

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



Overview...

PART 1

Introduction

PART 2

Proposed System

PART 3

Device Concept and Design

PART 4

Milestones

PART 5

Ongoing Research & Challenges

Introduction

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

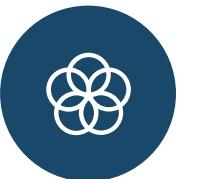
This project aims at producing locally maintainable weather stations at cheaper cost ,low power capabilities while ensuring accurate and dependable results using Machine Learning(ML) at the Edge.

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



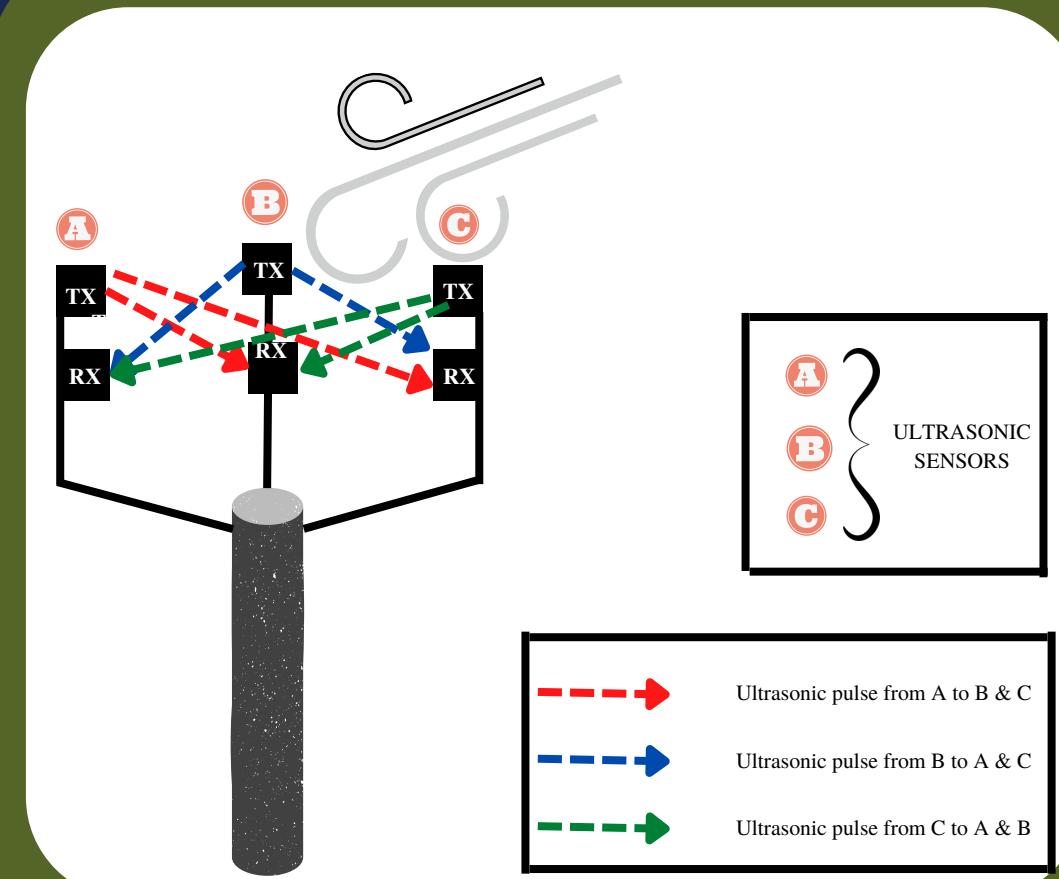
LOW POWER



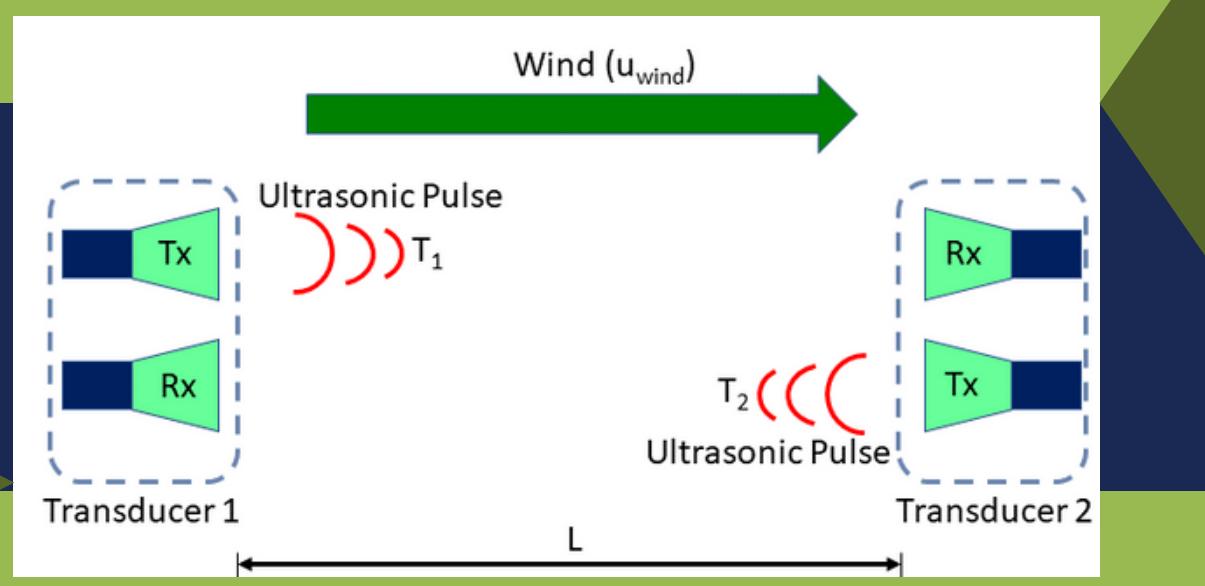
WIND

Proposed System

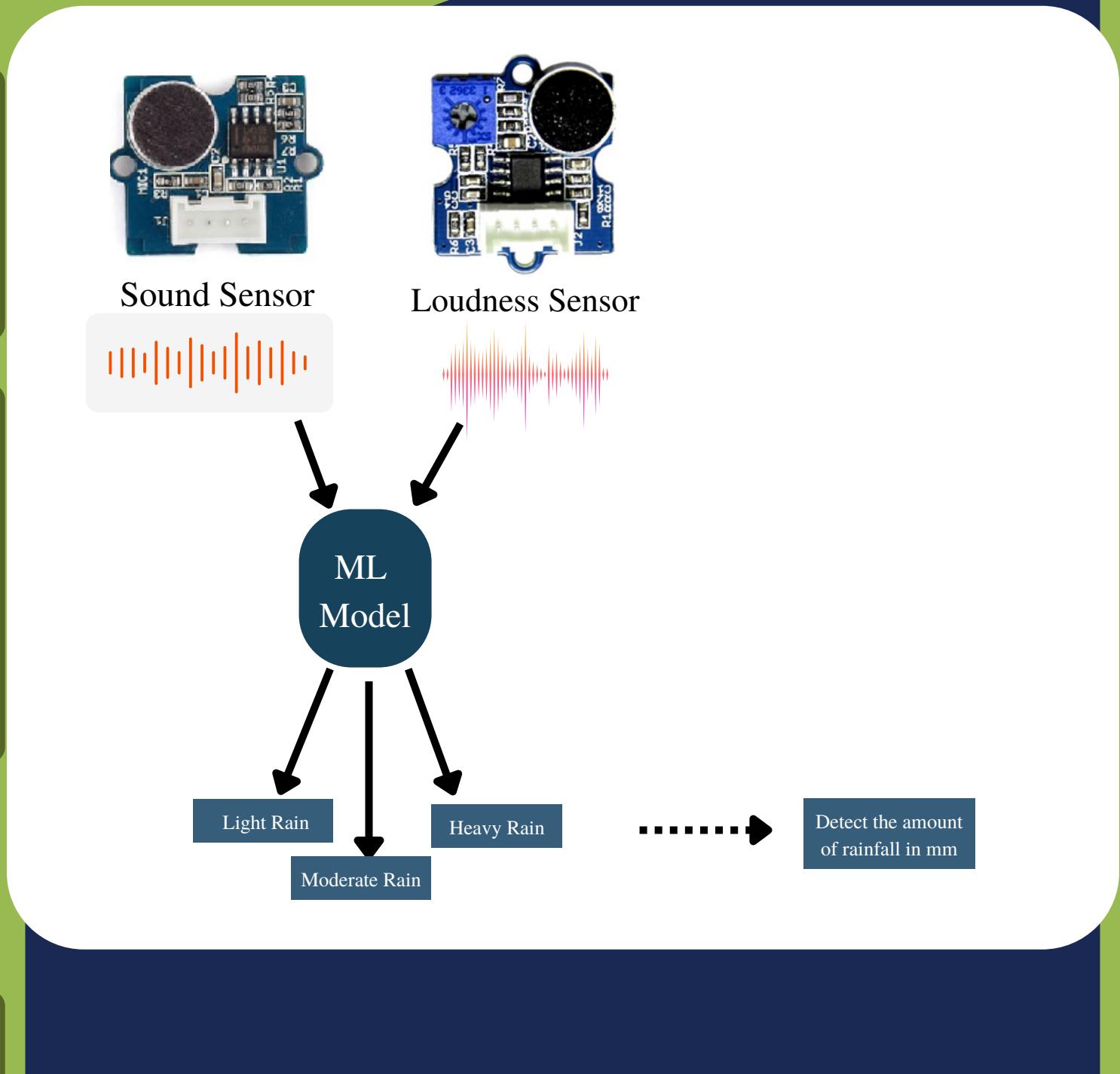
RAIN



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 from 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



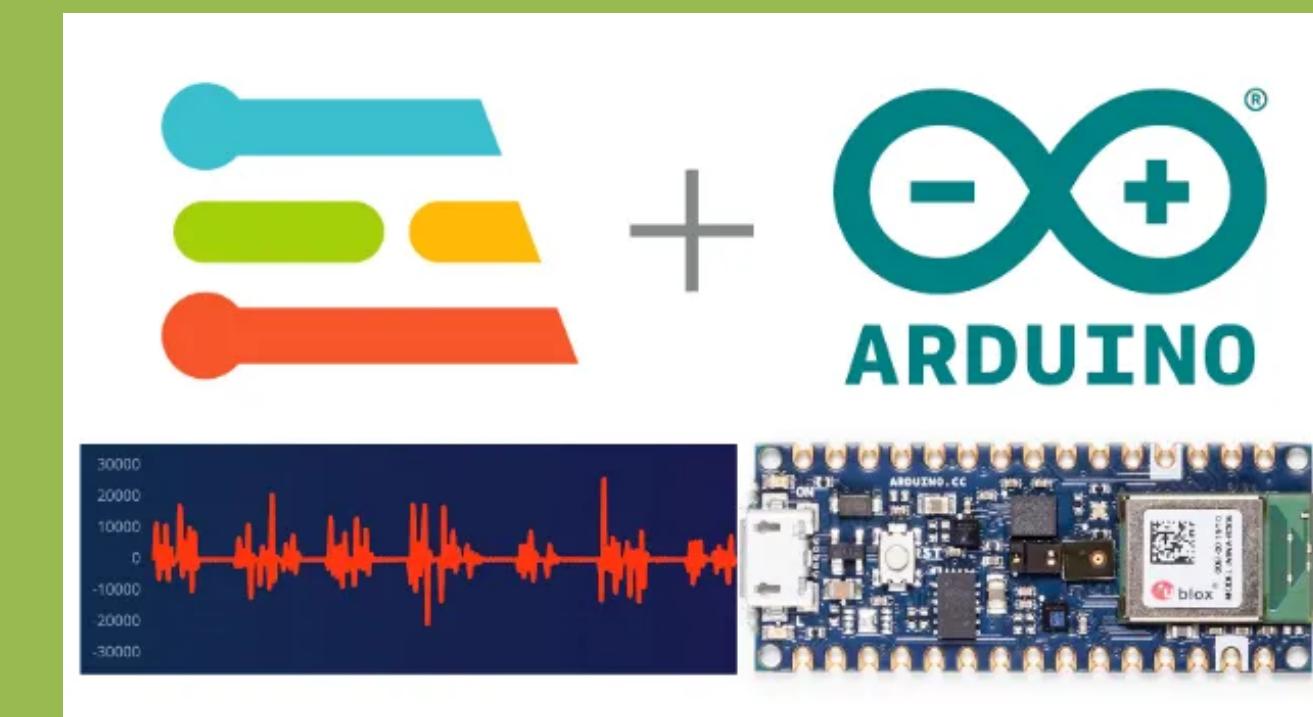
Ultrasonic sensors are used for the determination of wind direction and wind speed



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

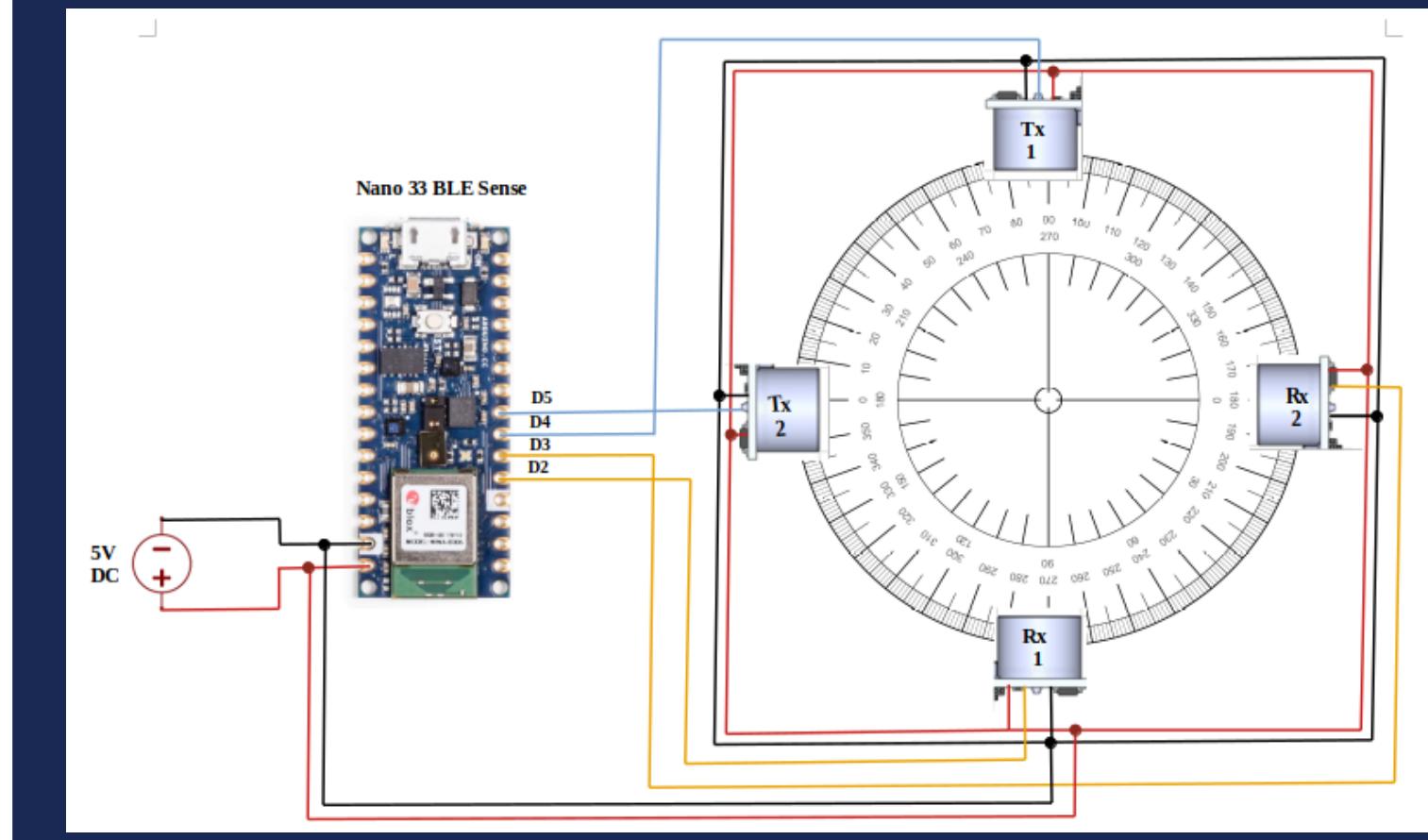
Data Collection Module



Components

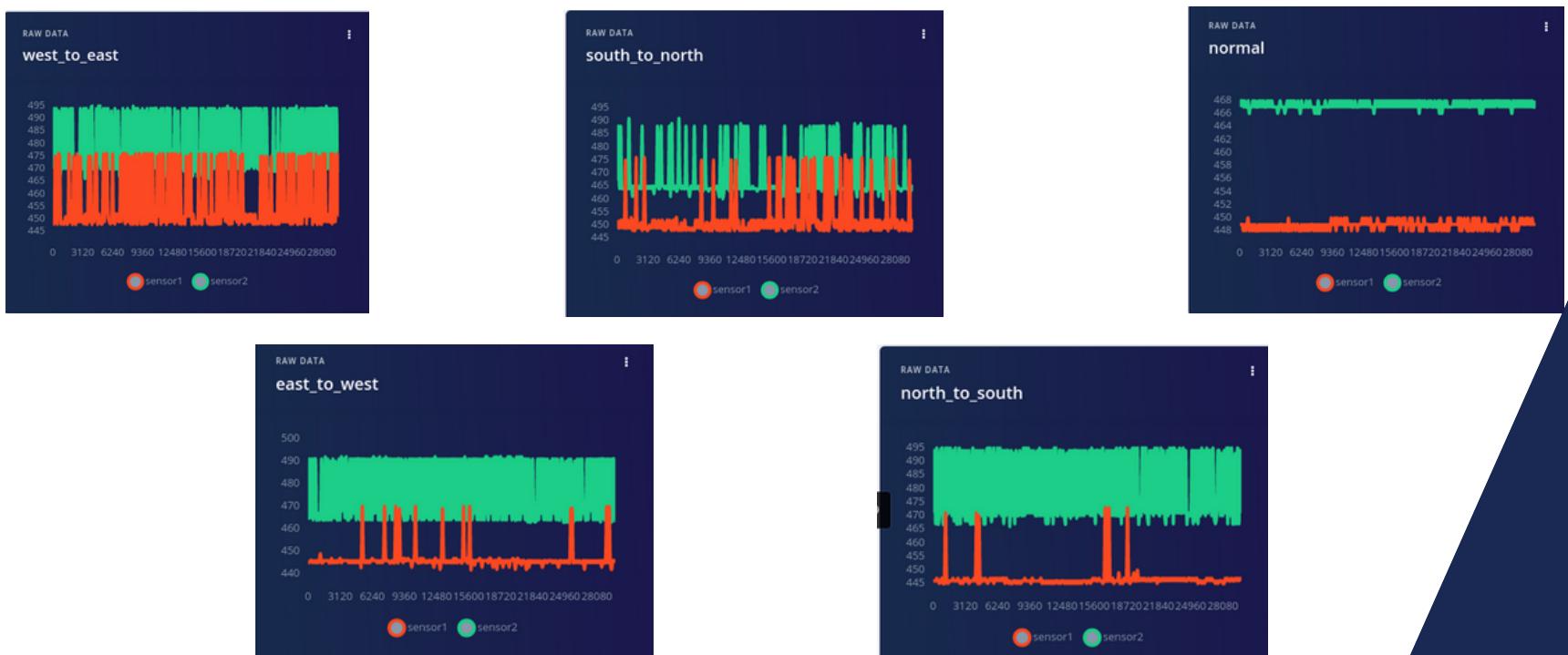
- HC-SR04 Ultrasonic sensor-2 Nos

Circuit Setup

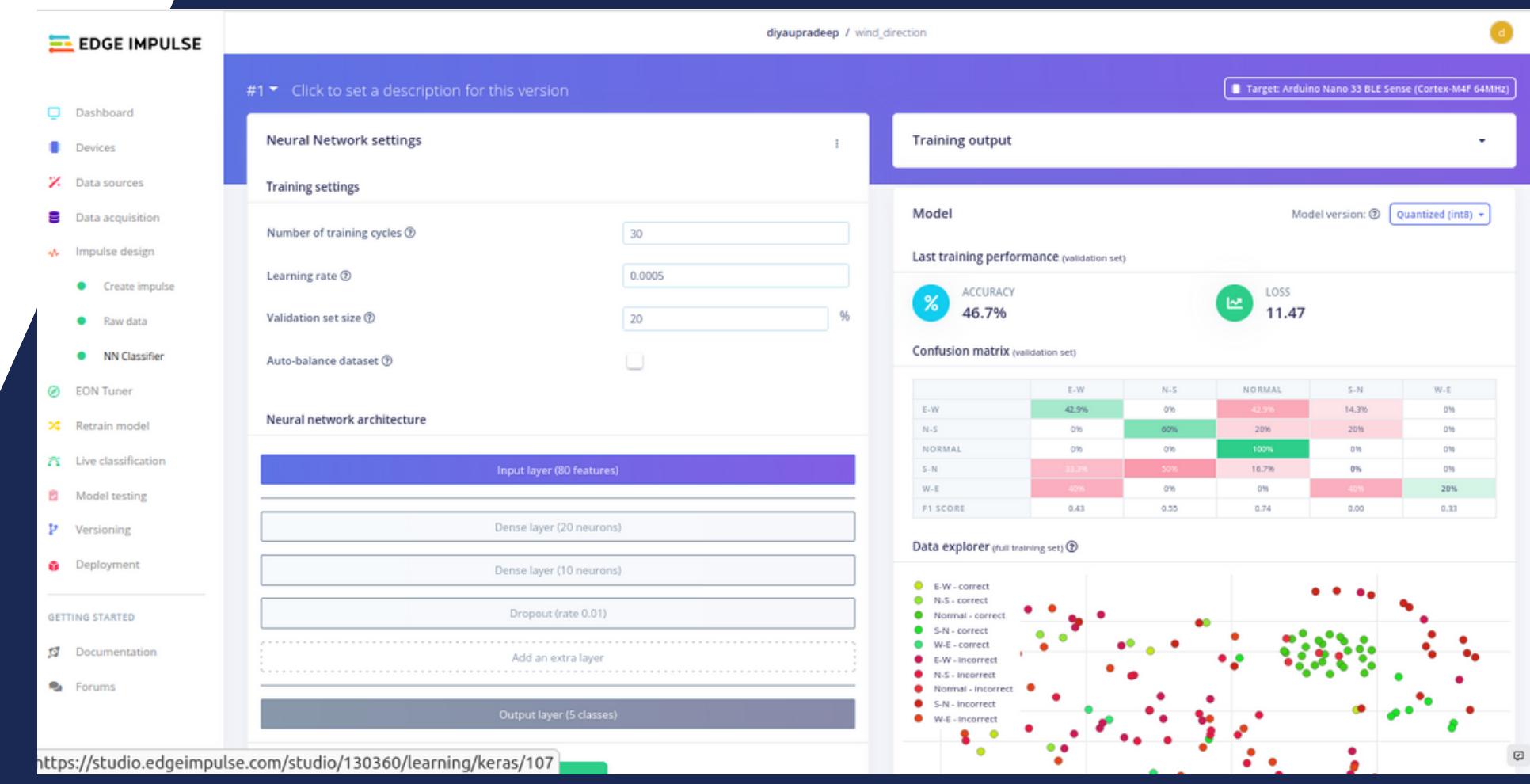


Dataset Creation

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

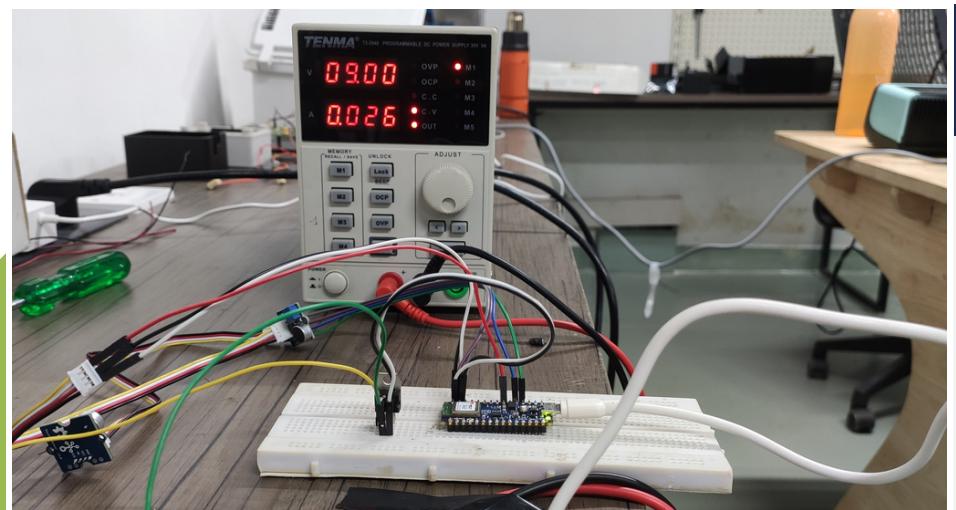
Power Analysis

1.RTC MODULE

Operating Voltage= 3.63 V - 5.5 V
Current Requirement= 200 μ A - 300 μ A
Power = $V \cdot I$
Minimum Power= $3.63 \cdot 200 \cdot 10^{-6} = 0.000726$ W
Maximum Power= $5.5 \cdot 300 \cdot 10^{-6} = 0.00165$ W

2.MICRO SD ADAPTER

Operating Voltage= 4.5 V - 5.5 V
Current Requirement= 0.2 mA - 200 mA
Minimum Power= $4.5 \cdot 0.2 \cdot 10^{-3} = 0.0009$ W
Maximum Power= $5.5 \cdot 200 \cdot 10^{-3} = 1.1$ W



3.SOUND SENSOR

Operating Voltage= 5 V
Current Requirement= 4 mA ~ 5 mA
Minimum Power= $5 \cdot 4 \cdot 10^{-3} = 0.02$ W
Maximum Power= $5 \cdot 5 \cdot 10^{-3} = 0.025$ W

4LOUDNESS 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

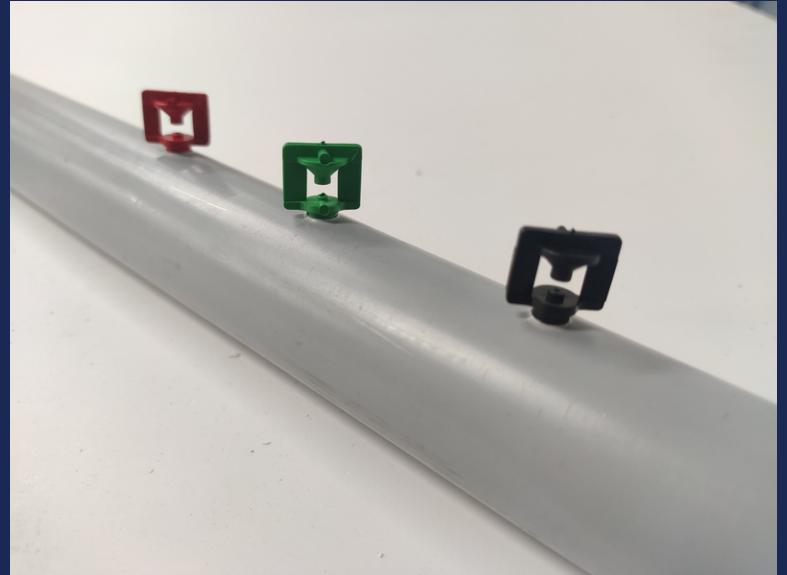
Overall power consumption for Data Collection setup (Arduino Nano BLE, Sound sensor, Loudness sensor, 7805 voltage regulator, microSD adapter, RTC) = 0.405 Watts

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



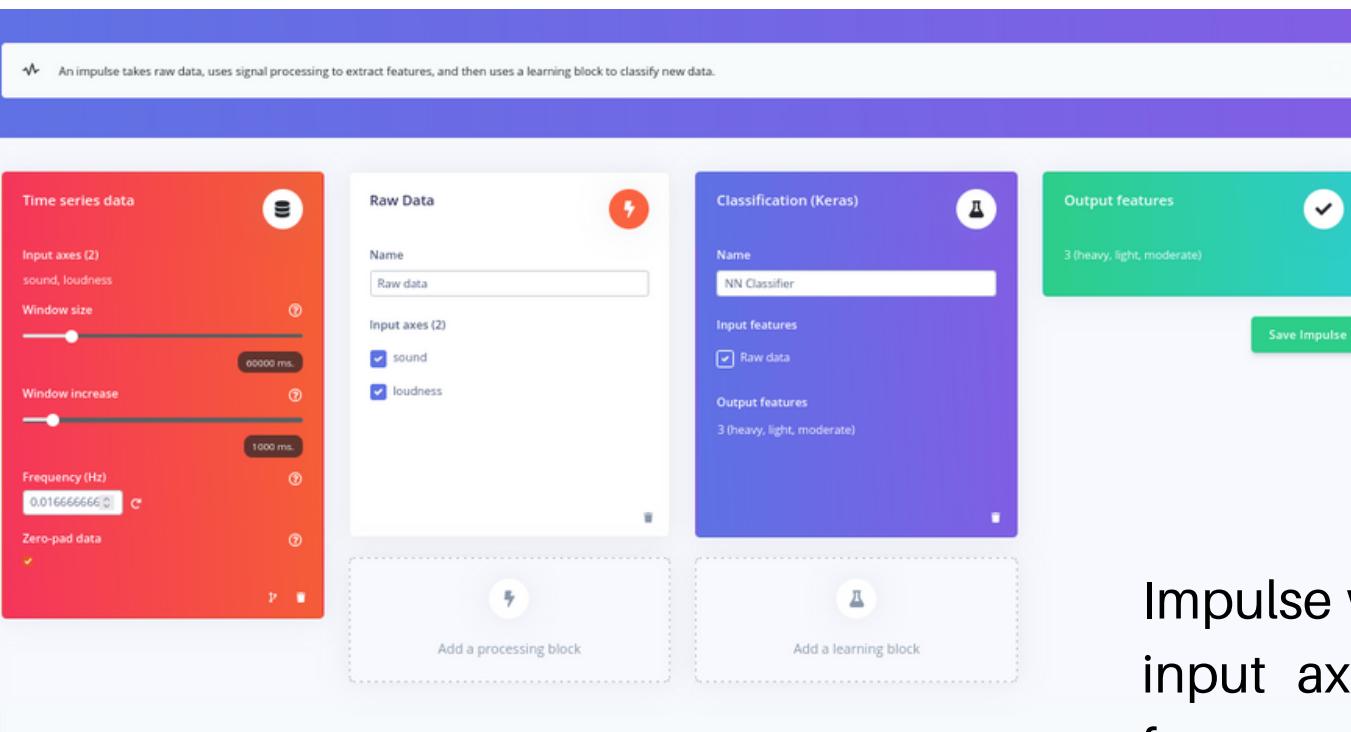
Arrangements

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.

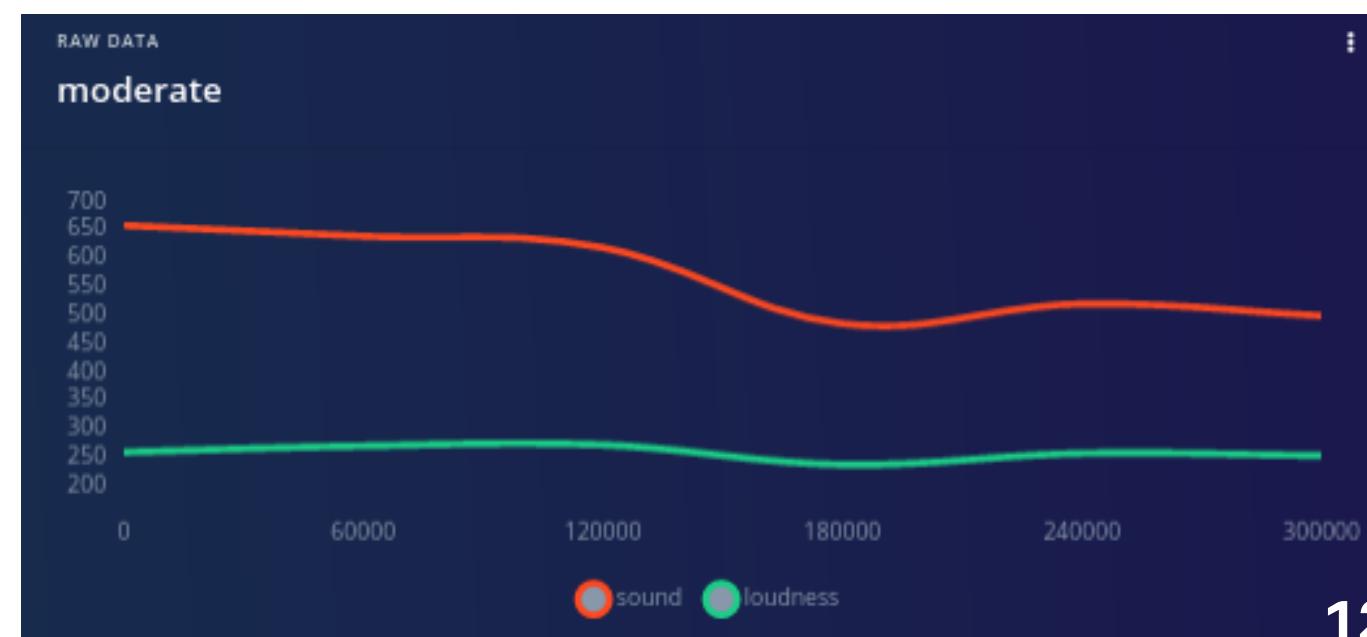
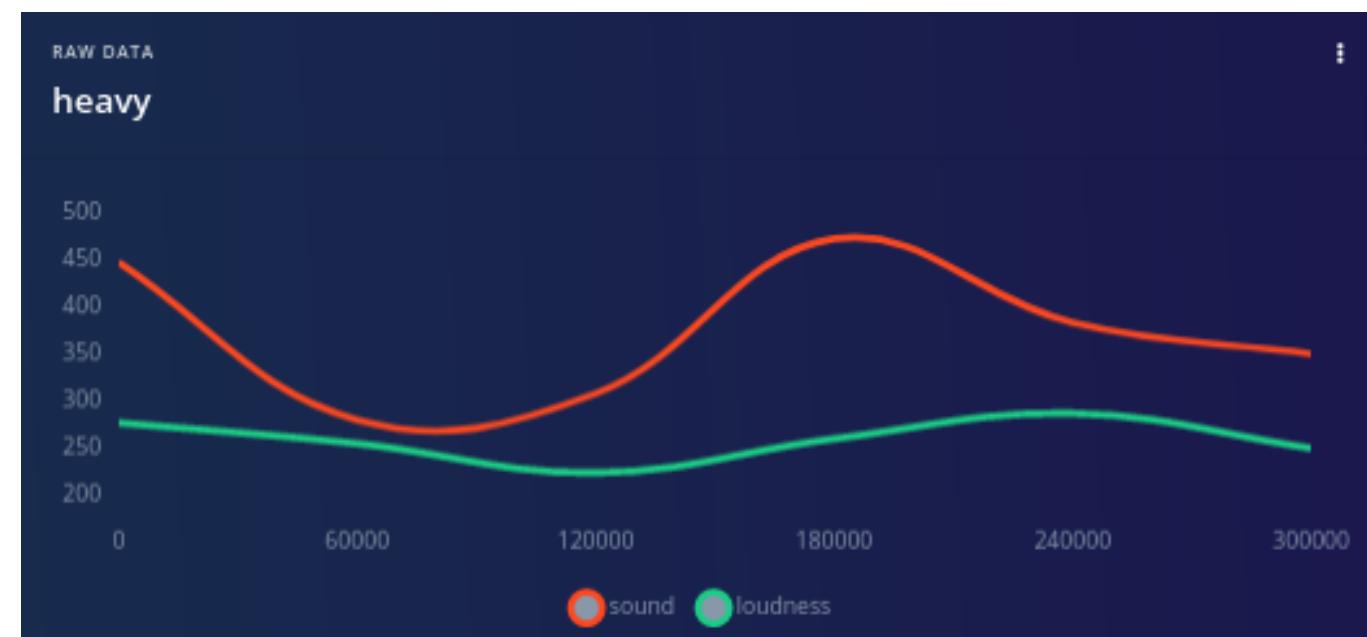
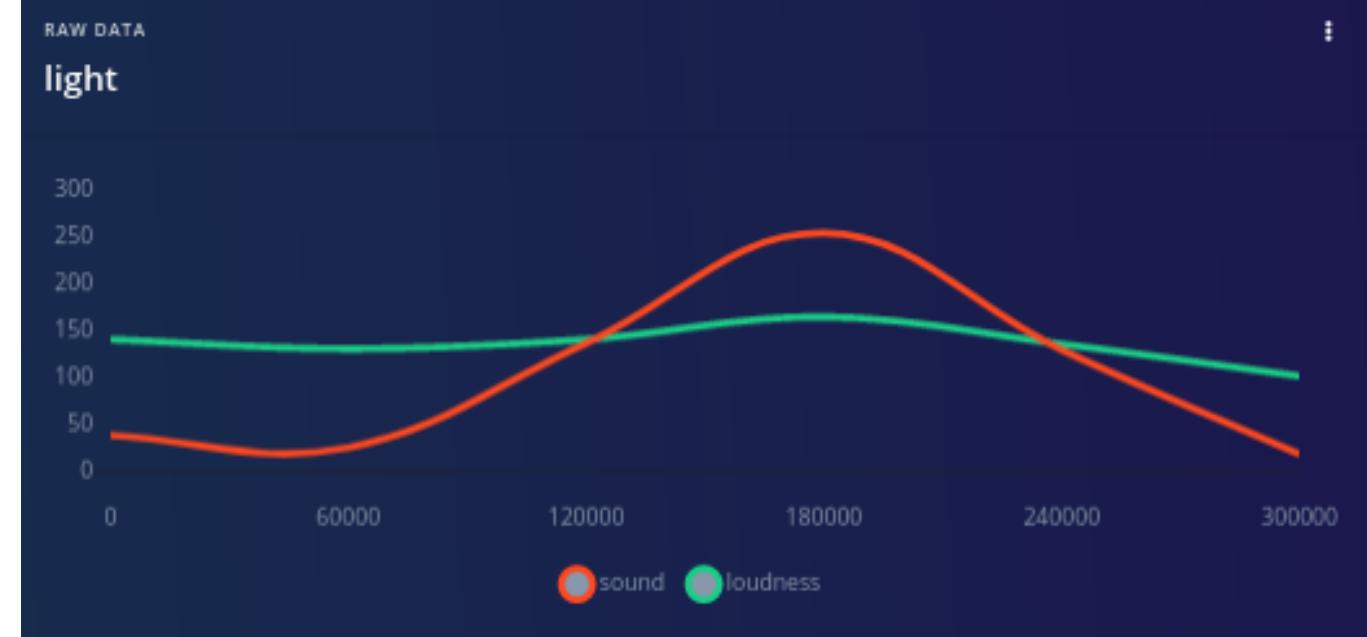


Impulse design

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

Precision:TP/(TP+FP) F1 score:2*(Precision*Recall)/(Precision+Recall)

Heavy rain:1

light rain:1

moderate rain:1

Heavy rain:1

Light rain:1

Moderate rain:1

Accuracy:(TP+TN)/(TP+TN+FP+FN)

Recall:TP/(TP+FN)

Heavy rain:1

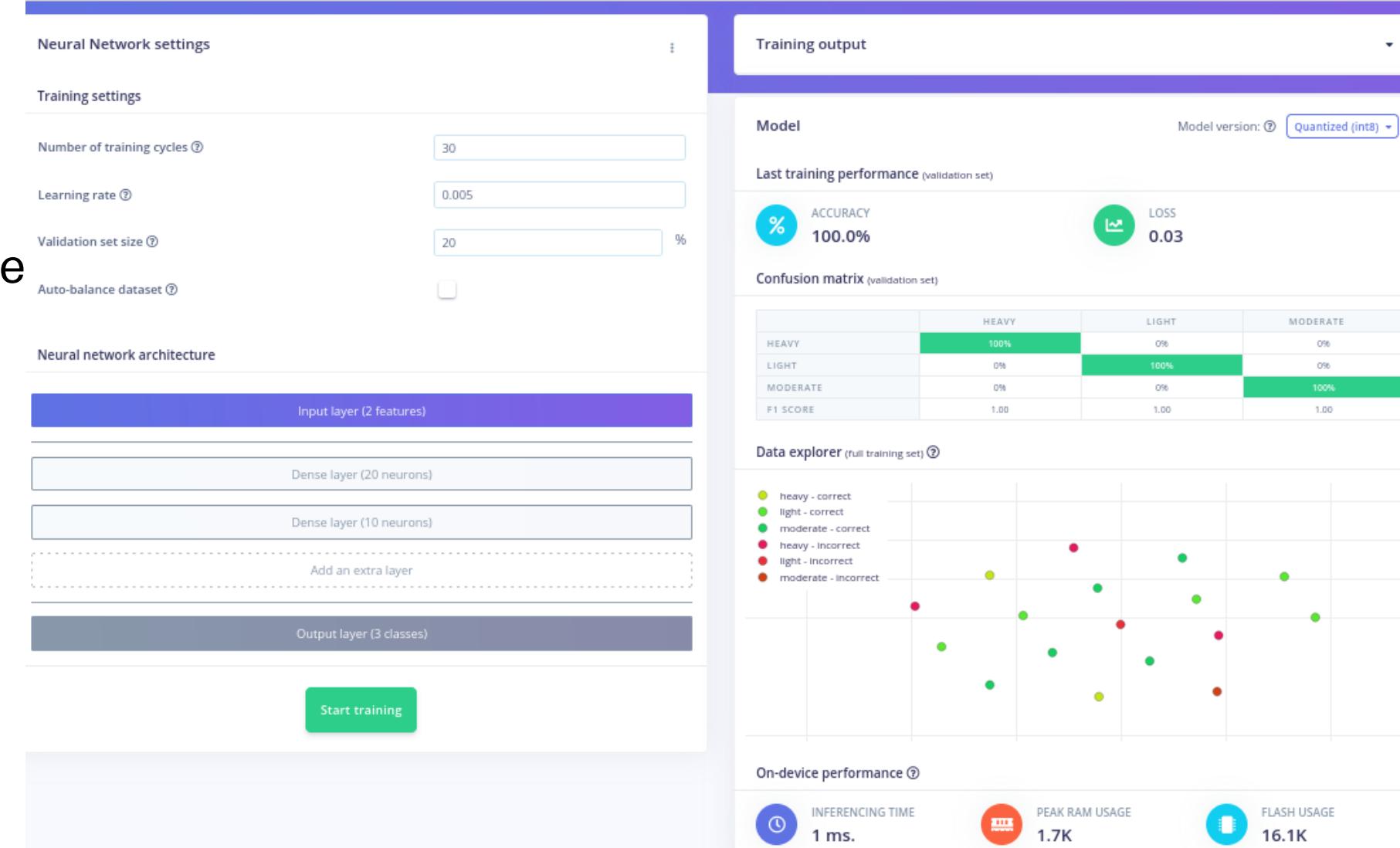
Light rain:1

Moderate rain:1

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

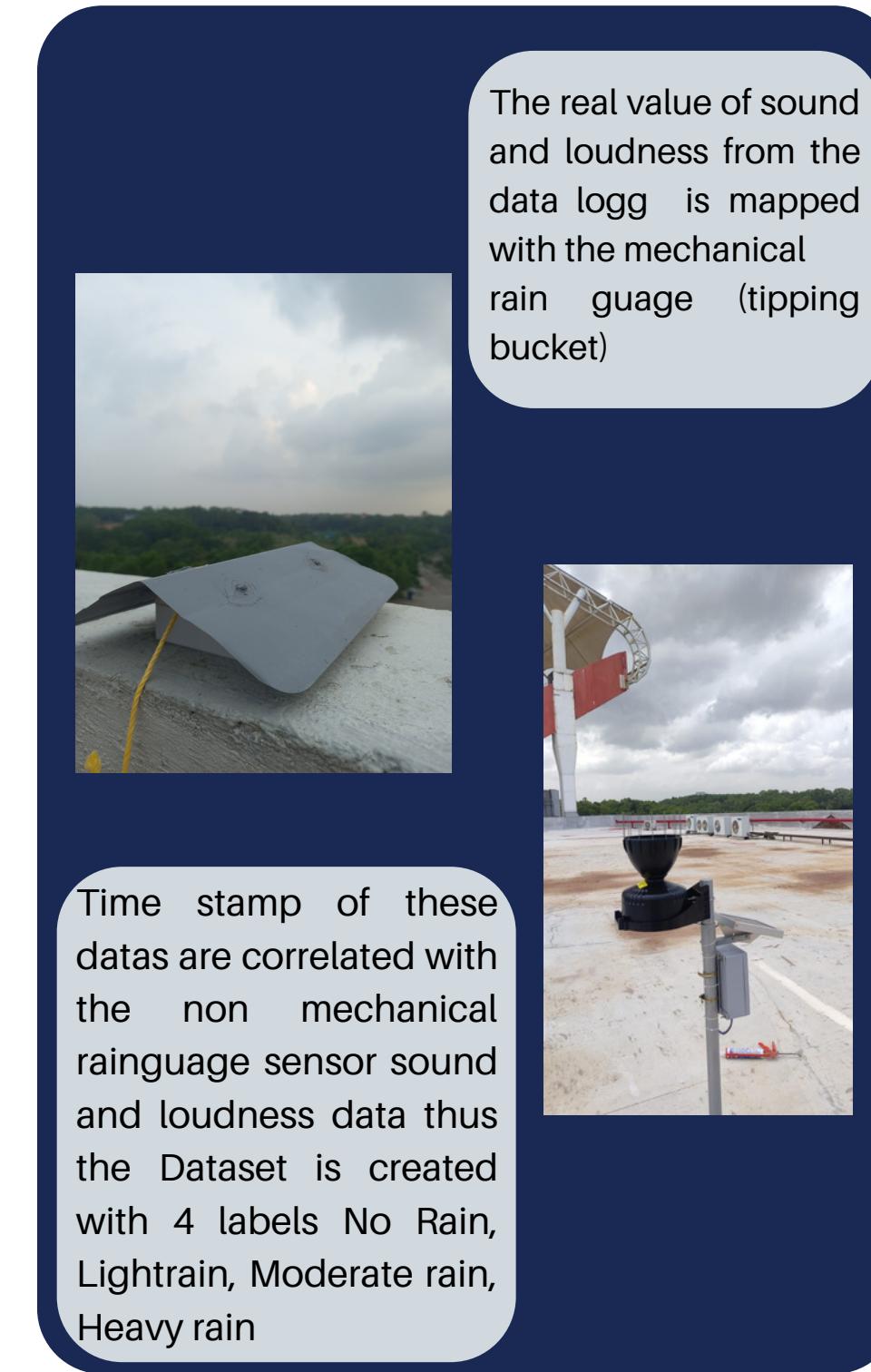
heavy rain>7.6mm

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**



EDGE IMPULSE

Neural Network settings

Training settings

Number of training cycles: 30

Learning rate: 0.005

Validation set size: 20 %

Auto-balance dataset:

Neural network architecture

Input layer (2 features)

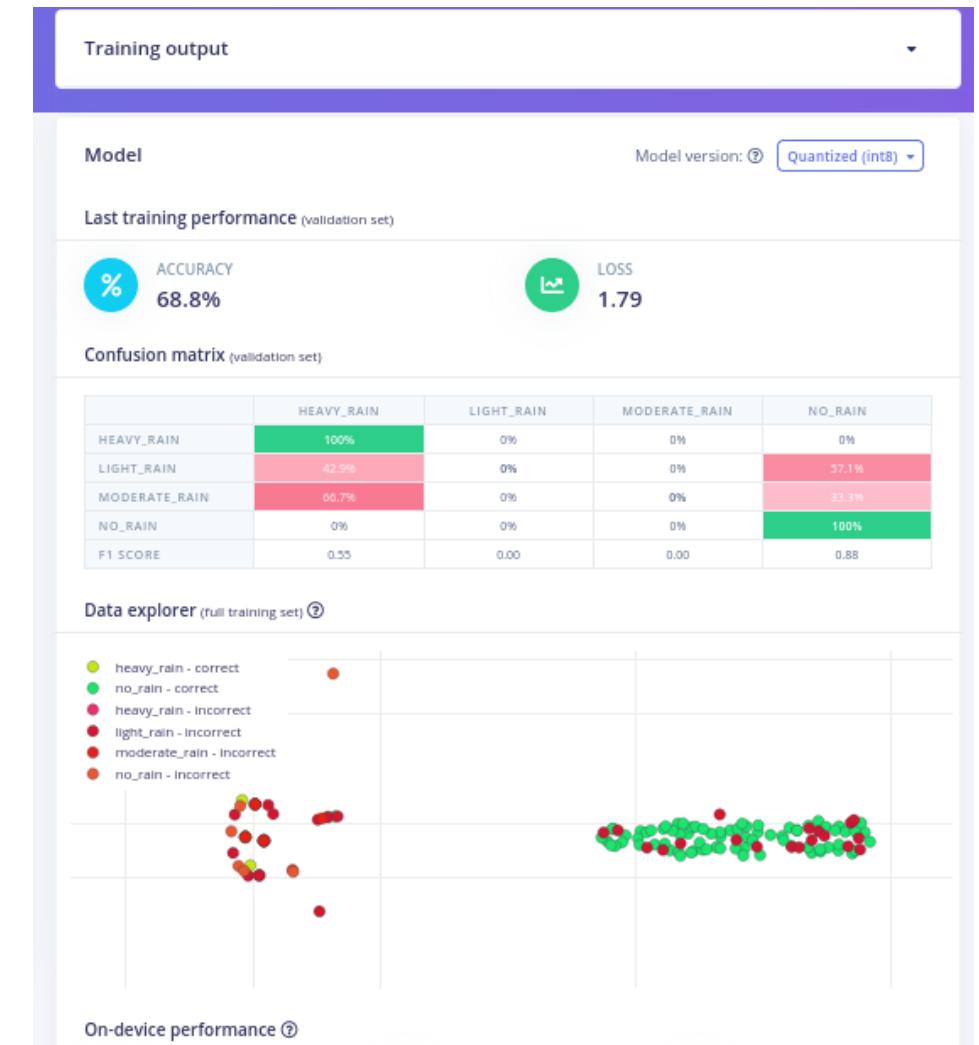
Dense layer (20 neurons)

Dense layer (10 neurons)

Add an extra layer

Output layer (4 classes)

Start training



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)

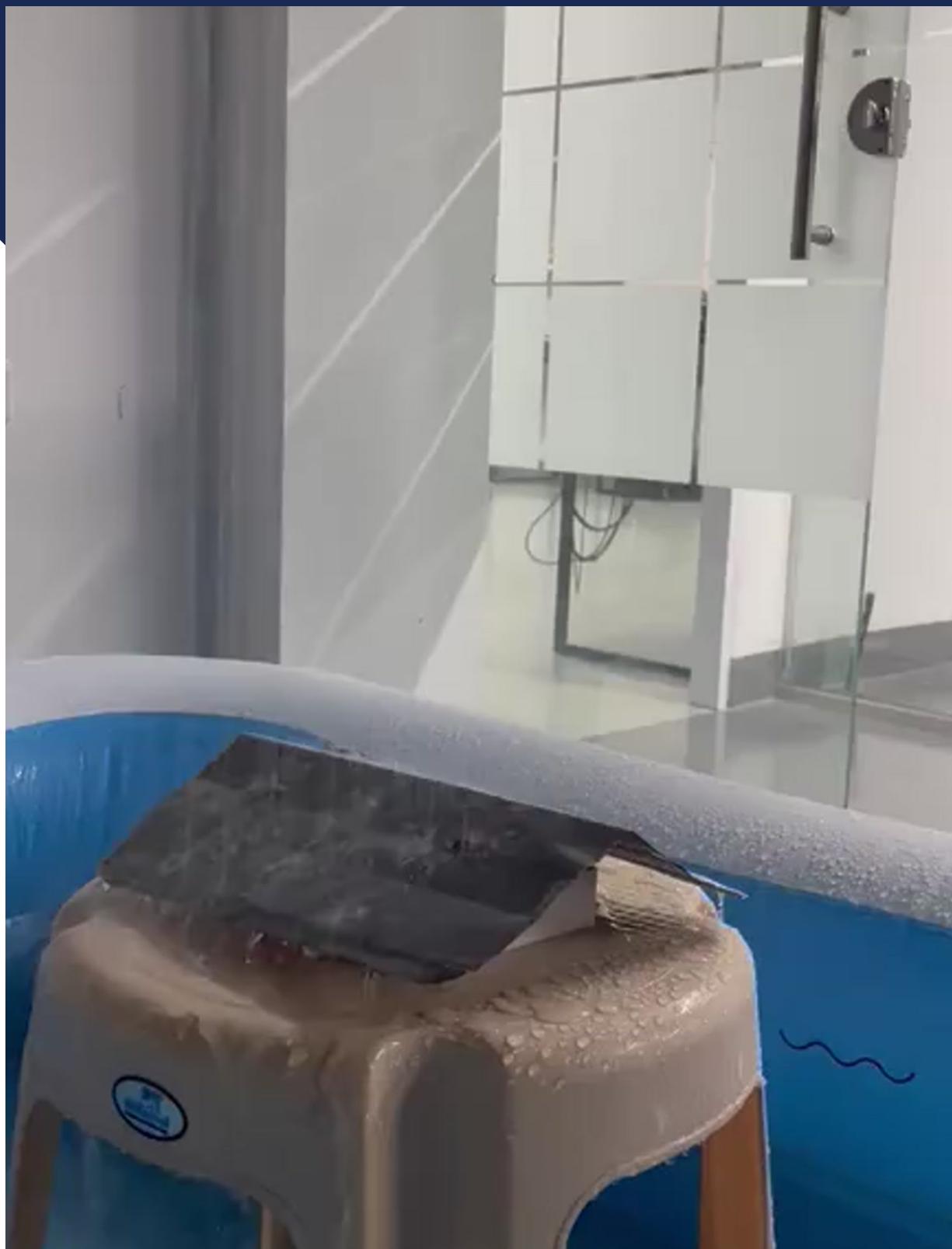
Hydraulic specifications

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/>

Thank you...