UNIVERSITY of RWANDA

ACEIoT

COLLEGE OF SCIENCE AND TECHNOLOGY

IOT BASED BIOGAS STATUS MONITORING SYSTEM FOR PREVENTIVE MAINTENANCE

Case Study: NGOMA DISTRICT

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INTRODUCTION

- Many countries had put in place policies regarding environmental protection.
- For this reason, Biogas energy have been adopted as alternative cooking energy.
- The conversion of waste to energy are very useful as they allow a partial mitigation of the environmental control. One of the possible ways to convert waste to Energy is the, **anaerobic digestion** (**AD**) which is a green technology to transform solid or liquid organic wastes in biogas .

INTRODUCTION cont'd

- In Rwanda, the government have implemented a program called National Domestic Biogas Program (NDBP) with the objectives of reducing Woods and charcoal consumption.[1]

- There is a problem of continuous monitoring of biogas plant already built in order to maintain their health and provide quick support whenever needed by end user.[1]
- In this research , we present a system which exploits this skill of IoT to monitor Biogas production status and provide real time feedback to end users and which can predict the biogas Yield based on the inputs supplied to the digester.

PROBLEM STATEMENT

- Lack of regular biogas monitoring,
- Improper biogas feeding methods ,

PROPOSED SOLUTION

- This research aims is to put in place a biogas monitoring system in order to reduce the Biogas malfunctioning and to put in place the way to predict the biogas yield.

Related Works

The above literature has been used to understand my research and determine the key area of improvement.

- V. Acharya[7] developed the biogas efficiency monitoring system where biogas data like temperature,Gas pressure are measured with microcontroller and the data are sent to the remote database and the system provide alert to user. The gap in the system is that there is missing biogas parameters like ph and methane gas concentration which plays important role in biogas production .

Related Works cont'd

- **R. R. Pansari, S. R. Patil, and M. S. Khan[9]** developed a biogas monitoring system for biogas plant. They have used sensors to monitor biogas parameters and data are sent directly to the cloud using wifi chip connected to wireless network. This work also lacks the ability to process data locally

- **P. Huo, F. Yang, H. Luo, M. Zhou, and Y. Zhang[10]** developed a wireless network for traditional biogas appliances to monitor the status of household equipments that use biogas for cooking. The system shows the biogas usage amount and can detect the leakage in pipe and then provide alert users. production.This work also lacks the ability to process data locally to facilitate end user to access information without using cloud service.

Related Works cont'd

- The above literatures reviewed doesn't include the data processing at edge layer
- By using edge computing:

  - bandwidth utilization is reduced by eliminating the necessity of repetitive request to the central or cloud server.
  - Low latency
  - Reduced operational cost

- In this research:

  - Edge computing is used for real time data collection and reporting
  - cloud computing used as data storage on cloud for future reference and for prediction

Objectives of the Study

❑ General Objective:

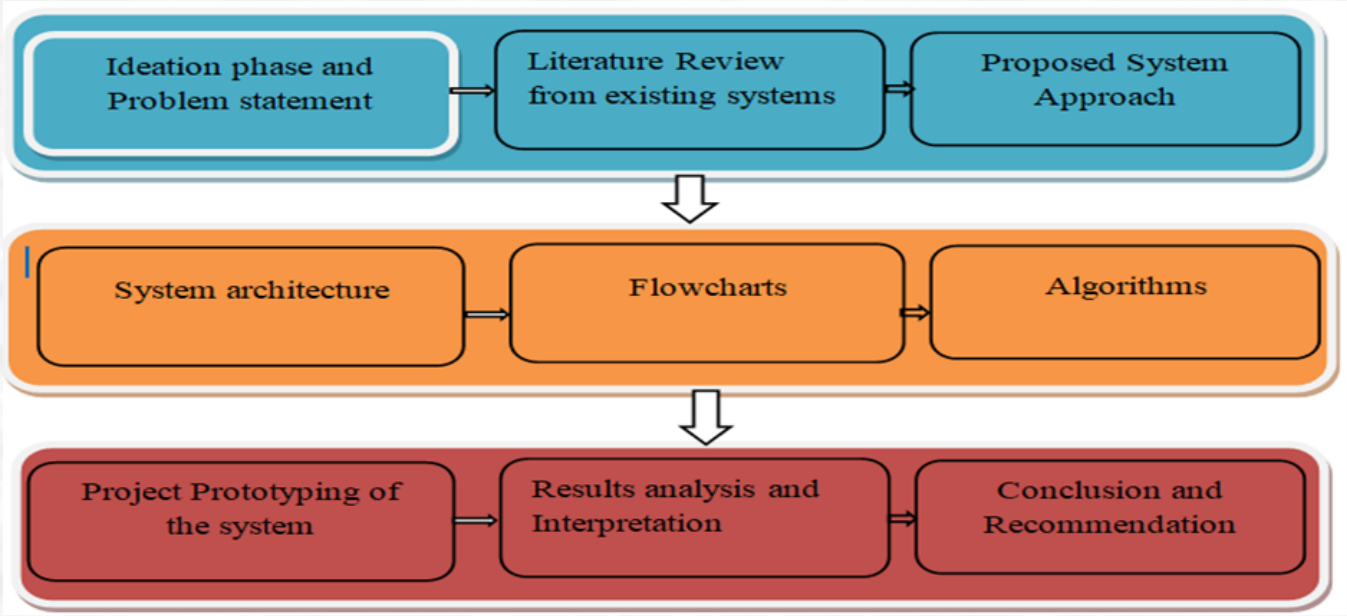
Develop biogas monitoring system to provide information on the biodigester status in order to provide support before malfunctioning of digester.

❑ Specific Objectives

- ❖ To put in place biogas status monitoring system
- ❖ To minimize or reduce the biogas malfunctioning
- ❖ To help end users in terms of getting necessary information about biogas status
- ❖ Prediction of biogas Yields with Machine learning algorithms

METHODOLOGY

Research approach, design of the system and activities sequence plan



METHODOLOGY cont'd

System Development Methodology

To implement the IoT based Biogas monitoring system, many technologies are involved from the sensor node design to the cloud server.

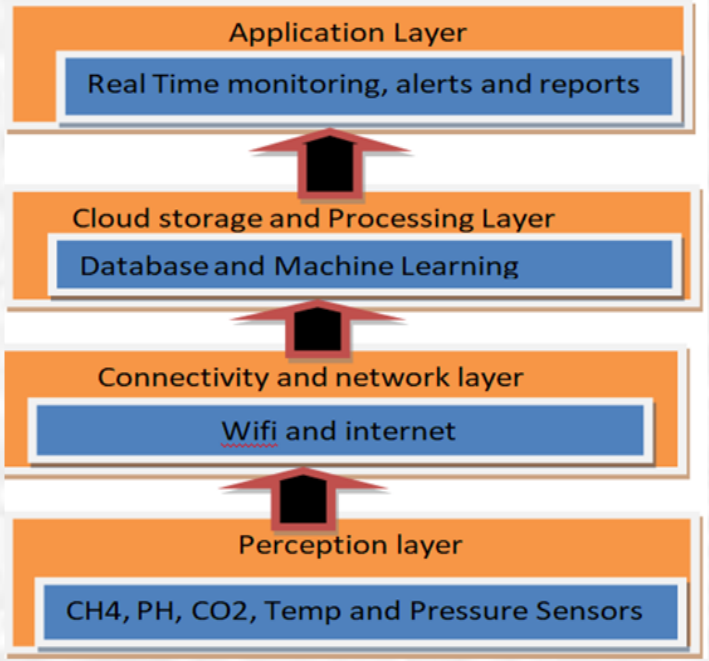
★ Hardware skills have been used to interface sensors with microcontroller.

★ Embedded systems programming skills was required to process sensor data and communicate them from the fog device to the cloud server.

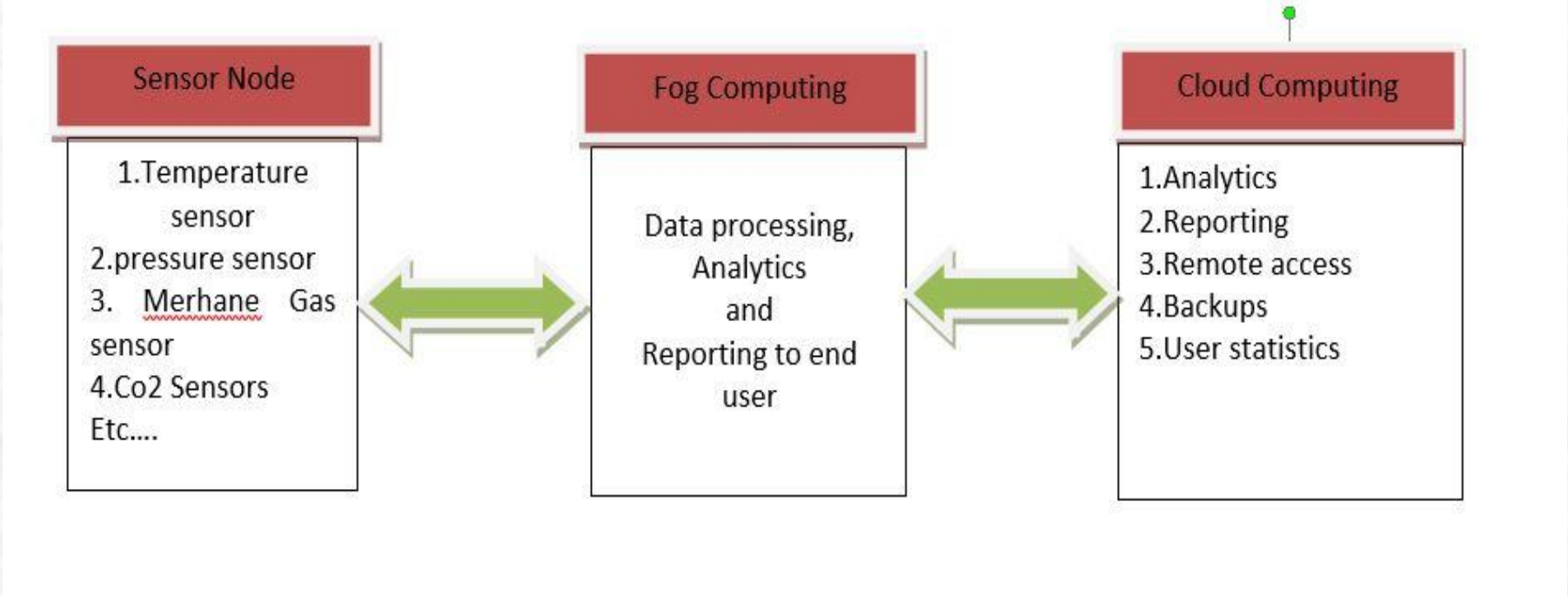
METHODOLOGY cont'd

Proposed system design

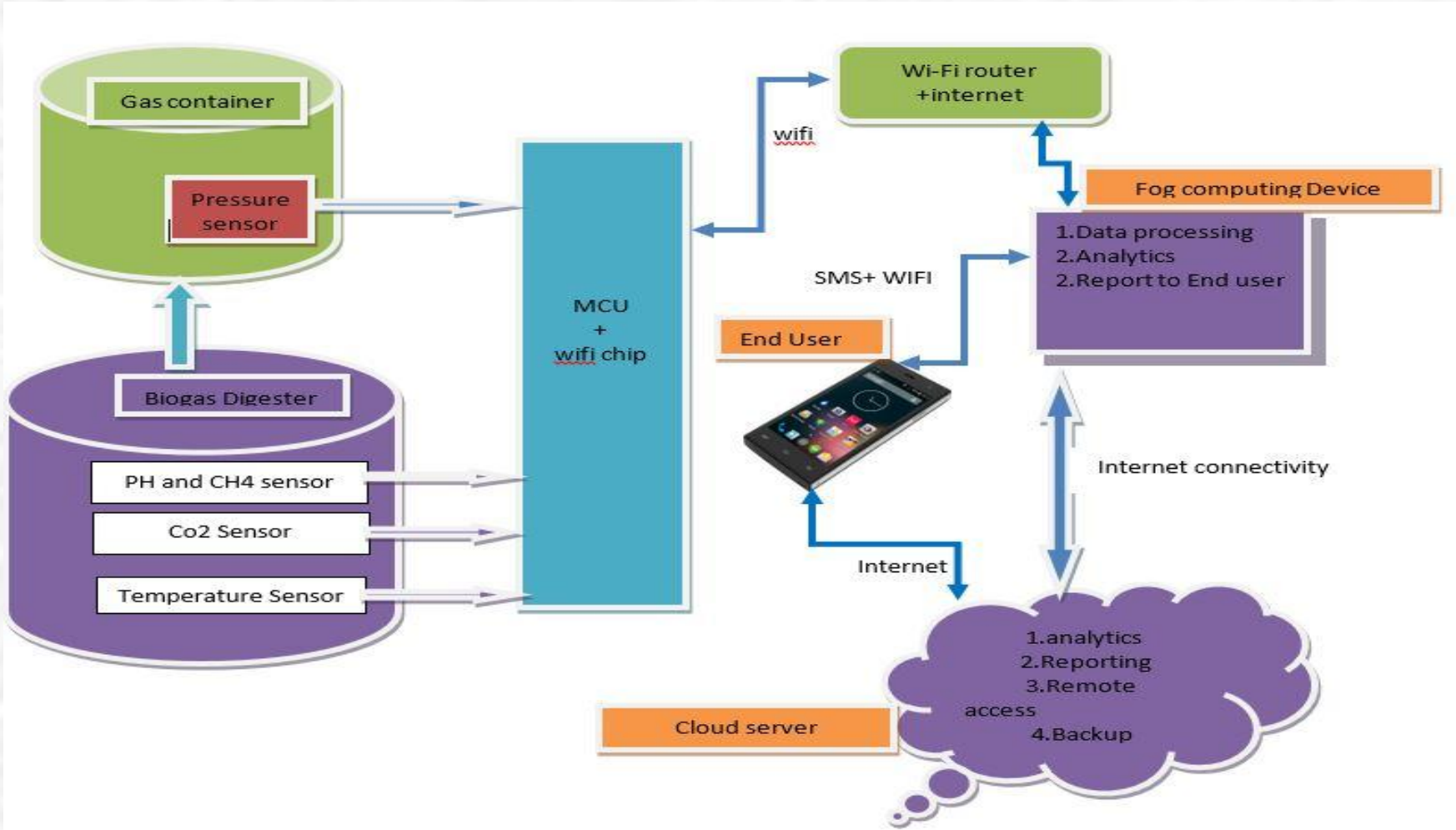
The proposed system has four layers which are arranged from perception layer to application layer



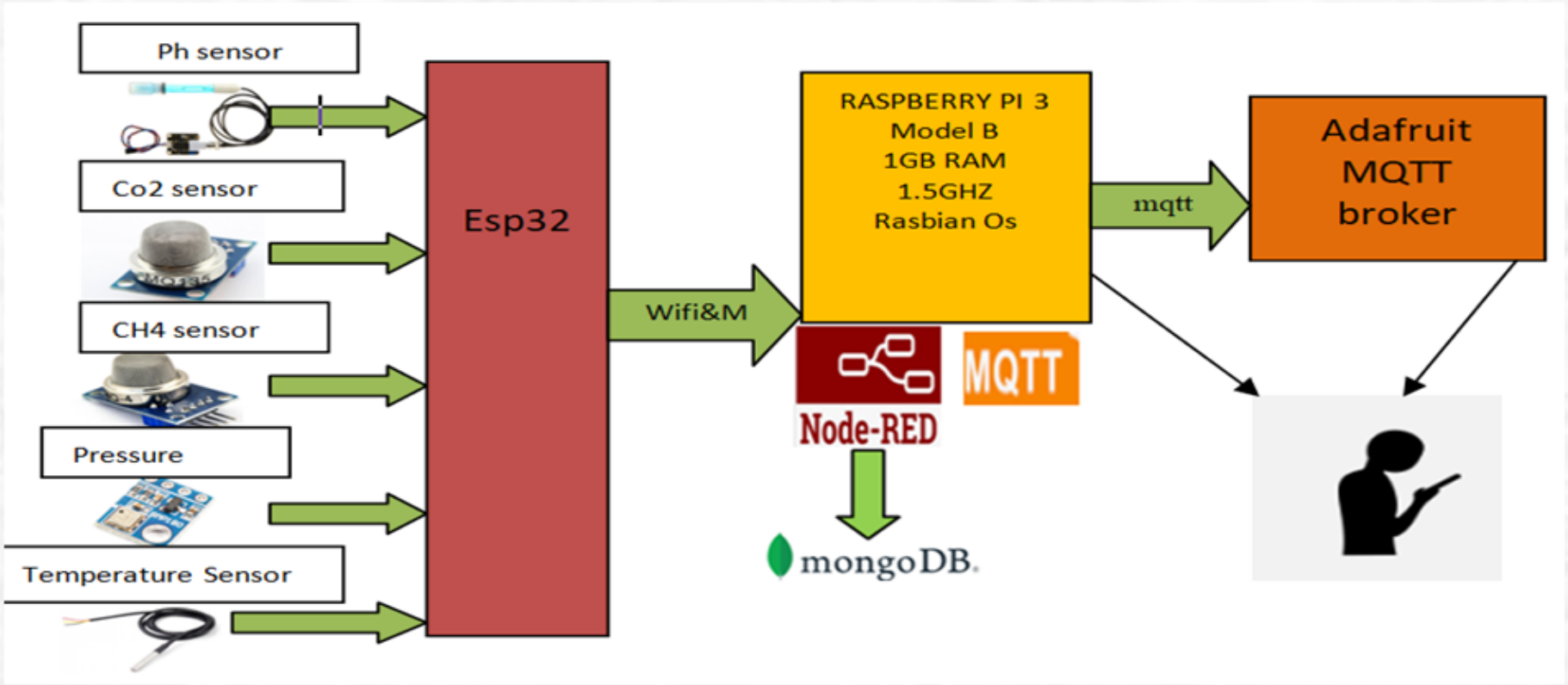
SYSTEM BLOCK DIAGRAM



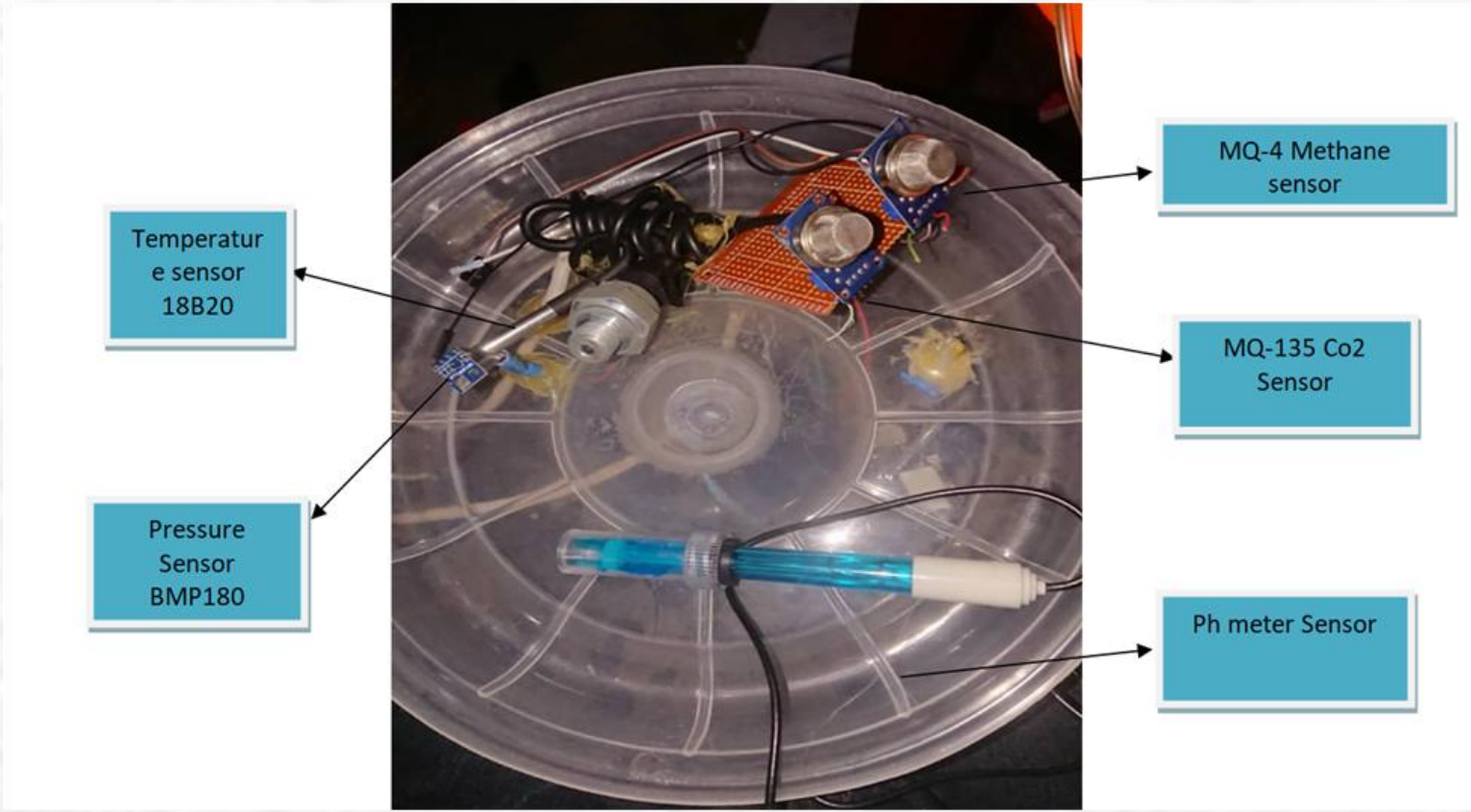
DETAILED SYSTEM ARCHITECTURE



System Prototype



Sensing part



VALUES OBTAINED DURING SENSOR TESTING

PARAMETERS	MIN	MAX
PH	3.5	7
Co2	100 ppm	700 ppm
Methane level	80 ppm	800 ppm
Temperature	22 *C	27 *C
Pressure	1 psi	60 psi

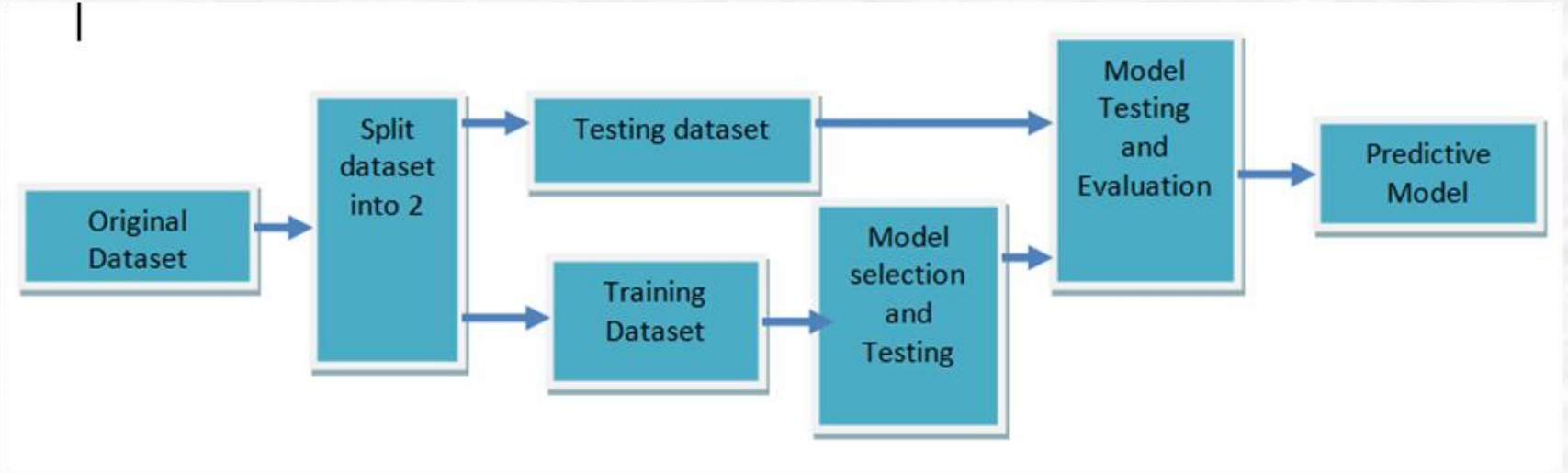
Machine Learning Model Training and Evaluation For prediction

Why prediction for biogas production ??

- Anaerobic digestion is a complex process of biogas production
- The gas production depends on the organic wastes supplied under given temperature and PH Value of organic waste supplied (typically between 3.6 to 8).
- This process produces several gas(CO2,Methane, Ammonia,hydrogen)
- Those Gases can be enough or not to produce expected biogas based on the conditions under which the AD is being done
- There is no rule saying that you can produce like 5kgs of biogas when you have supplied 20 kgs of cow manure . The nature of supplied organic wastes and AD process play important role in the process.
- By Using machine learning , we can find out the relationship between supplied organic waste and other parameters in order to predict biogas yield shown by pressure inside the biogas container

Machine Learning Model Training and Evaluation

Model training and evaluation process



Results and Discussions

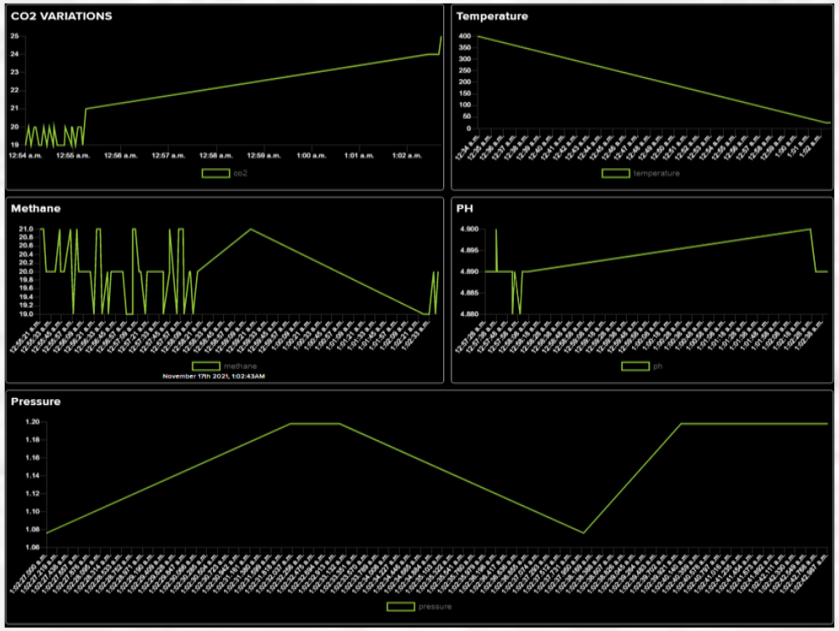
One of our objective was to put in place biogas monitoring system. This objective has been achieved . the following figures shows dashboard of real time sensor data accessed locally by the end user

Dashboard for all data measurements with node-red server

Real time data charts on node-red server

Results and Discussions cont'd

Real time biogas data monitoring via adafruit MQTT cloud server



Graphs showing biogas digester data variation over time on adafruit cloud server

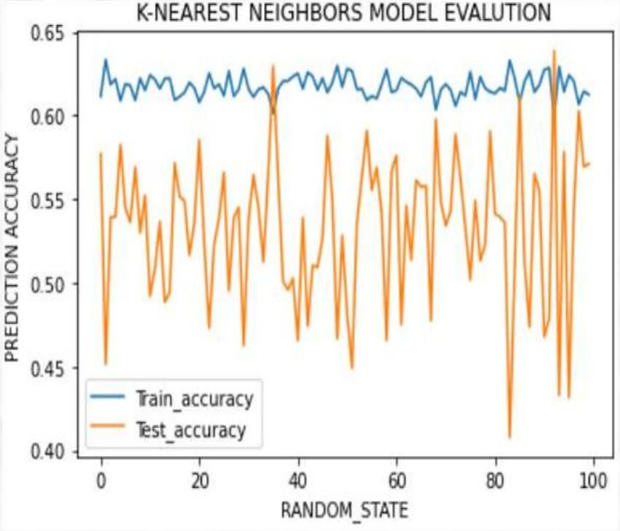
Results and Discussions cont'd

- The second objective of this research was to put in place the biogas prediction model based on organic waste supplied and biogas AD status.

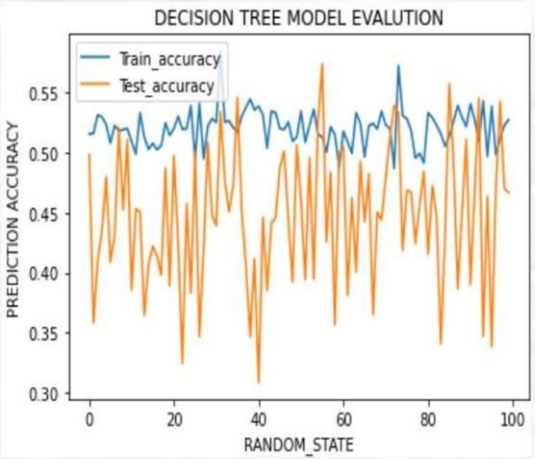
- The model have been built using several machines learning algorithms available.

- The model training and evaluation was done using python programing language, anaconda software package and sklearn python package which has several models used .
- In this research a supervised machines learning models have been used because they are suitable to our dataset nature. K-nearest neighbor model, Decision tree and Gradient boosting model have been selected because they presented a highest accuracy among other models tested.

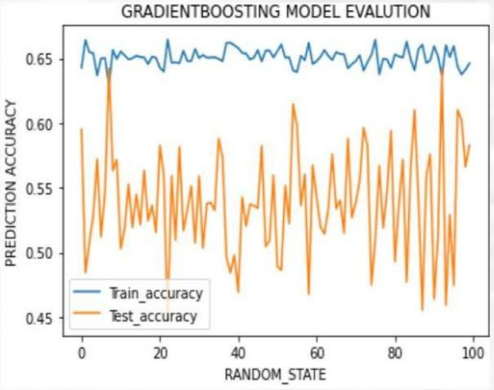
Results and Discussions cont'd



With KNN, The accuracy obtained tend to be near 70 % .



With Decison tree, The accuracy obtained tend to go lower to 70 % .



With Gradient boosting , both the training and testing accuracy became roughly around 65 %.

Conclusion

- This research aimed to make the biogas monitoring system and making biogas prediction model to predict biogas production based on inputs feedings with organic materials.

- The monitoring system have been implanted successfully

- The outcome of the current research shows that the biogas production in biogas container could be predicted with high accuracy (between 65% and 70%) by using K-nearest neighbors (K-NN), gradient boosting and Decision tree Machine Learning Algorithms respectively comparing with the other algorithms tested through this research.

Recommendation

- I recommend the decision makers to help in developing a complete biogas digester and apply this IoT technology in order to optimize the biogas production in rural to reduce the use of biomass and it will contribute in environmental protection.
- I also recommend decision makers to work with available stakeholders in order to convince rural population to adopt biogas technology .

Future works

- ★ For the future work, we expect to employ some advanced machine learning models like time series models (Recurrent Neural Networks) to predict the biogas production rate because of the complexities of anaerobic digestion that occurs inside biogas digester to produce biogas [8].
- ★ In this research, only one organic material has been considered (cow dung and water).
- ★ The next researcher could do deep analysis of different feeding materials available as they do not contain the same amount of biogas and the dataset could be taken in order of several months or years which could help the accuracy of the prediction by the machine learning algorithm
- ★ The next researcher could find industrial gas sensors which produce highest accurate values in order to be consistent in the measurement .

Thank you