Project Completion Report

On

DST-IDP project on

"Hardware based field-type E-Nose for Flavour Detection of Tea using Metal Oxide Semiconductor (MOS) sensors."

DST No:ID/Sensor-New/06/2010-11, Dated:18.11.2011

Submitted by

Prof. M Bhuyan

Dept. of ECE,

Tezpur University,

Napaam-784028,

Assam

Annexure-IX

PROJECT COMPLETION REPORT

Notes:
1. 10 copies of the Project Completion Report (PCR) should be sent within one month of the completion or termination of the project.
2. The PCR should be in bound form.
3. Cover page should include the title of the project, file number, names and addresses of the investigation.

1. Title of the project: *"Hardware based field-type E-Nose for Flavour Detection of Tea using Metal Oxide Semiconductor (MOS) sensors."*

2. Principal Investigator(s) and Co-Investigator(s):

Principal Investigator

Name : Dr. M. Bhuyan
Designation : Professor, Department of Electronics and Communication Engineering, Tezpur University, Assam
Institution : Tezpur University
Address : Department of Electronics and Communication Engineering Tezpur University, Napaam -784028, Assam, India

Co-Investigators:

i. **Name** : Mr. R. Chutia
Designation : Assistant professor
Institution : Tezpur University
Address : Department of Electronics and Communication Engineering Tezpur University, Napaam -784028, Assam, India

ii. **Name** : Mr. B. Mondal
Designation : Assistant professor
Institution : Tezpur University
Address : Department of Electronics and Communication Engineering Tezpur University, Napaam -784028, Assam

3. Implementing Institution(s) and other collaborating Institution(s):

Implementing Institution

Department of Electronics and Communication Engineering,
Tezpur University,
Assam,
India

Collaborating Institution

Center for Development of Advanced Computing (CDAC)
Plot- E-2/1, Block-GP, Sector - V
Saltlake Electronics Complex
Bidhannagar, Kolkata - 700 091

4. **Date of commencement** : 01-04-2012

5. **Planned date of completion** : 31-03-2014

6. **Actual date of completion** : 31-12-2014

7. **Objectives as stated in the project proposal:**

PC based Tea flavor detection systems are computationally efficient but there is a big disadvantage – reluctance of the tea industries to use PC based instruments which is hindrance to its commercialization. This is basically due to the fact that most of the tea factory workers are illiterate and they have fear for learning computers. Acceptability of the tea E-Nose can be increased by shifting the PC based system to an electronic gadget type of system which can automatically display the tea quality without the need for a PC. The objective of this research is to develop a hardware based field of Tea E-Nose system which will have the following features-

i) Portable and stand alone type
ii) The inbuilt ANN can be trained locally
iii) Minimum user functions
iv) Low cost

8. **Deviation made from original objectives if any, while implementing the project and reasons thereof:**

No deviation

9. **Experimental work giving full details of experimental set up, methods adopted, data collected supported by necessary table, charts, diagrams & photographs:**

9.1 Method for Sensor selection:-

Development of a hand held and portable E-nose requires experimentation on sensor selection from a set of commercially available MOS gas sensors which can discriminate the tea aroma with optimum sensitivity and selectivity. Moreover the acquisition of responses from the selected sensors, their training in ANN and network configuration is important for verification of correct prediction of the sample class. Therefore prior to development of the hand-held system for training and testing of the samples –

- A PC based E-Nose setup set up was developed.
- Comprises of an array of 12 tin oxide based MOS gas sensors (TGS 813, TGS 821, TGS 822, TGS 825, TGS 826, TGS 832; TGS 2600, TGS 2602, TGS 2610, TGS 2611, TGS 2620 and TGS 2201) obtained from Figaro Engineering, Inc. (Osaka, Japan).
- The sensor array is first used to determine the change in voltage level on application of different class of tea flavor as shown in Fig.1.
- The sensors having low sensitivity as well as same sensitivity towards different grades of tea were rejected

- Out of the 12 only 4 sensors (TGS 2201, TGS 2602, TGS 2620 and TGS 832) are used to classify tea flavor in hand held system as the sensitivity of these sensors are comparatively found good through repeated experimentation as shown in Fig.2.

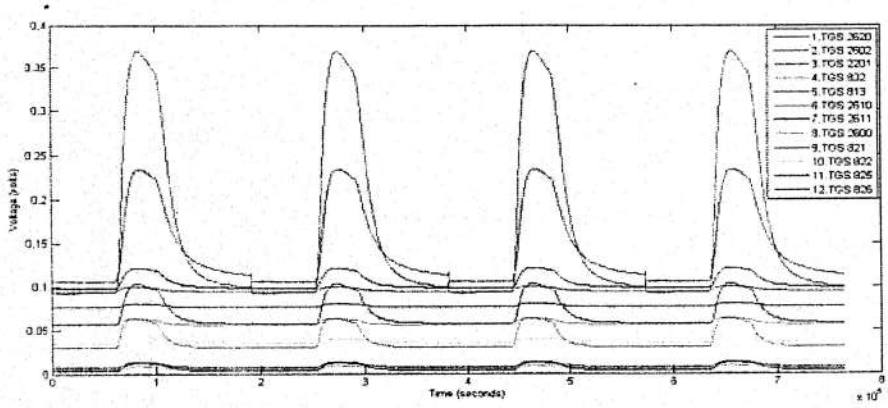

Fig. 1. Response of the 12 sensors on exposure to a tea sample.

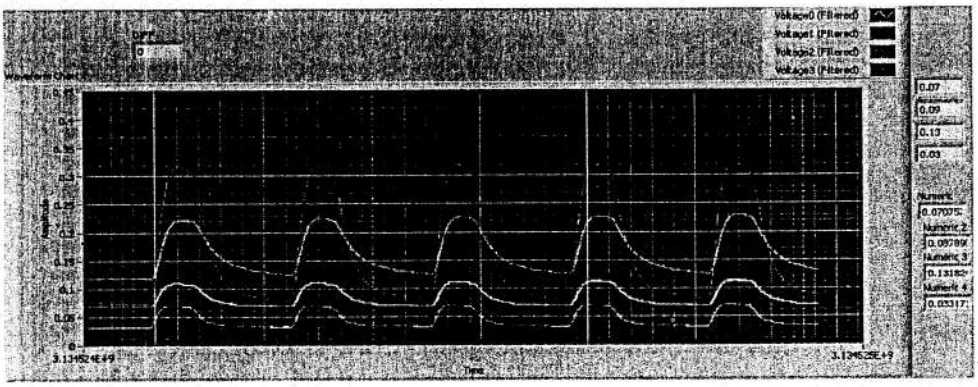

Fig. 2 Example of repeatability of the 4 selected sensors response on exposure to same tea sample.

9.2 Sample cum Sensor Chamber

- Identical cylindrical shaped plastic sample chambers 4 cm × 5.5 cm are used to place the sample.
- The PCB of the sensors is fixed on the cover of the sample chamber and mounted in a Teflon sheet (10 cm×5 cm ×2.5 cm) as shown in Fig.3.
- The temperature required for volatile gases emission of tea is typically above 50°C and is obtained from self heating of the sensors.
- The samples heating temperature provided by the sensors are measured at different phases during testing by a digital thermometer and found to be 55±5°C.

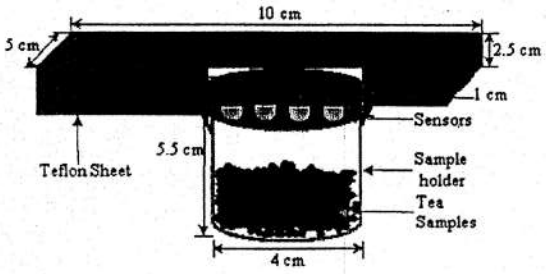

Fig.3 Sample cum sensor chamber.

9.3 Data acquisition and ANN configuration

- The sample cum sensor chamber is interfaced to a PC via LABVIEW to collect the signals for each class of tea
- The signals are captured and stored using data acquisition card NI 6024E that digitize the incoming signal with resolution of 16 bit at 100 samples per second
- The signals acquired are first used to develop a Feed forward back propagation (FFBP) ANN model in MATLAB.
- The weights and biases of the developed ANN model shown in Fig.4. is then realized in the PIC microcontroller for developing a hand held system.
- FFBP model having 4-4-1 layer is used to classify tea as shown in Fig.5. The performance parameter of the neural network simulated in MATLAB is shown in Table 1

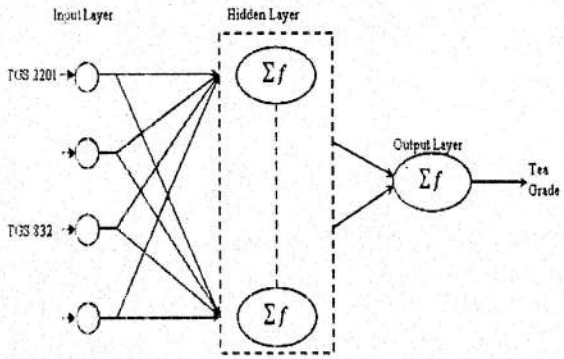

Fig. 4. ANN model

Table 1 Weights and biases

Weights/ Biases layer	values
net.IW{1,1}	[4.0822 -14.7264 70.4382 -4.2148; 0.0320 2.8070 -0.2072 6.1479; 27.3580 -22.8518 -2.6353 -16.5874; -5.4591 4.1239 -8.8655 1.6665]
net.LW{2,1}	[-1.1923 3.4025 -26.4381 -7.6345; 8.2492 0.3640 -10.7840 2.0576; -1.1398 -0.5508 -1.0945 -3.6377; 6.9775 -7.7034 -4.0654 2.8507]
net.LW{3,2}	[-20.6269 24.3084 15.7980 3.6618]
net.b{1}	[-1.3262; 3.1998; 5.3442;1.6291]
net.b{2}	[1.7566; -0.3482; -3.7649;-1.3279]
net.b{3}	[-0.1839]

Table 2 Performance parameters of handheld tea classifier.

Hidden Neurons	Epochs set	Goal	Learning Rate	Epochs Reached	Time (seconds)	Training Accuracy	Remarks
2	1000	0.01	0.1	4	4	12.5	Under trained
4				175	175	100	Well trained
6				251	251	95.83	Over trained
8				110	110	91.66	Over trained

The activation functions used in the input and hidden layers are hyperbolic tangent sigmoid (tansig) and log-sigmoid (logsig) given by-

$$Tansig\ (n) = \frac{e^{n} - e^{-n}}{e^{n} + e^{-n}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$logsig\ (n) = \frac{1}{1 + e^{-n}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The developed ANN model for the sample cum sensor chamber is first tested on PIC microcontroller board EASY PIC V7 having the following configuration-

a) PIC 18F45K22 Microcontroller.
b) mikroProg™ on board (On-board programmer)
c) On board modules (Displays, Buzzer, Temp sensors, Ethernet, USB)
d) mikroBUS™ sockets
e) Ethernet on-board
f) Dual power supply (3.3 volt and 5 volt)
g) Miscellaneous features (I/O port organization,
   a)Serial port communication,
   b) two on-board potentiometers for simulating analog signal,
   c)a jumper for selecting the button press level (0 or 1), I2C serial EEPROM)

9.4 Design of Handheld system

The handheld tea grading system is developed with the circuit diagram as shown in Fig.5-

- Using Metal oxide semiconductor (MOS) gas sensor array for tea aroma sensing,
- PIC 18F45k22 microcontroller which computes the tea grading
- Programmed Feed forward back propagation neural network (FFBP) algorithm
- Alphanumeric LCD display to display the ongoing processes throughout all the phases during testing,

- Keypad for control of input process parameters
- *12 volt 2200mAh lithium-ion polymer rechargeable battery for powering up the portable* device.
- 15 grams of tea samples is weighted every time and placed in the sample chamber which is directly exposed to the sensor head,
- Data is collected by exposing the sensor array to tea sample, for 16 minutes approximately till the sensor response gets to the peak sensitive value and stabilizes.
- PCB layouts of the various components are designed in DIP trace 2.4.0.2 as shown in Fig.6.

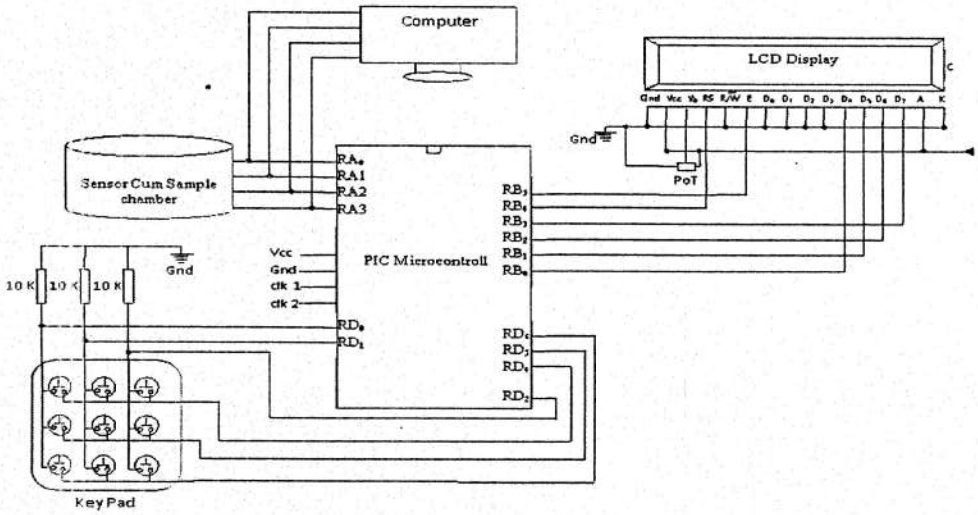

Fig.5 Circuit diagram of the handheld system.

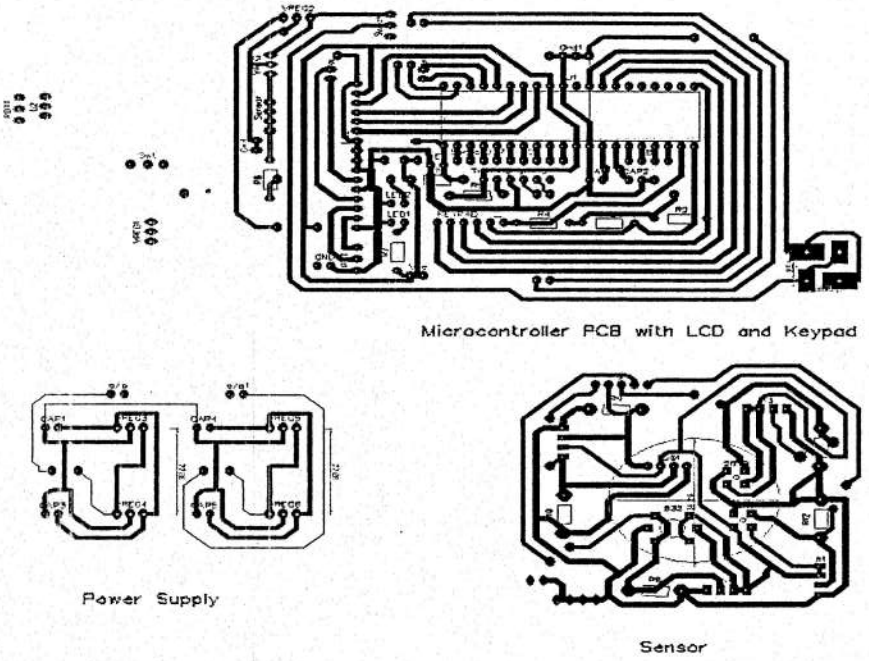

Fig. 6 PCB layout.

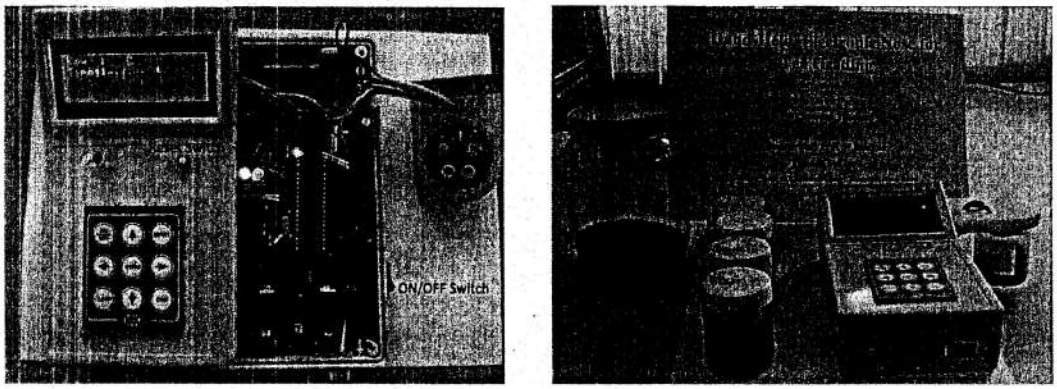

Fig.7 Prototype hand held system with all the components mounted on the designed PCBs

- The PIC microcontroller comprises of a 10 bit resolution successive approximation type internal ADC module,
- 32KB of reprogrammable flash memory and has 2KB of RAM.
- The software was coded using MikroC PRO for PIC 6.4.0 compiler version with same IEEE 754 floating point precision as MATLAB.
- The input data set as computed in MATLAB is obtained with the help of internal ADC of the microcontroller with a sampling frequency up to 65 KHz.
- The program size is 7.72 kb and uses 24% RAM and 38% ROM.
- The result of the tea grading obtained by the microcontroller is displayed in 20x4 LCD display.
- The steps that are implemented in the microcontroller for tea grade estimation are detailed in Fig.8.

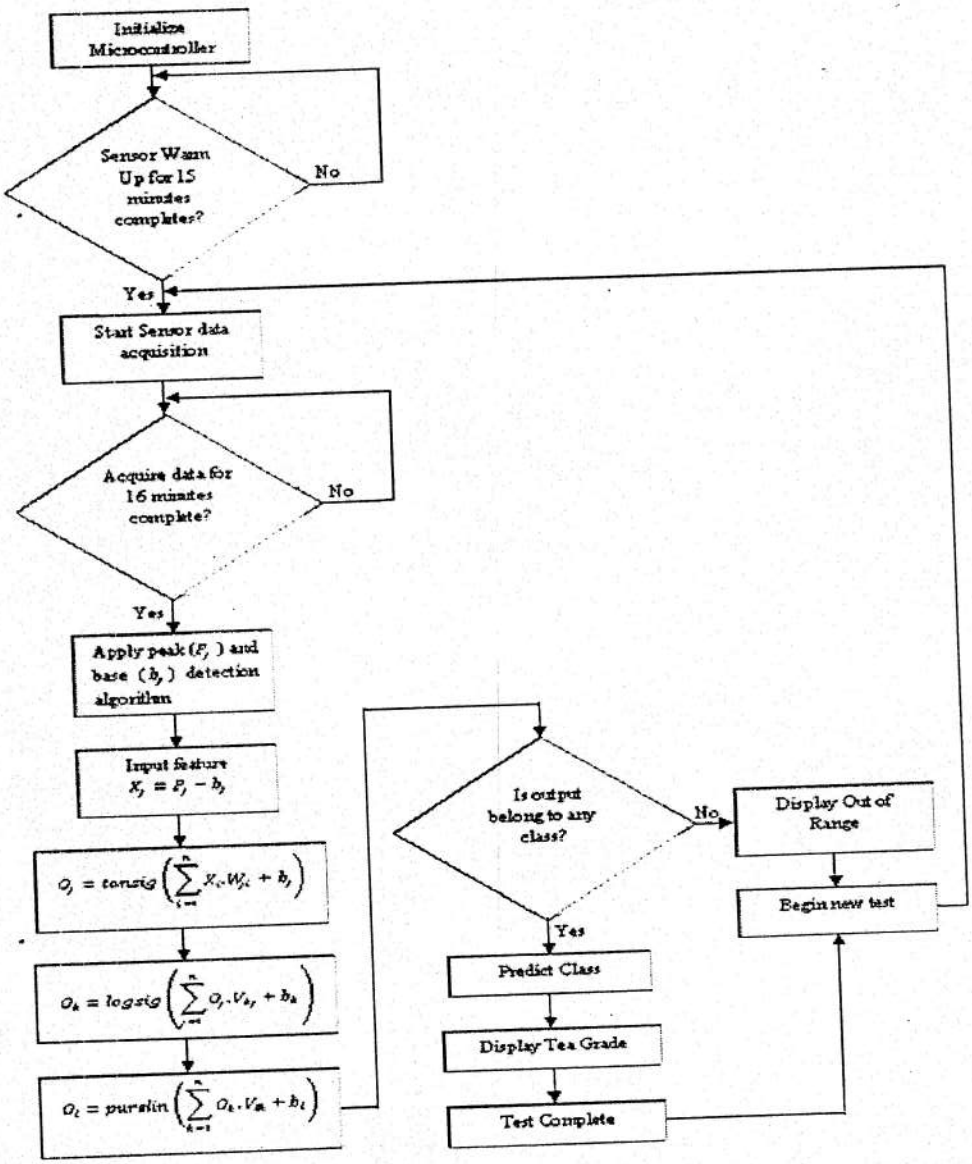

Fig.8 Flow diagram of embedded tea classifier.

10. Detailed analysis of results indicating contributions made towards increasing the state of knowledge in the subject:

10.1 Results and achievement

- Total classes of tea grades : 8
  (0.2, 0.8, 2.5, 5.5, 6.0, 7.5, 8.0 and 9.0)
- Tea type: CTC
- Total no of samples tested: 80(8 x 10)
- Classification accuracy: 90%. Shown in confusion matrix of Fig.10.

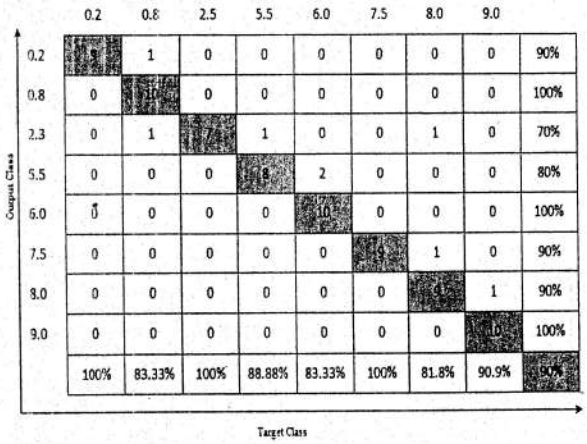

Fig.9 Confusion matrix of hand-held system.

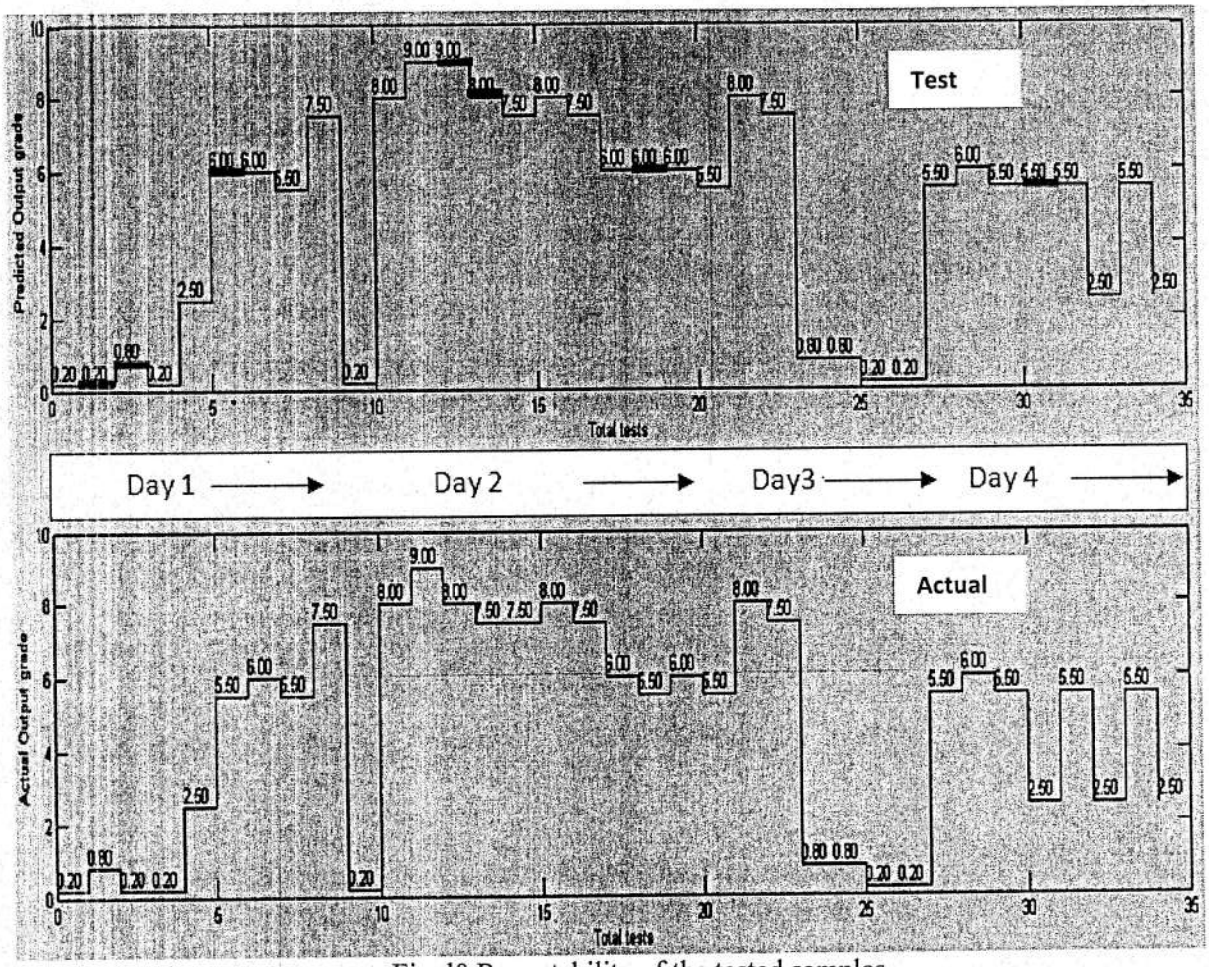

Fig. l0 Repeatability of the tested samples.

The repeatability tests (fig. l.) of the e-nose is performed and Misclassification (=7/35 = 20 %) is evaluated.

10.2 Prototype

Material/components used:

i) Plastic Cabinet: 19 × 10.4 × 6.15 cm.
ii) Microcontroller: PIC 18F45K22.
iii) LCD: 20 × 4
iv) Keypad: 3 × 3 Matrix keypad.
v) Battery: 12 volt 2200mAh Li-Po battery.
vi) ICs and accessories: LM 7805, LED, Switches, Capacitors, Resistances, wires, connectors, IC base, PCB etc.
vii) Teflon sheet (sensor cum sample chamber): 10 × 2.5 × 5 cm
viii) Plastic sample chamber (cylindrical): 4 × 5.5 cm
ix) Approx. Cost: **12,500.00**

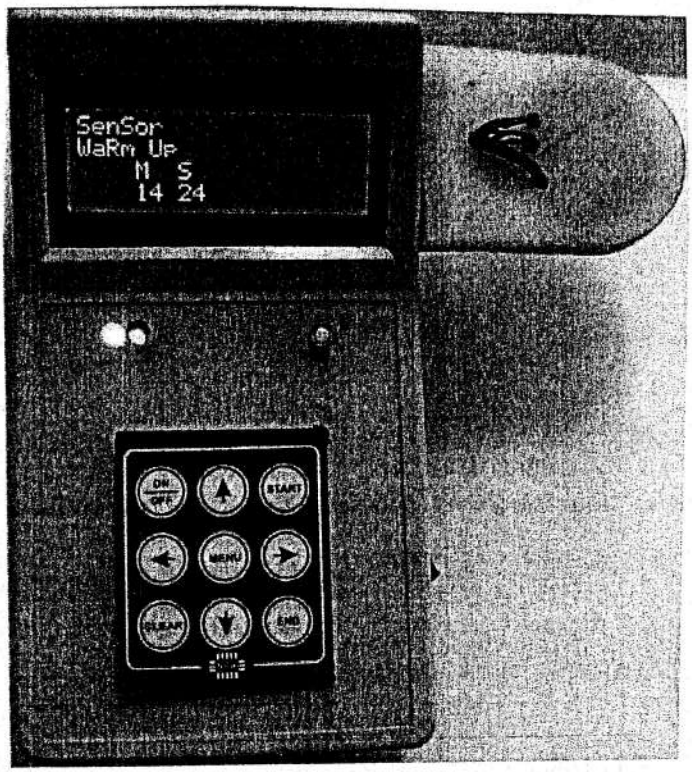

Fig. 11 Prototype

Salient features of prototype:

i)	Power Supply Voltage	: 5 volt
ii)	Power consumption (sensors)	: 1.83 Watt (approx.)
iii)	Battery type	: lithium-ion polymer rechargeable battery
iv)	Battery Capacity	: 12 volt 2200mAh.
v)	Total Power consumption	: 2.33 watt (approx.)
vi)	Full charge test number	: 11.
vii)	Sensor warm up time	: 15 minutes
viii)	Grading time	: 16 minutes
ix)	Tea Chamber temperature	: 55±5°C.
x)	Tea quantity	: 15 grams.

Sequence of operation:

Switch ON > Sensor Warm Up: 15 min (down timer)> Initializing: 5 s >Display Add sample and press test> Display Calculating Score: 16 min (down timer)> Display Tea Grade value > Remove tea chamber and refresh: 10 min (down timer)> New test

11. Conclusions summarizing the achievements and indication of scope for future work:

Achievements

i) Portable and stand alone type
ii) The inbuilt ANN can be trained locally
iii) Minimum user functions
iv) Low cost

Future Scope

i) Reducing the time required for grading
ii) Training with more grading of tea will make the system more reliable

12. S&T benefits accrued:

i. List of Research publications

S No	Authors	Title of paper	Name of the Journal	Volume	Pages	Year
1.	Mr. Pranaya kr. Mallik (Mtech Project)	COMPARISON OF PERFORMANCE OF TWO ANN PARADIGMS- FFBP AND RBF FOR TEA FLAVOUR DETECTION				2013

ii. Manpower trained on the project

a) Research Scientists or Research Associates

i. Lachit Dutta (JRF)
ii. Champak Talukdar (SRF)

b) No. of Ph.D. produced : One (ongoing)

c) Other Technical Personnel trained : NIL

iii. Patents taken, if any : None (However the developed Prototype has been transferred to Innovation and Incubation centre of Tezpur University).

13.Financial Position:

Sl. NO.	HEADS OF EXPENDITURE AS PER SANCTION ORDER	AMOUNT ALLOCATED/ SANCTIONED			AMOUNT UTILIZED			TOTAL EXPENDIURE
		2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	
1.	Salaries	4,16,400.00	2,41,600.00	NIL	2,60,933.00	1,51,000.00	2,41,600.00	6,53,533.00
2.	Consumables	30,000.00	40,375.00	NIL	29,973.00	NIL	39,507.00	69,480.00
	Contingency	30,000.00	29,974.00	NIL	25,306.00	4,668.00	27,494.00	57,468.00
4.	Travel	1,00,000.00	77,843.00	NIL	52,773.00	67,643.00	34,906.00	1,55,322.00
5.	Overhead	1,15,280.00	1,10,208.00	NIL	54,608.00	60,672.00	1,09,048.00	2,24,328.00
6.	Equipment	17,00,000.00	NIL	NIL	15,12,555.00	1,24,850.00	52,773.00	16,90,138.00
	Total	**23, 91,680.00**	**5,00,000.00**	**NIL**	**19,36,148.00**	**4,08,833.00**	**5,05,328.00**	**28,50,309.00**

14.Procurement/ Usage of Equipment:

a)

Sl. No.	Name of Equipment	Model & make	Cost (Rs)	Utilization Rate (%)
1.	Gas sensors :	Figaro (55 Nos of different nos) 1) TGS813 2) TGS821 3)TGS 822 4) TGS 825 5) TGS826		

		6) TGS2610 7) TGS2611 8) TGS2442 9) TGS2444 10) TGS2620 11) TGS2600 12) TGS2602 13) TGS2201 14) KE25 15) KE50 16) TGS6810 17) TGS6812 18) TGS5042 19) TGS3870 20) TGS4160 21) TGS830 22) TGS832 23) TGS880	1,33,846.00 + 9263.00	100
2.	Data acquisition card (high Resolution & low Resolution) and accessories)	National Instruments NI USB 6351 X series card. NI USB 6211 card Accessories SH68:68 Ep_cable NI SCB :68 Connector	2,71,950.00	100
3.	Digital Multimeter	Rishab/RishMulti-18s	26,105.00	100
4.	a) Mass Flow Controller			

	(2 no's) b) Cable c) Power Supply d) Flow vision Software	Alicat/MC50SCCM-D	3,71,280.00	100
5.	a) Mass Flow Meter(1 No's) b) Cable c) Power Supply	Alicat/M50SCCM-D	1,21,170	100
6.	PIC Microcontroller kits(3 No's)	Dynalog/EASYPICV7	88,530.00	100
7.	C-cross compiler for microcontroller (Software) a) PIC b) AVR c) dsPIC30/33 & PIC 24 d) PIC 32 e) 8051	Micro-Electronica/ Micro-C	1,71,385.00	100
8.	Function generator(1 No)	Dynaxact/DX-4010	40,950.00	100
9.	EPROM Programmer (1 No)	Advantech/LAB TOOL-48UXP	99,880.00	100

10.	Dip-trace PCB Design tool(Software) 5 user	Novarm/Extended(2000pins.6L)	1,16,970.00	100
11.	Air-conditioner 1.5-ton with accessories (2 No's)	Hitachi	70,489.00	100
12.	PC based digital multimeter	Keithley 2110	1,24,850.00	100
13.	Thermostatic water bath	Serological water bath / NSW India	43,510.00	100
		Total	**16,90,178.00**	

b) Plans for utilizing the equipment facilities in future

The equipments are working properly and has been used by students in doing their research and project work.

Name and Signature with Date

30-09-15

a.(Manabendra Bhuyan)
Principal Investigator

30/09/15

b.(Riku Chutia)
Co-Investigator)

30/09/15

c. (Biplob Mandal)
Co-Investigator)

UTILIZATION CERTIFICATE

Certified that out of Rs **NIL** grants in sanctioned during the year 2014-15 in favour of Registrar, Tezpur University under Department of Science & technology and **Rs 5,46,699.00** on account of unspent balance of previous year and bank interest received on grant of **Rs 54,873.00**(total fund **Rs 6,01,572.00**), a sum of **Rs. 5,05,328.00** has been utilized for the purpose of the IDP project on "*Hardware based field type of E-Nose for Flavour Detection of Tea using Metal Oxide Semiconductor (MOS) sensors*" for which it was sanctioned. The balance of **Rs 96,244.00** remaining unutilized at the end of the year will be refunded to DST.

27-05-15
Signature of PI

25/05/15
Signature of the Finance Officer
Finance Officer
Tezpur University

Signature of Registrar
Registrar
Tezpur University

(TO BE FILLED IN BY DST)

Certified that I have satisfied myself that the conditions on which the grants in aid was sancti oned have been fulfilled/ are being fulfilled and that I have exercised the following checks to see that the money was actually utilized for the purpose for which it was sanctioned: -

Kinds of checks exercised.

1.
2.
3.
4.

Signature

Designation

Date