Topic : Breath – Based Bio Signal Analyzer For Disease Detection

24AIM114 Analog System Design
&
24AIM113 Introduction to NN, CNN and GNN

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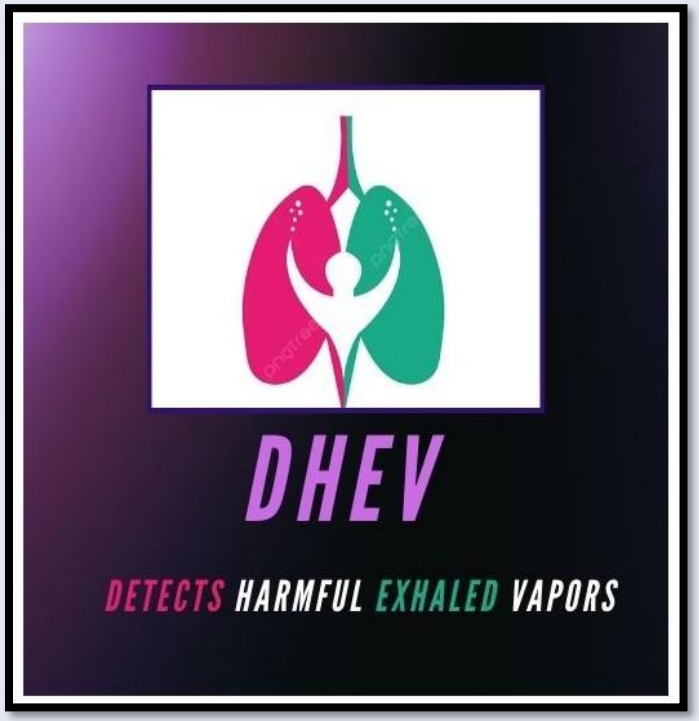
Project Overview:

- Developed a portable breath analyser device,DHEV(Detecting Harmful Exhaled Vapors) using ESP32, MQ-3, MQ-135, and DHT22 to detect VOCs related to diabetes (acetone) and GI issues (ammonia).
- Displayed real-time sensor data on OLED and merged synthetic + real dataset for model training.
- We have built an MLP model



Model Training :

1. Model Type: Multilayer Perceptron (MLP)
2. Input Features: Normalized values of Acetone, Ammonia, Temperature, and Humidity.
3. Output: Disease classification (4 classes).
4. Evaluation Metrics:
    1. Train Accuracy: **98.50%**
    2. Test Accuracy: **98.00%**
    3. Test F1 Score: **0.9799**
    4. 5-Fold Cross-Validation F1: **0.9312 ± 0.0370**

Disease Detection Logic (Based on sensor values):

1. If acetone level (MQ-3) > threshold AND ammonia level (MQ-135) > threshold:

   Result: Both diseases detected (Diabetes and GI issue).

2. If only acetone level > threshold:

   Result: Diabetic detected.

3. If only ammonia level > threshold:

   Result: GI issue detected.

4. Else:

   Result: Healthy.

TABLE 1. THESHOLD RANGE FOR DISEASE DETECTION

DISEASE	*NORMAL LEVEL*	*DISEASE LEVEL*
Diabetes (Acetone)	<1.8ppm	>1.8ppm
Gastro Intestinal (Ammonia)	<1.5ppm	>1.5ppm

➢ Why only ADAM optimizer is preferred?

1. **Adaptive Learning Rates**: Adjusts learning rates for each parameter.
2. **Faster Convergence**: Converges faster than SGD(Stochastic Gradient descent).
3. **Low Memory Usage**: Requires less memory.

Limitations of MQ3 and MQ135 Sensors:

1. **Cross-Sensitivity:**
   - MQ3 cross-reacts with methane, hydrogen (affects acetone detection).
   - MQ135 cross-reacts with benzene, CO_2, sulfides (affects ammonia detection).
2. **Limited Sensitivity:**
   - Operates at ppm-level; disease-specific VOCs often require ppb-level sensitivity.
   - Cannot distinguish between similar molecules (e.g., acetone and other ketones).
3. **Environmental Interference:**
   - Humidity/temperature fluctuations alter sensor resistance, requiring complex calibration.
4. **Stability and Recovery Issues:**
   - Baseline drift over time requires frequent recalibration.

S. No	Hyperparameter Tuning				
	Hidden layers	*Alpha*	*Learning rate*	*F1 score-Training*	*F1 score-Testing*
1	(32)	0.0001	0.001	78.4%	76.0%
2	(64)	0.001	0.001	82.1%	85.1%
3	(64, 32)	0.01	0.01	88.6%	94.7%
4	(64, 32, 16	0.05	0.01	91.3%	94.1%
5	(128, 64, 32)	0.05	0.005	90.7%	93.8%
6	(64, 64)	0.01	0.01	89.5%	92.5%
7	(32, 32, 32)	0.01	0.001	87.9%	83.0%
8	(128)	0.001	0.01	83.2%	81.2%
9	(128, 64)	0.001	0.005	88.0%	89.5%
10	(64, 32, 16)	0.001	0.005	87.3%	90.7%
11	(32, 32)	0.1	0.1	98.5%	97.9%

Hyperparameter	Value
Hidden Layers	(32, 32)
Activation Function	ReLU
Learning Rate	0.1
L2 Regularization (α)	0.01
Early Stopping Patience	20 epochs
Max Iterations	1500

Sensor Specifications & Detected Gases

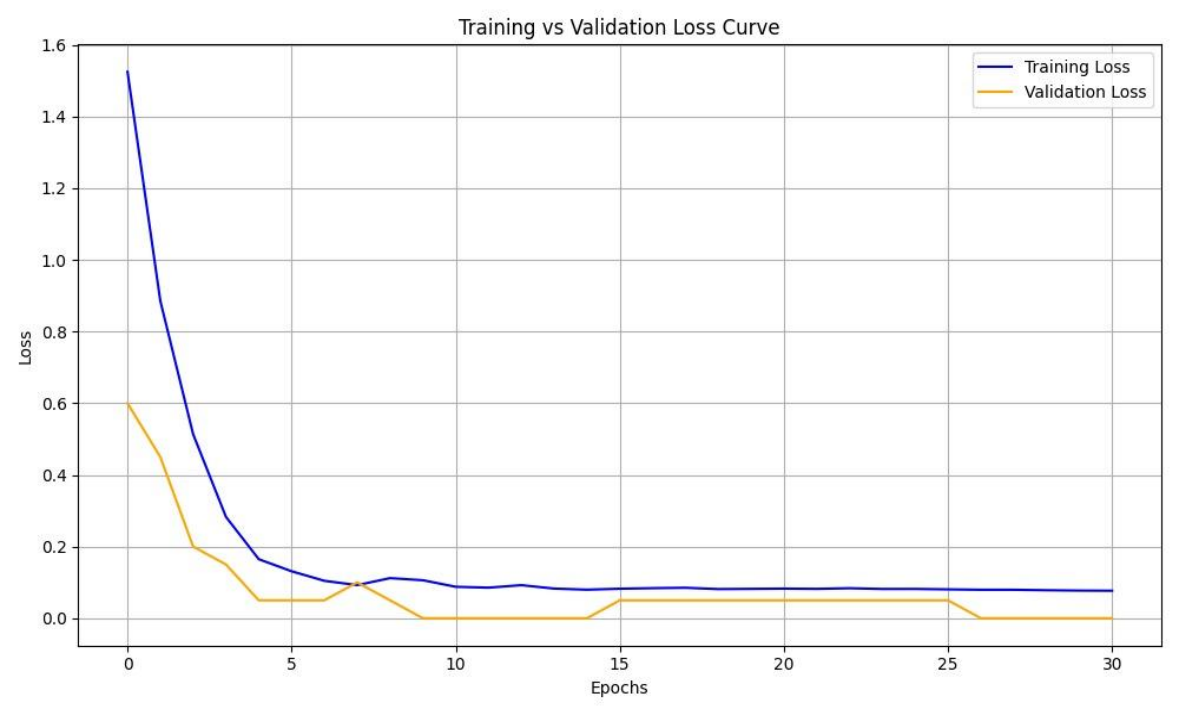
Sensor	Detected Gas	Working Principle	Specifications
MQ-3	Acetone (Diabetes)	Semiconductor Gas Sensor –Detects acetone.	Range: 0.1 – 10 ppm
MQ-135	Ammonia (GI Issues)	Semiconductor Gas Sensor – Detects NH3 and other harmful gases.	Range: 0.1 – 10 ppm
DHT22	Temperature & Humidity	Capacitive Humidity & Thermistor – Measures environmental conditions.	Accuracy: ±0.5°C, ±2% RH

Sensor Connections

Sensor	AO (Analog Output)	GND	VCC
MQ-3	GPIO-35	GND	5V
MQ-135	GPIO-39	GND	5V

Sensor	-	OUT	+
DHT22	GND	GPIO4	3.3V

Output:


Training vs Validation Loss Curve
Training Loss
Validation Loss
Loss
Epochs
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30

```
5-Fold Cross-Validation F1 Score (Weighted): 0.9312 ± 0.0370

Train Accuracy: 0.9850
Test Accuracy: 0.9800
Train F1 Score: 0.9850
Test F1 Score: 0.9799
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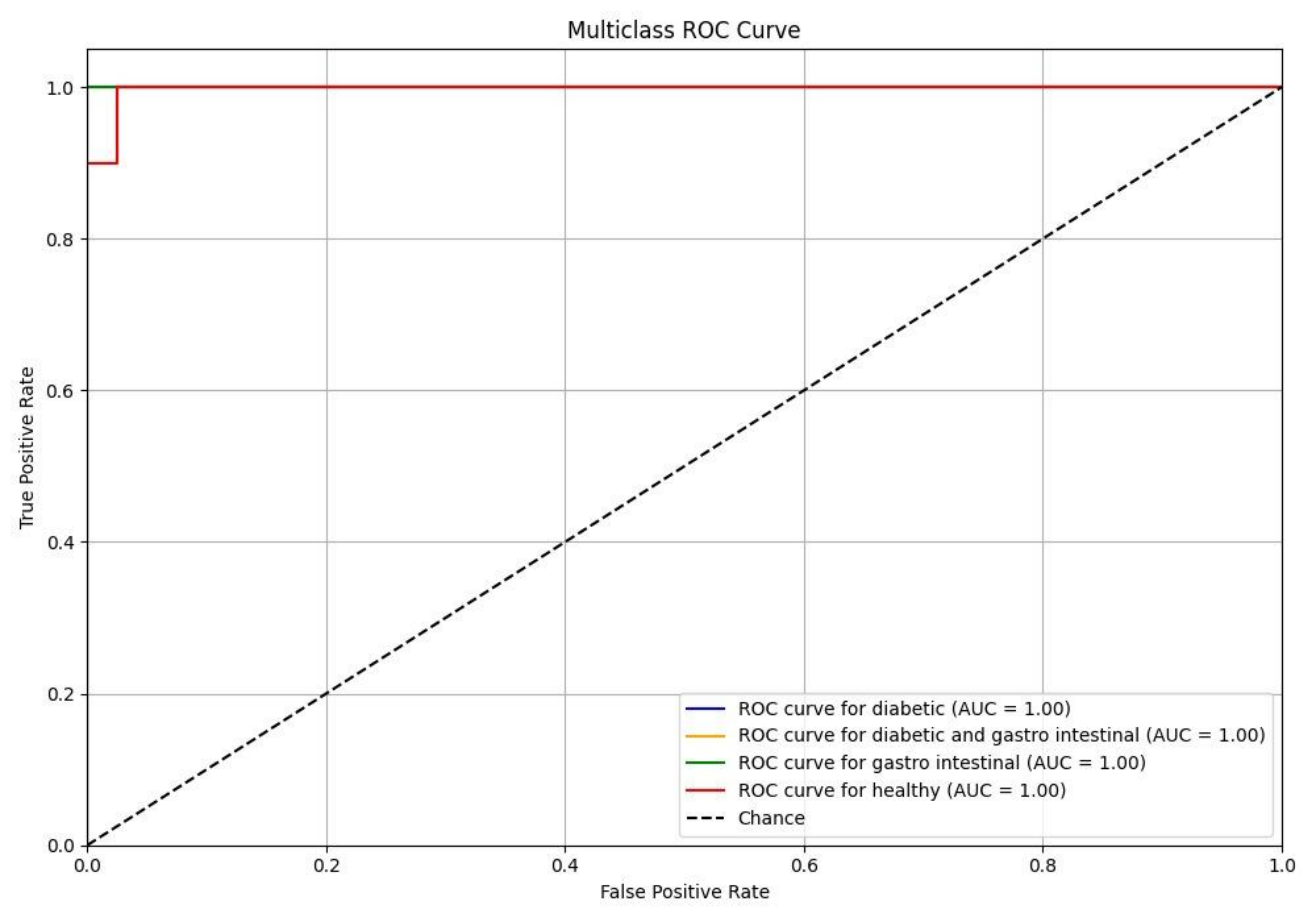
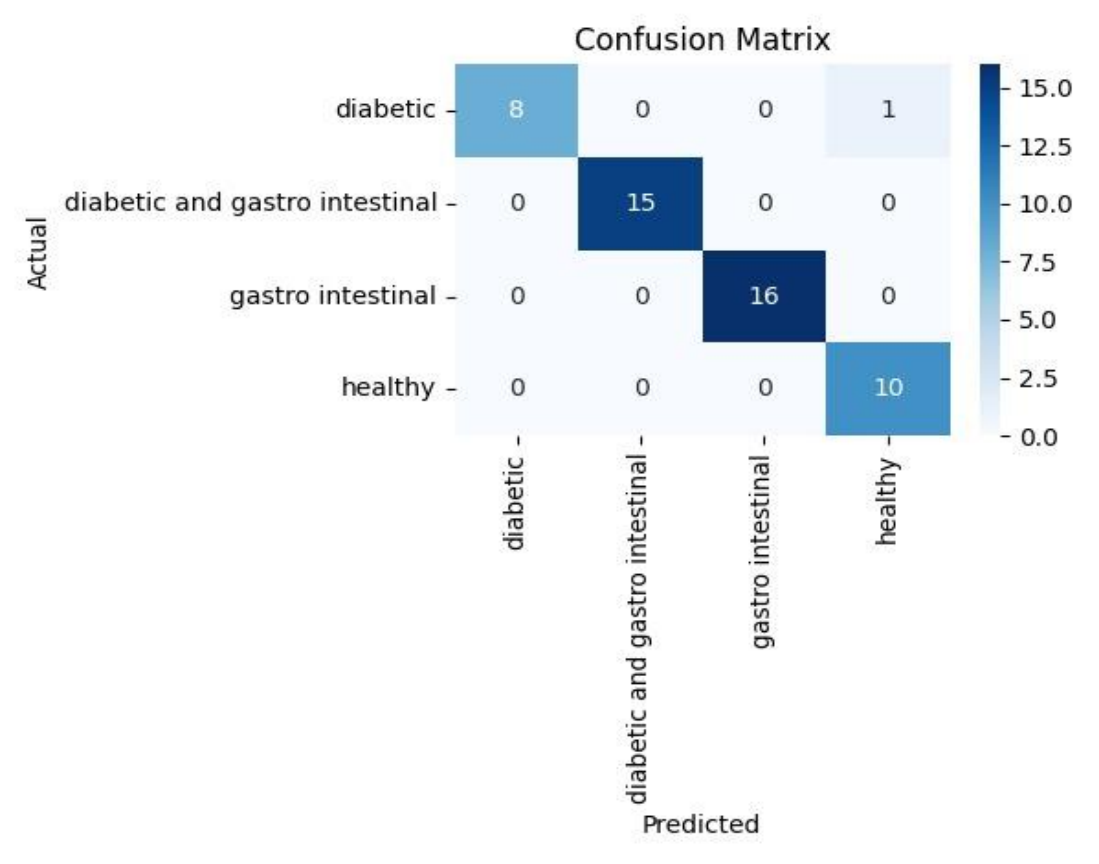

Multiclass ROC Curve
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
ROC curve for diabetic (AUC = 1.00)
ROC curve for diabetic and gastro intestinal (AUC = 1.00)
ROC curve for gastro intestinal (AUC = 1.00)
ROC curve for healthy (AUC = 1.00)
Chance


Confusion Matrix
diabetic
diabetic and gastro intestinal
gastro intestinal
healthy
Actual
8
0
0
1
0
15
0
0
0
0
16
0
0
0
0
10
15.0
12.5
10.0
7.5
5.0
2.5
0.0
diabetic
diabetic and gastro intestinal
gastro intestinal
healthy
Predicted