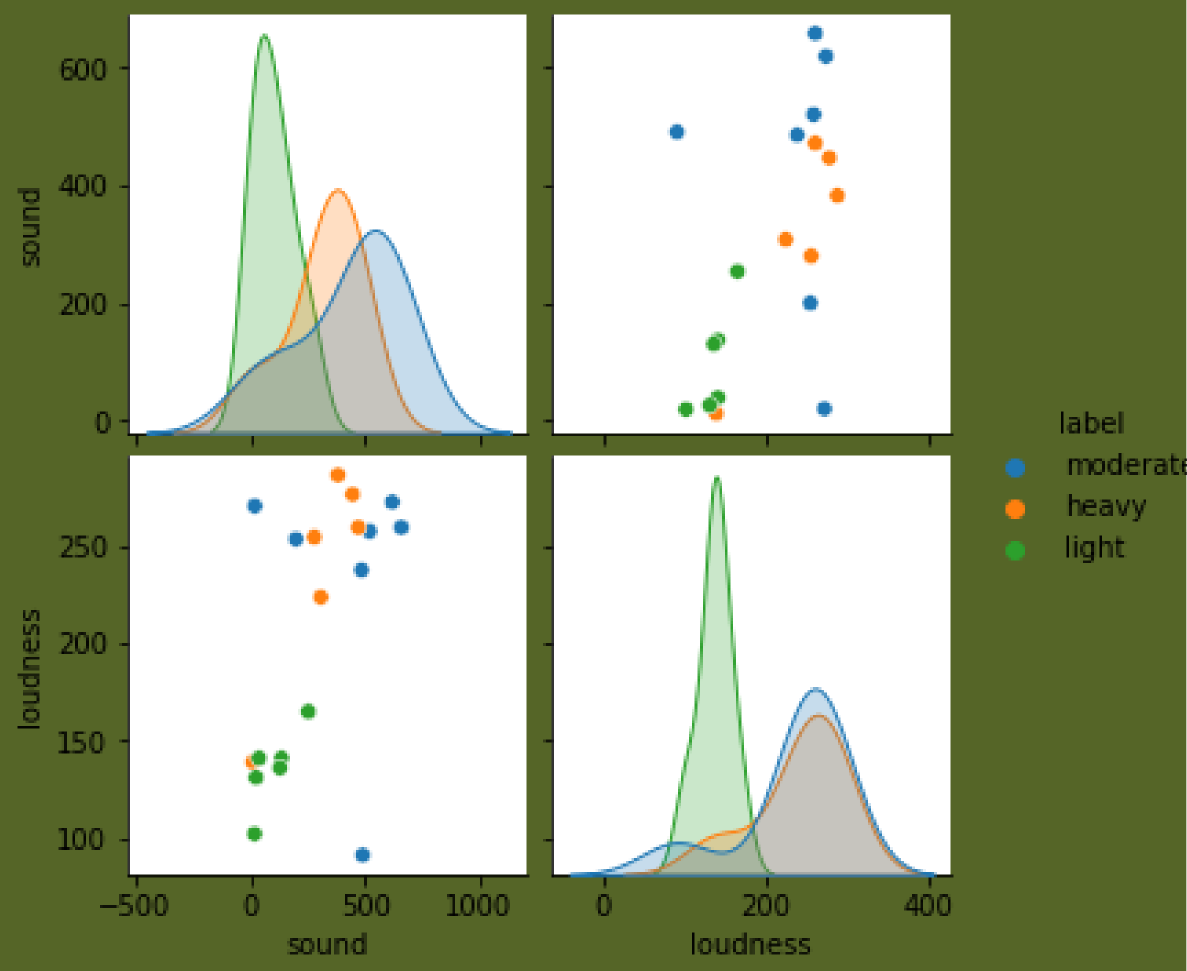
Setup 6
Settings used for creating this condition:

The Fan Jet Nozzle was used
Tap was same as previous setup.

Labelled data

Sound	Loudness	Label
659	260	moderate
20	271	moderate
620	273	moderate
486	238	moderate
521	258	moderate
200	254	moderate
491	91	moderate
447	277	heavy
280	255	heavy
308	224	heavy
472	260	heavy
383	287	heavy
12	139	heavy
39	141	light
26	131	light
137	141	light
254	165	light
130	136	light
19	102	light

CLASSIFIED LABELLED DATA



LABELLING CONSTRAINTS

labelling of rain is based on the constrain over a period of 45 minutes.

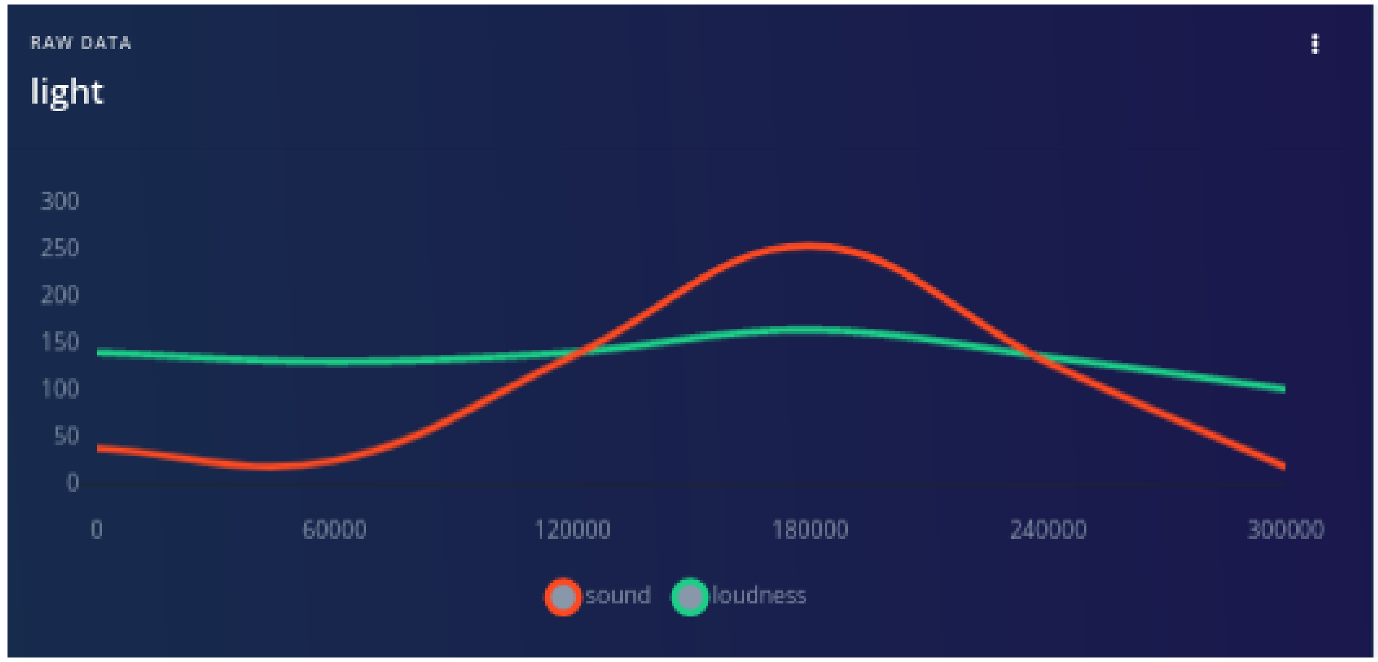
- lightrain <2.5mm
- moderate rain 2.5mm-7.6mm
- heavy rain>7.6mm

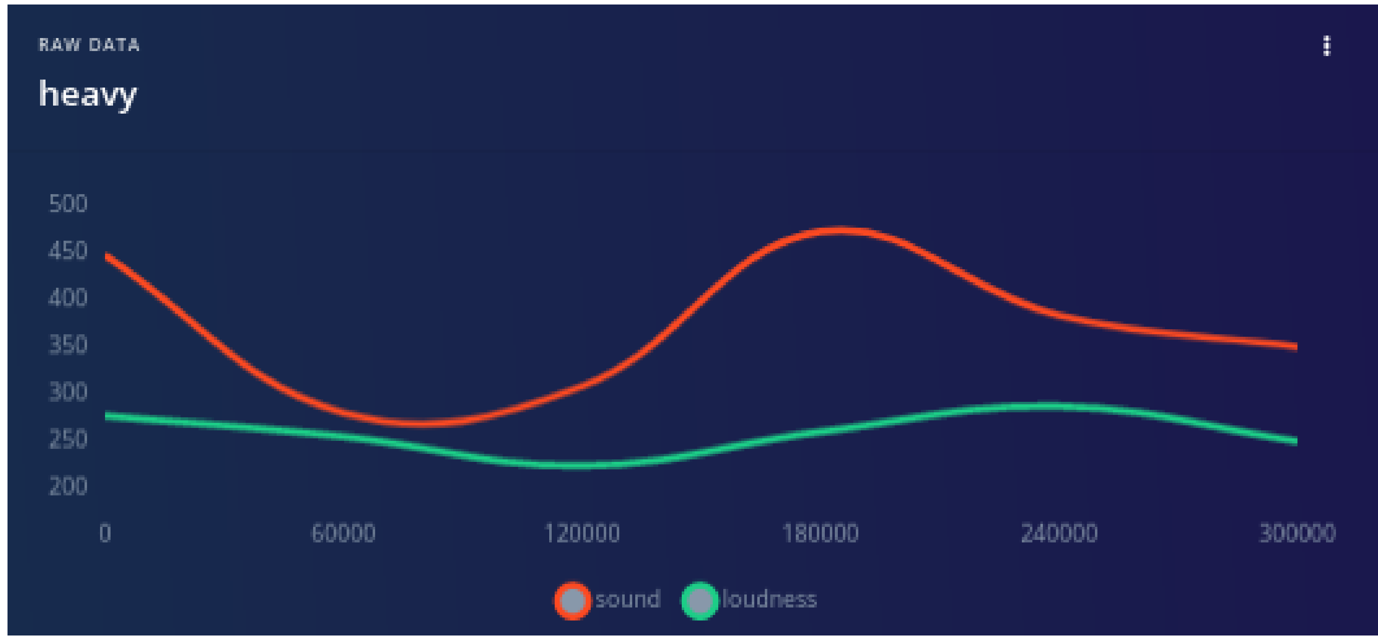
Here the nozzle is adjusted to precipitate <2.5 mm,2.5mm-7.6mm,>7.6mm

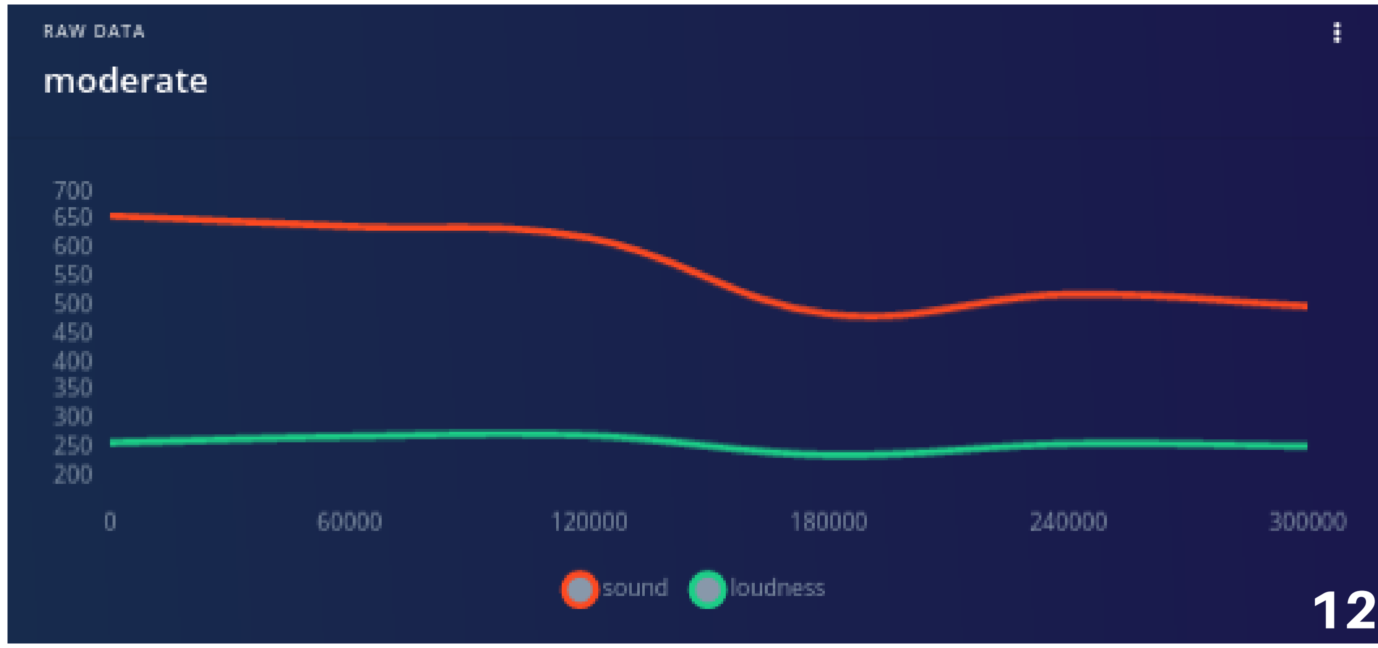
Model Creation

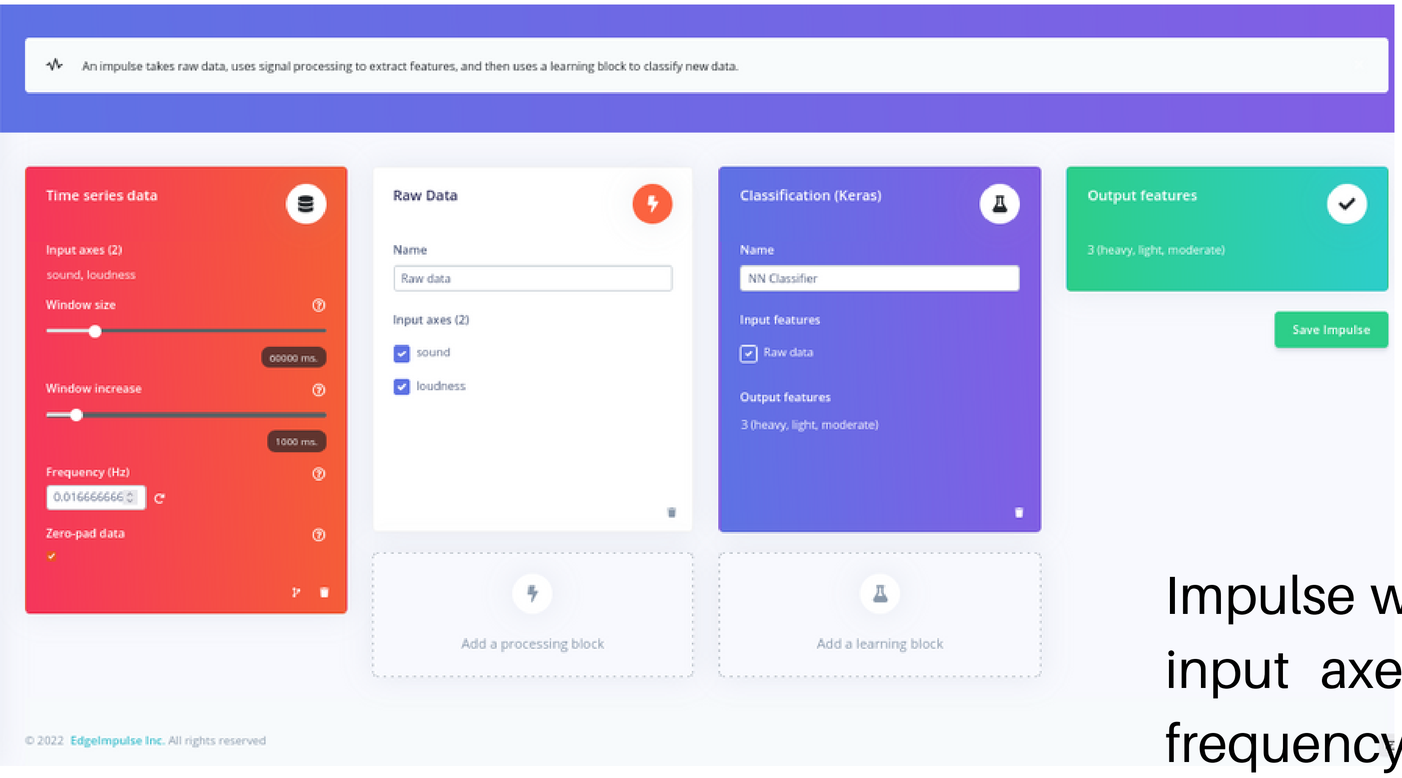
Training data

Classified Labelled data is cleaned by eliminating anomalies and kept as a time series in CSV format with a 60000-millisecond time interval.
Light rain, moderate rain, and heavy rain are indicated on weather labels.









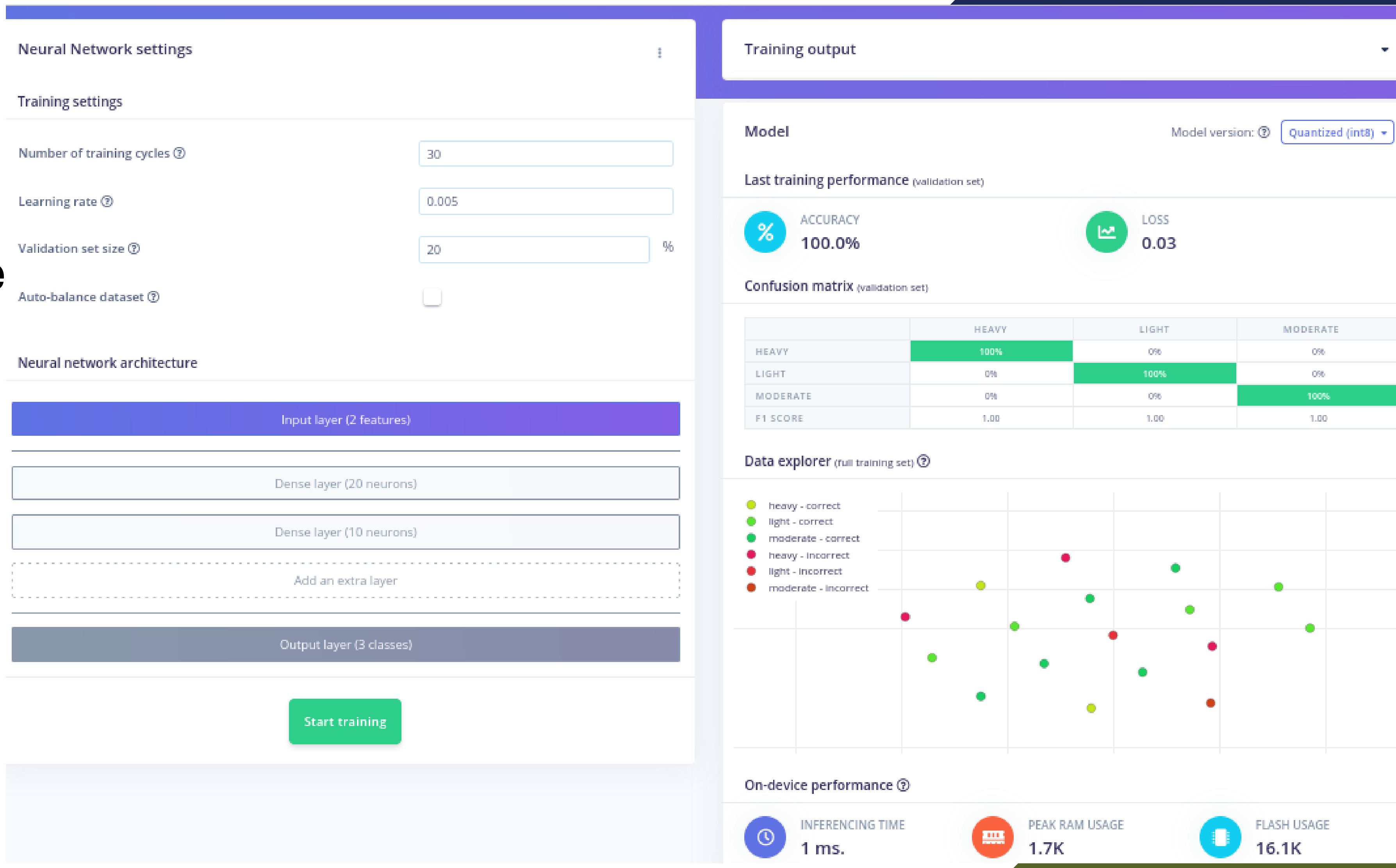
Impulse design

Impulse was created using timeseries raw data, two input axes, a window size of **60000** ms, and a frequency of **0.16667 Hz**, along with the features of sound and loudness.

Labels for the weather indicate whether it will rain **lightly, moderately, or heavily.**
and choose to classify using keras using input (**sound, loudness**) and output attributes (**light,moderate and heavy**)

Model Training

The model was trained during 30 training cycles with 20% of the validation training data and a learning rate of 0.0005 and got a 0.03 loss with **100%** accuracy.



Performance Evaluation

Performance metrics found while performing classification predictions are

<u>Precision:TP/(TP+FP)</u>

Heavy rain:1
light rain:1
moderate rain:1

<u>F1 score:2*(Precision*Recall/Precision+Recall)</u>

Heavy rain:1
Light rain:1
Moderate rain:1

<u>Recall:TP/(TP+FN)</u>

Heavy rain:1
Light rain:1
Moderate rain:1

<u>Accuracy:(TP+TN)/(TP+TN+FP+FN)</u>

Heavy rain:100%(1/1)
Light rain:100%(1/1)
Moderate rain:0%(2/2)

Milestones...

Real Rain Test Analysis

Data is gathered using a configuration similar to that of a mechanical (tipping bucket) rain gauge following which the data are correlated with respect to a time stamp of 1 minute, or **60000 milliseconds.**

A 2 hr data from **4th nov 2022 8PM-10PM IST** is considered. labelling of rain is based on the constrain over a period of ***1 hour***

lightrain <2.5mm
moderate rain 2.5mm-7.6mm
heavy rain>7.6mm

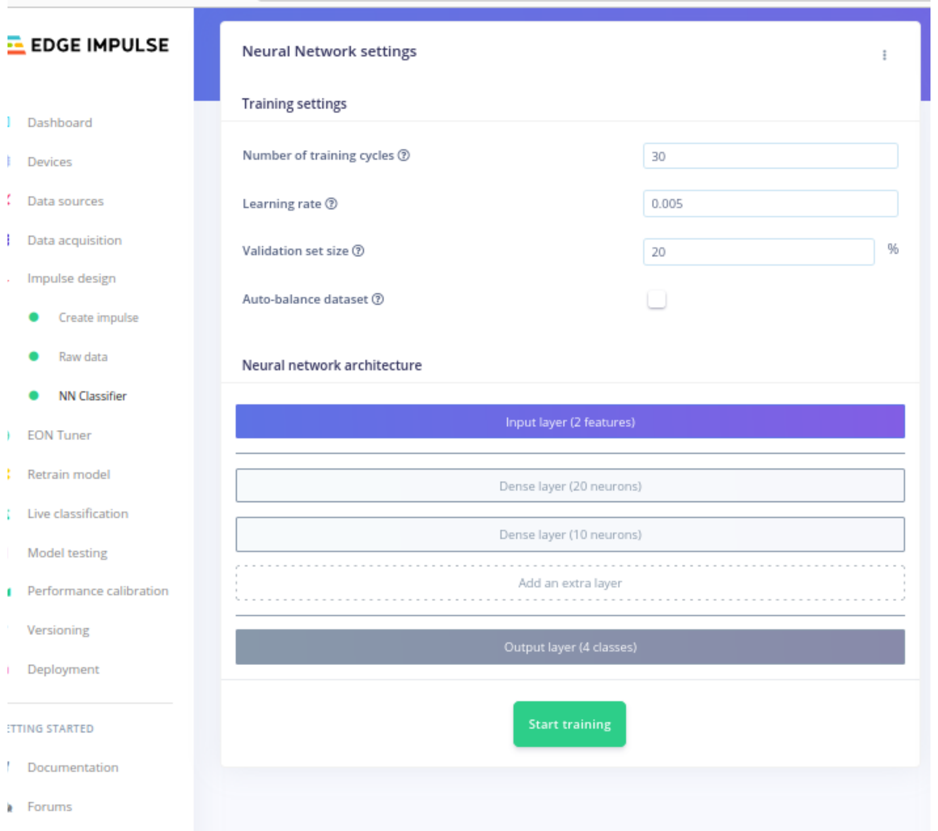
By comparing the data of mechanical(tipping bucket)rain guage
we have values of 0,0.4,9.6,4,1.2,0.2
these are categorized under

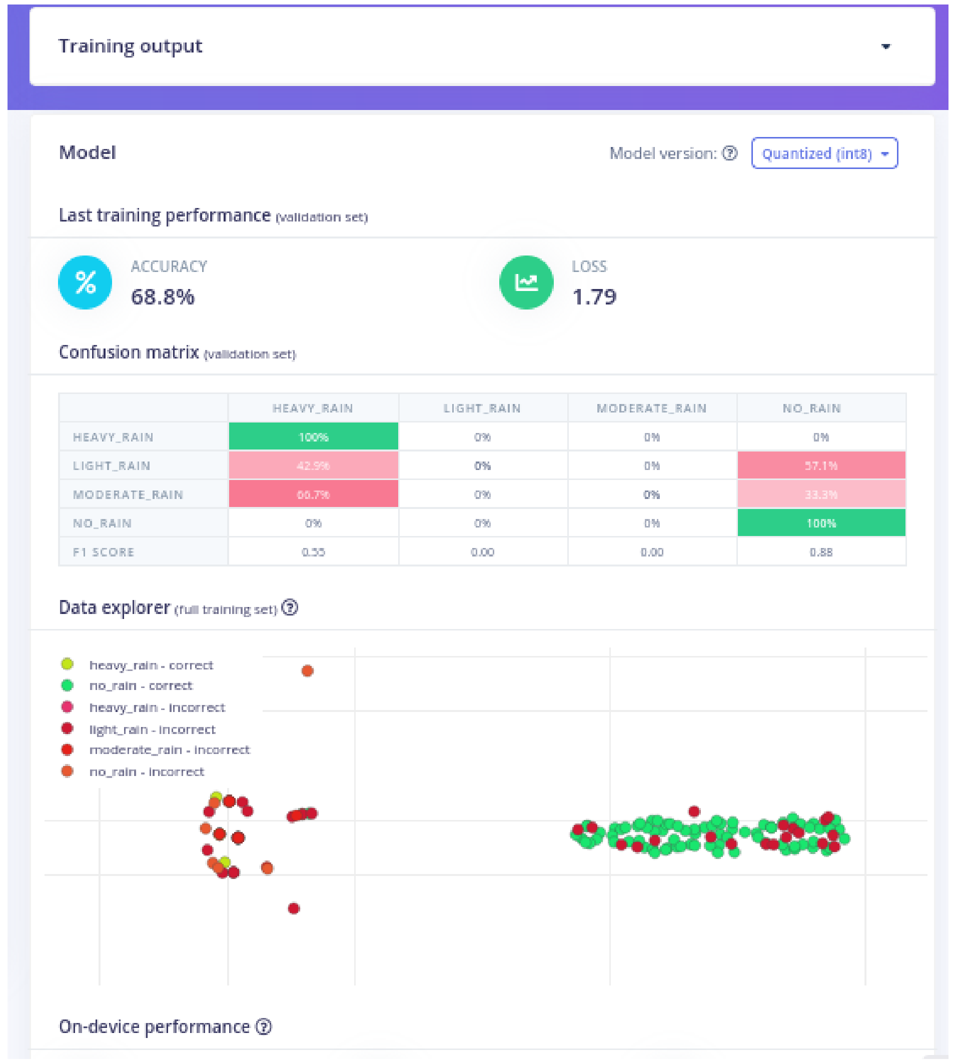
- **no rain:0**
- **light rain:0.2,0.4,1.2**
- **moderate rain:4**
- **heavy rain:9.6**

The real value of sound and loudness from the data logg is mapped with the mechanical rain guage (tipping bucket)

Time stamp of these datas are correlated with the non mechanical rainguage sensor sound and loudness data thus the Dataset is created with 4 labels No Rain, Lightrain, Moderate rain, Heavy rain

- **Accuracy:68.8%**
- **loss:1.79**
- **Learningrate:0.005**
- **no:of epoch:30**





Ongoing...

Data collection with rain simulator setup inside lab for more data set similar to real rain by adjusting the real rain parameters such as intensity of rain, duration of rain , frequency of rain, amount of precipitation is the current ongoing work.

Rain Simulator setup

Water trough specifications

Type : Plastic Inflatable
Outside length : 185 cm
Outside breadth : 135 cm
Inside length : 139 cm
Inside length : 88 cm
Height : 43 cm

Shower head specifications

Shower shape : Square
Shower size : 6 inch
Nozzle size : 1 mm Diameter (Appx.)
Nozzle arrangement : 10 x 10 No.s (100 No.s)

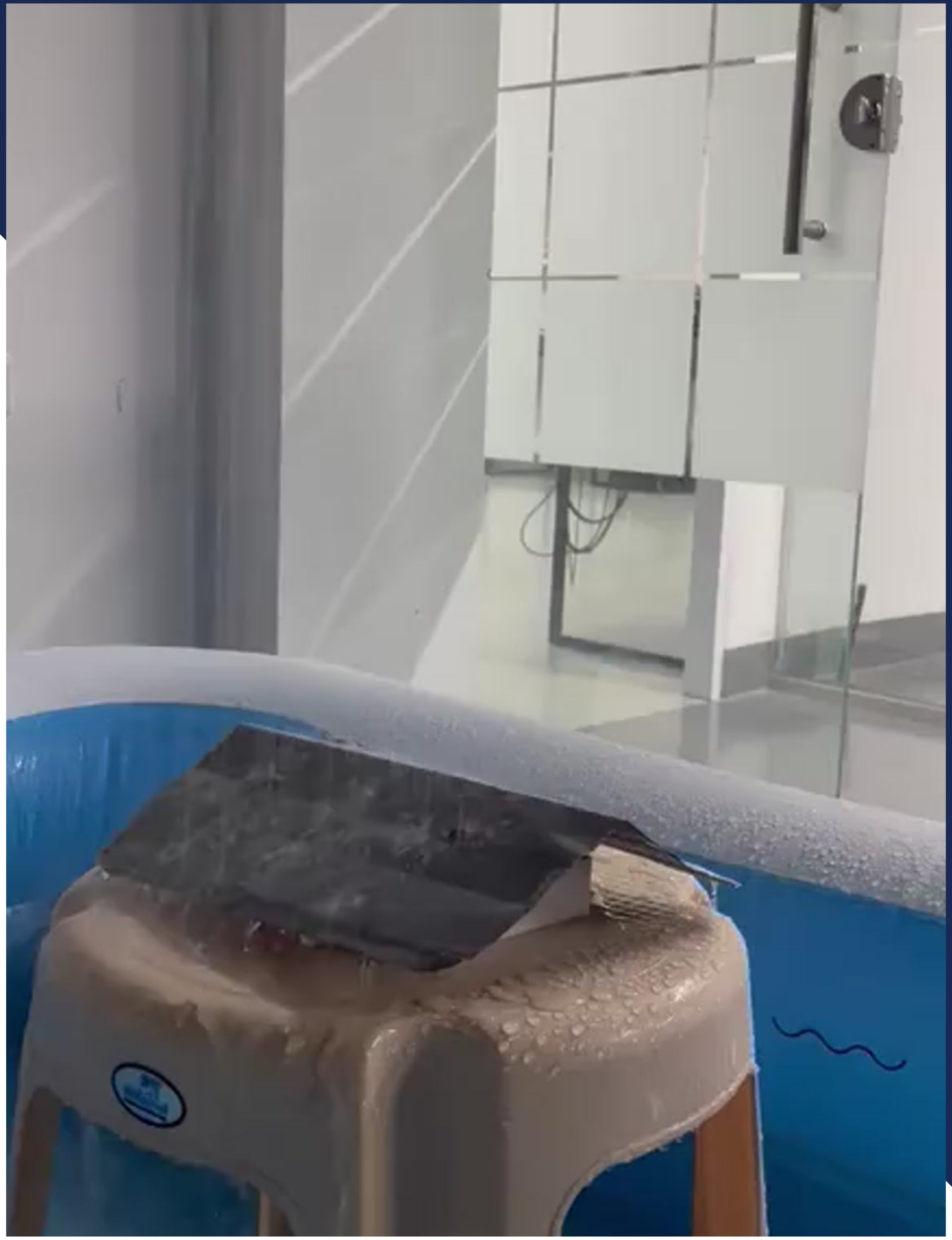
Hydraulic specifications

Height of water from ground level : 17 cm
Height of shower head water from water level : 177 cm

Pump specifications

Manufacturer : CRI PUMPS PVT LTD.
Model : MiKi 50
Suction size : 25 mm
Delivery size : 25 mm
Power : 370 Watts
Power supply : 220 volt , 50 Hz, Single phase AC

Demonstration



Challenges

Rain

- Paucity of data.
- Intensity of rain
- Effect of Wind.
- Duration
- Frequency/Return period
- Seasonal Distribution
- Amount of precipitation

Wind

- Building driver circuit for driving ultrasonic module as per the requirement.
- Data collection with Real wind Scenario.

Bill Of Materials

Cost Estimation

Sl No:	Commodity	Quantity	Cost (in USD)
1	Arduino nano BLE sense	1 nos	24.74
3	Seeed Grove - Loudness Sensor	1 nos	7.52
4	Seeed Grove - Sound Sensor	1 nos	5.01
3	Ultrasonic sensor hc-sr04	1 nos	3.72
4	Aluminum Sheet	1 square feet	0.75
5	GI pipe	2 meter	6.03
6	Concrete block	-	2.51
7	3-D printing	-	12.56
	Total Cost		62.84

Overall Cost:62.84$

References

- https://docs.edgeimpulse.com/docs/
- https://www.seeedstudio.com/

Shafeek PM (TC-ICFOSS)
Diya U Pradeep(RA-ICFOSS)
Gokhil AB(RA-ICFOSS)

Thank you...

CENTER FOR DEVELOPMENT OF OPEN HARDWARE(CDOH)