Development of Prototype E-nose to Detect the Ripening Stages of Fruits and Vegetables using Machine Learning Algorithm

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Abstract - *Over the past few years, Electronic nose technology is a non-destructive method to sense various gases released by fruits and vegetables, which can be used to determine the ripening stages of fruits and vegetables. An electronic nose device can also tackle many problems associated with the use of human panels. The developed electronic nose system consists of four functional components that operates serially on an fruit and vegetable sample- a fruit sample box, an array of five MOS gas sensors interfaced with Arduino Uno and a PC with LabVIEW software and machine learning algorithm developed in MATLAB software. The developed electronic nose is used to collect the odor (fragrance) data released by fruits and vegetables and can discriminate the patterns of gases released from fruits and vegetables which then processed on laptop computer using machine learning algorithm.*

Key Words: **Electronic nose, MOS gas sensors, LabVIEW software, MATLAB, Machine learning algorithm.**

1. INTRODUCTION

Agriculture is the main occupation for about 58 per cent of India's population. It is the widest economic sector in India and it plays an important role in economic development. In India, fruits are cultivated in the area of 6.3 million hectares and vegetables are cultivated in the area of 10.1 million hectares. Second largest producer of fruits and vegetables in world is India. India is the world's largest producer of mangoes, banana, papaya and lemon and ranks second in production of potatoes, onions, cauliflowers, brinjal, Cabbages, tomatoes, etc.There are various types of fruits and vegetables which are consumed in domestic market as well as they are exported to other countries. An increasing competition in our country as well as other countries fruit and vegetables markets leads to the need for improved ripeness evaluation techniques. Using ripeness evaluation techniques, potential losses to the grower and packer, as well as fast spoilage will be minimized at the consumer end. Monitoring and controlling ripeness is becoming a very important issue in the food industry. In order to detect the Ripening stages of fruits and vegetables, Variation in texture, color, shape and odor of the fruits and vegetables can be used. Nowadays, there are various methods and techniques for the classification of fruits and vegetables which are destructive and non-destructive methods. Destructive methods to assess fruit ripeness are the traditional methods and have its own drawbacks, and hence not desirable. For example, a force has to be applied to test the firmness of a fruit, it causes damage to the fruit resulting in spoilt produce. Other destructive methods include chemical species and parameters measurement that are used to assess ripeness such as pH, sugars contents and ethylene contents. Other than these destructive methods, several non-destructive methods are developed. The non-destructive type methods does not harm the fruit and vegetable under test. This methods are most preferred to assess ripeness stages of fruits and vegetables based on classification. Some non-destructive methods are nuclear magnetic resonance (NMR), proton magnetic resonance (PMR), vision system and acoustics. All of the above methods have its own drawbacks. Based on An electronic-nose is the most popular non-destructive method to assess ripeness of fruits and vegetables.

An Electronic nose is a device which has the behavior of human olfaction. A non-destructive E-Nose is an artificial olfactory system to sense various gases which can be used to classify the fruits and vegetables at the time of harvest, post-harvest and during storage with various conditions. E-Noses comprises of an array of independent semi-selective and reversible gas sensors. In most cases electronic noses commonly use resistive sensors, whose impedance varies with the presence of certain gases. The output of sensor array is analysed by some form of machine learning algorithm.

2. LITERATURE REVIEW

[1]. L. P. Deshmukh, M. S. Kasbe, T.H.Mujawar, S.S.Mule and A.D.Shaligram proposed a paper which aims to develop a wireless electronic nose to detect the ripening stages of different fruits. The sensing system in the wireless electronic nose (WEN) is employed using XBee, an array of gas sensors, LabVIEW GUI and samples of the green and yellow mangos. A wireless electronic nose consists of a wireless sensor node, coordinator node and software development using LabVIEW for monitoring. An array of sensors collects the various gases released from fruits. The sensors produces gives an output voltage and the output from the sensors is sent to an Arduino controller and the controller sends it to the XBee S2 module for wireless data transmission. A LabVIEW stand-alone-application (LVSAAPP)is used for data analysis. Principal

component analysis (PCA) is used as data classification technique.

[2]. Ms.N.Geethapriya & Dr. S. Mary Praveena proposed a paper which aims at use of an Electronic nose which acts as an artificial nose that mimics the human nose behaviour. Here, an electronic nose was designed to detect the ripeness of fruits based on ethylene concentration. An e-nose system comprises of three parts namely sampling system, sensing system and processing system. Here, the sensor detects the presence of ethylene gas released from the fruit samples. Output is then transferred to ADC in the microcontroller unit. The LCD displays the ethylene concentration and is transmitted to the receiver module through ZIGBEE protocol. The VISUAL BASIC software is used to display the ethylene concentration in the PC. Classification and coding mechanisms are coded into MCU. This setup determines the maturity stages of the fruit based on the ethylene concentration.

[3]. J. Brezmes, E. Llobet, X. Vilanova, G. Saiz and X. Correig proposed a paper that presents the use of an electronic nose to monitor the fruit ripening process. An electronic olfactory system is designed using a chemical sensor array and suitable pattern recognition techniques.The three modules of an Electronic Nose: the concentration chamber 5-l plastic box., the measurement chamber 2-l box and the Personal Computer unit. A number of pieces of fruit is placed in the concentration chamber, then the measurement routine starts. A vapour sample of 150ml of the fruit headspace is extracted by using a gas chromatographic syringe and is transferred into the sensor chamber. Here, the conductance of the tin oxide sensors changes due to modification in sudden concentration change and the concentration changes are recorded in the PC. Both chambers are passed with synthetic dry air to clean it after each measurement. Then, the new measurement starts with concentration phase.

[4]. Mridushmita Borborah, Pranab Jyoti Haloi, Pranjal Jyoti Hazarika proposed a paper that explicates the Electronic nose to monitor the fruit ripeness & to recognize fruits with the application of Artificial Neural Network based Micro-controller. Here, an array of sensors is used detect the ripeness of fruits. This project mainly uses the following sensors: gas sensor, temperature sensor, humidity sensor, moisture sensor & RGB color sensor. This sensor array produces the raw data and that data is given to the microcontroller. The program is fed to the Arduino microcontroller through Arduino software. The final output section are LCD and Relay. LCD displays of the output of the sensors while the relay is the actuator for the FCE (Final Control Element) like the fan and SOV. Based on the output value, this system determines ripeness stage of various fruits.

[5]. Ashok Kanade and Arvind Shaligram proposed a work to develop an application specific e-nose system with pattern recognition tool. Here, Fuzzy logic is used as an pattern recognition tool. The developed system is used to classify and identify guava fruits during the prepackaging time. The developed e-nose system consists of an array of eight SnO2 MOS gas sensors, static odor delivery system, signal conditioning circuit, data acquisition and pre-processing software using LabVIEW2012. Here, The measurements process comprises of three different phases 1) concentration 2) measurement and 3) stand-by. Once the stand-by mode enters, Measurement process starts again.

[6]. M.S. Kasbe, S.L.Deshmukh, T.H.Mujawar, V.D.Bachuwar, L.P. Deshmuk and A.D. Shaligram proposed a paper that describes about electronic nose which comprises of a semiconductor gas sensor array and an artificial neural network (ANN). An electronic nose is employed to determine the ripening stages of fruits. A gas sensor array (SnO_2 type) detects gases released from the fruits in during different freshness stages of the fruits. The various gases which are emitted from the fruits are: alcohol, methane, carbon dioxide, ammonia and carbon monoxide, have been detected by the sensor array. LabVIEW software is used to design an artificial neural network. Various ripening stages of both the fruits are compared. An e-nose is a smart novel system which is portable and is of low cost. DAQ card makes an interfacing between an array of MQ-gas sensors and (computer) LabVIEW software.

3. METHODOLOGY

Fig -1 shows the block diagram setup of the developed E-Nose system, which comprises of five MQ series gas sensor array, an Arduino Uno board, a test chamber, and a PC with self-developed LabVIEW program and MATLAB program.

Fruits, vegetables samples and the MQ series sensor array is placed in a test chamber which is then connected to Arduino Uno board. Five analog channels (A0-A4) are used for sensor array. Analog inputs are used to obtain analog signals from the sensor array. LabVIEW block diagram is designed in order to obtain an analog response from sensor array. Obtained analog inputs are converted to voltage form and are displayed in a LabVIEW front panel. Once the voltage dataset is ready, the MATLAB program is built to determine the ripening stages of fruits and vegetables based on machine learning algorithm.

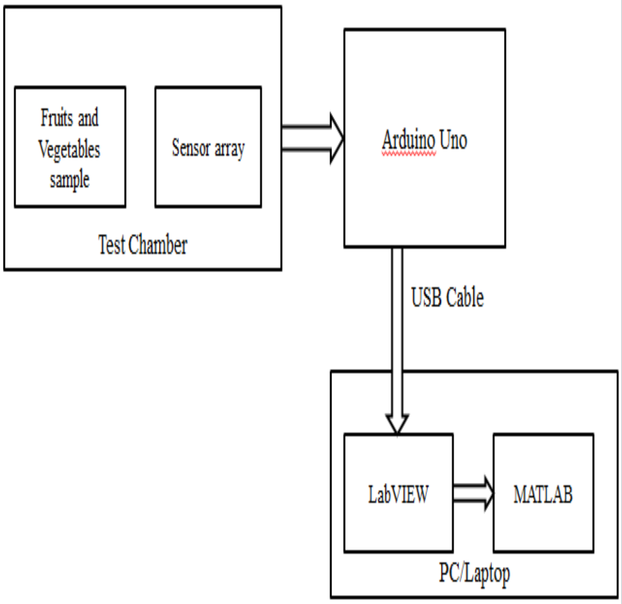

Fig -1: Block Diagram of Electronic Nose.

Table 1 shows the list of MQ gas sensors used in the proposed work.

Table -1: List of MQ gas sensors

Sensors	Sensitive to
MQ3	Alcohol
MQ5	LPG, natural gas, and town gas
MQ7	Carbon monoxide(CO)
MQ9	Carbon monoxide, methane, Propane and LPG
MQ135	Ammonia, Sulfides and Benzene

4. IMPLEMENTATION

Fig -2 shows the experimental setup of the proposed work. In this work, fruits and vegetables samples will be placed in an air-tight plastic chamber called as test chamber which consists of an array of five MQ series gas sensors attached to it. Here, Gas sensors are interfaced with Arduino Uno and then Arduino Uno board is connected to PC/Laptop through USB cable.

Fig -2: Experimental setup of the proposed work.

Once the connections are made, the LINX resource firmware has to be uploaded to the Arduino Uno board to work with the LabVIEW. LabVIEW VI consists of Block Diagram and Front panel. Block diagram to read sensor values has to be built using LINX resource in LabVIEW. Fig -3 shows the block diagram of the present work in LabVIEW.

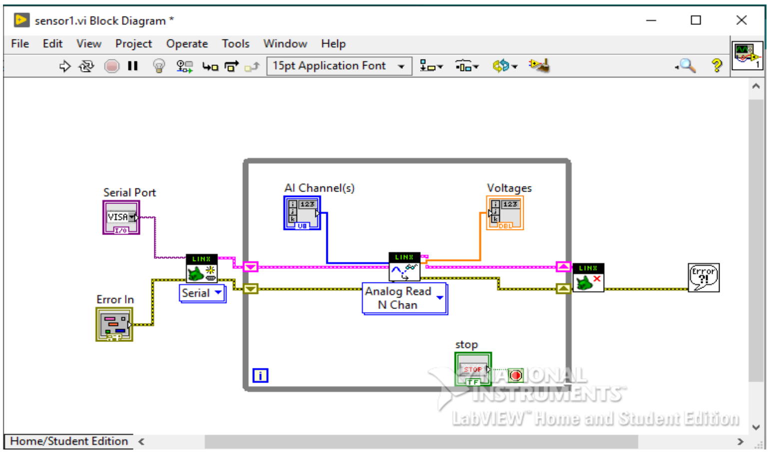

Fig -3: Block Diagram to read sensor values in LabVIEW

Fig -4 shows the front panel of the present work in LabVIEW.

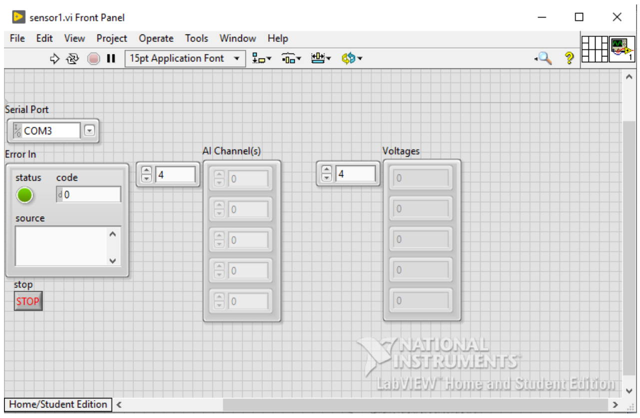

Fig -4: Front Panel of the present work in LabVIEW.

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After designing the block diagram and front panel is built, LINX firmware has to be uploaded to the Arduino uno board using serial communication. Fig -5 shows the LINX firmware uploadation.

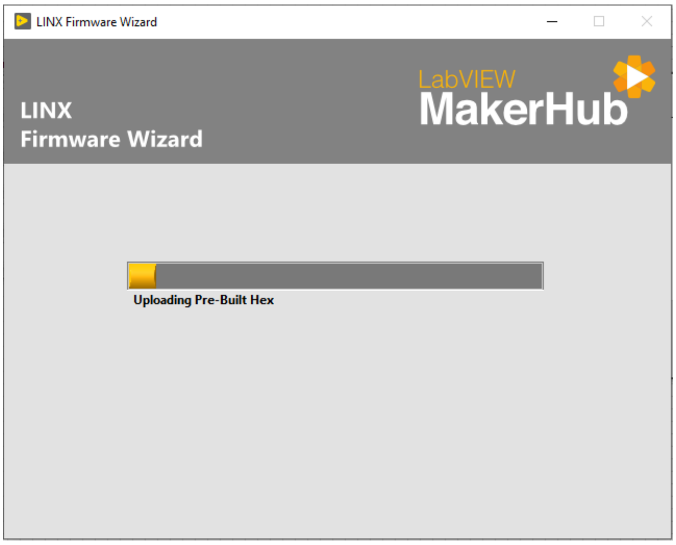

Fig -5: LINX Firmware uploadation

Once the LINX firmware is uploaded to the Arduino Uno, LabVIEW compiles, runs and display the sensor readings. Here, Sensor readings are obtained in the form of Voltages. Sensor voltages increases as the concentration of gases released from taken sample increases. Sensor Voltages are displayed in the front panel of the LabVIEW and then voltage values are exported to excel sheet. Then, MATLAB program is written to discriminate the ripening stages of fruits and vegetables based on voltage values using machine learning algorithm.

5. RESULTS AND OBSERVATION

In this work, Banana and Tomato were taken for experiment. The experiment was conducted for fruits and vegetables of under-riped, riped and over-riped stages. The response of sensors for different gases released by fruits and vegetables was analyzed using Microsoft excel.

MQ-3 sensor is used to detect alcohol concentration in the sample. The alcohol concentration is high for under-riped and over-riped tomato when compared to riped tomato.MQ-5 detects the concentration of natural gas released by sample. The concentration of natural gas increases with each stages of ripeness. MQ-7 is used to detect the concentration of Carbon monoxide in the sample. The concentration of CO increases with each stage of ripeness. MQ-9 sensor is used to detect propane and methane gases. The response of MQ-9 sensor is constant for each stage. MQ-135 sensor is used to detect ammonia present in the sample. The concentration of Ammonia increases with each stage of ripeness. Chart -1 shows the sensor array response for different stages of ripeness of banana fruit.

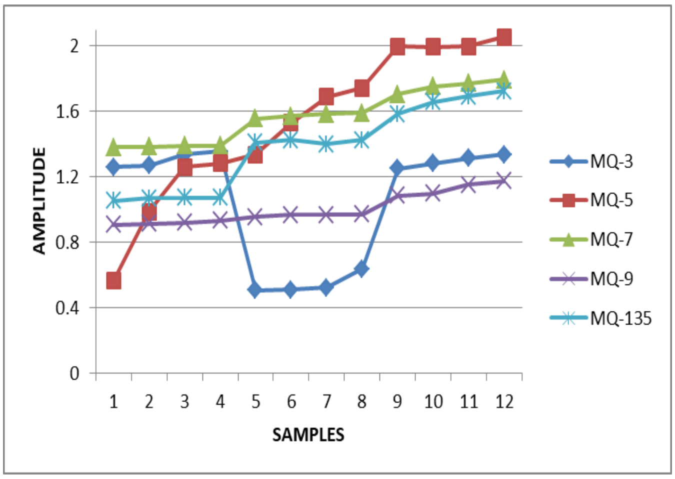

Chart -1: Sensors response for different stages of ripeness of Banana.

The alcohol concentration is less for under-riped tomato when compared to riped and over-riped tomato. The concentration of natural gas increased with each stages of ripeness. The concentration of CO slightly increases with each stage of ripeness. The response of MQ-9 gas is constant for each stage. The concentration of Ammonia increases with each stage of ripeness. Chart -2 shows the sensor array response for different stages of ripeness of tomato.

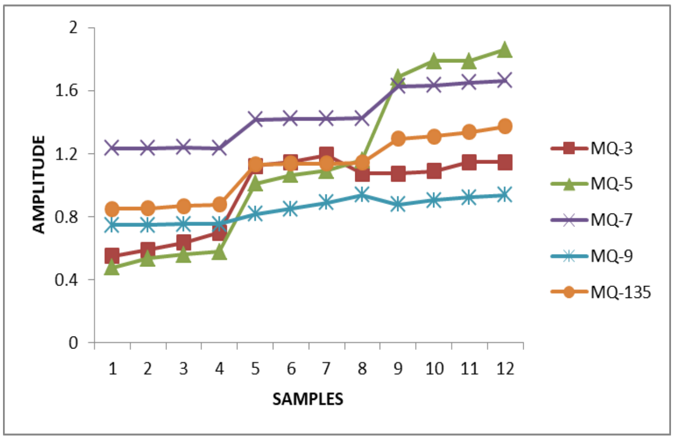

Chart -2: Sensors response for different stages of ripeness of Tomato.

6. CONCLUSION

Different fruits and vegetables emits various gases in varied concentrations. Here, An electronic nose which is a non-destructive method is employed to determine the ripening stages of fruits and vegetables. It is an very easy and efficient method to detect the freshness of fruits and vegetables. An E-nose system provides more accurate results than the other destructive and non-destructive techniques. Here, Banana and tomatoes are used for experimentation. Further work can be done to determine the ripening stages of all fruits and vegetables. This electronic-nose requires simple and very less cost gas chamber like tight plastic box or a closed metallic chamber. The system can be altered. The present work is experimented in a close tight chamber; instead it can be conducted in open atmosphere, which is a challenging task.

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